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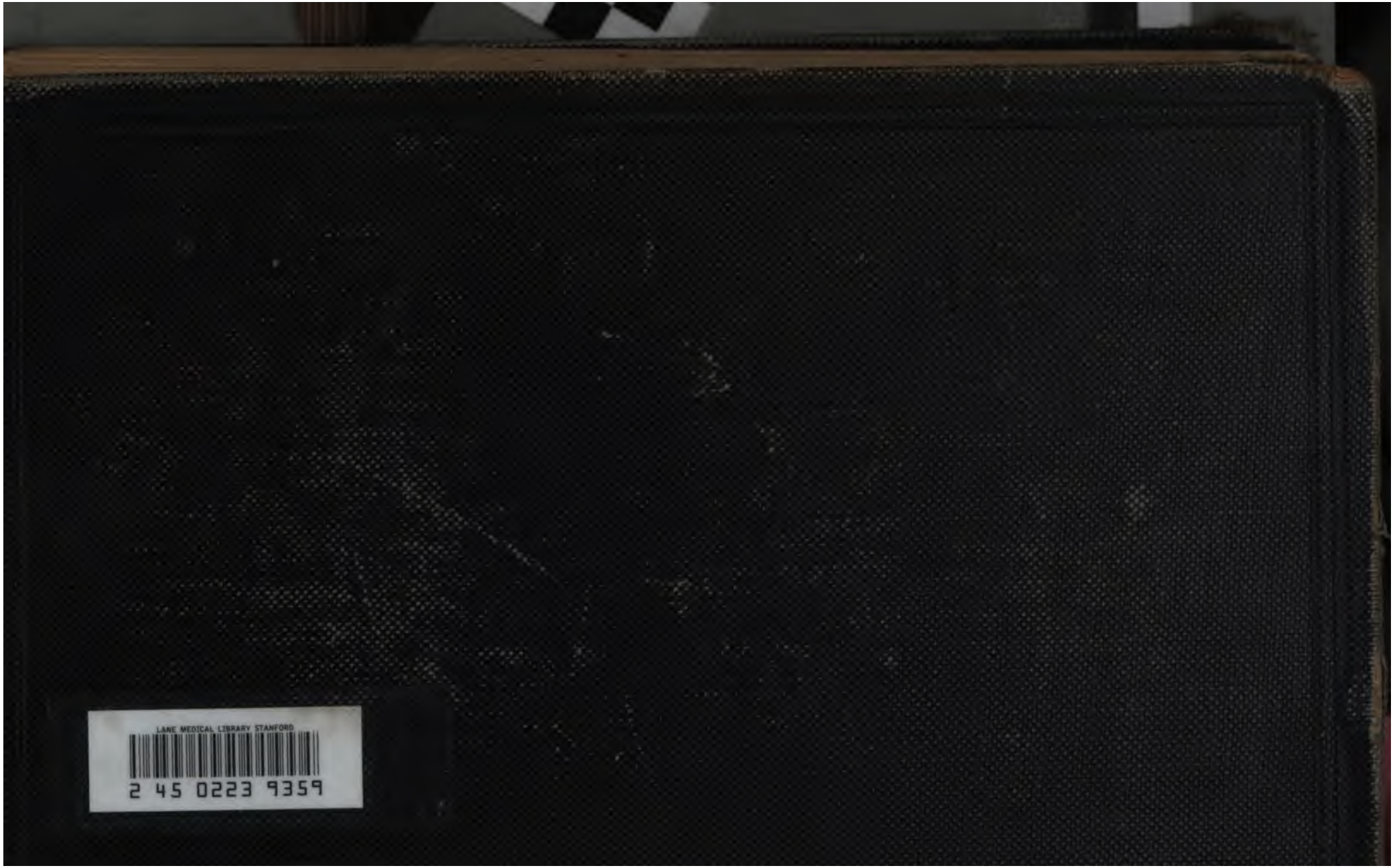
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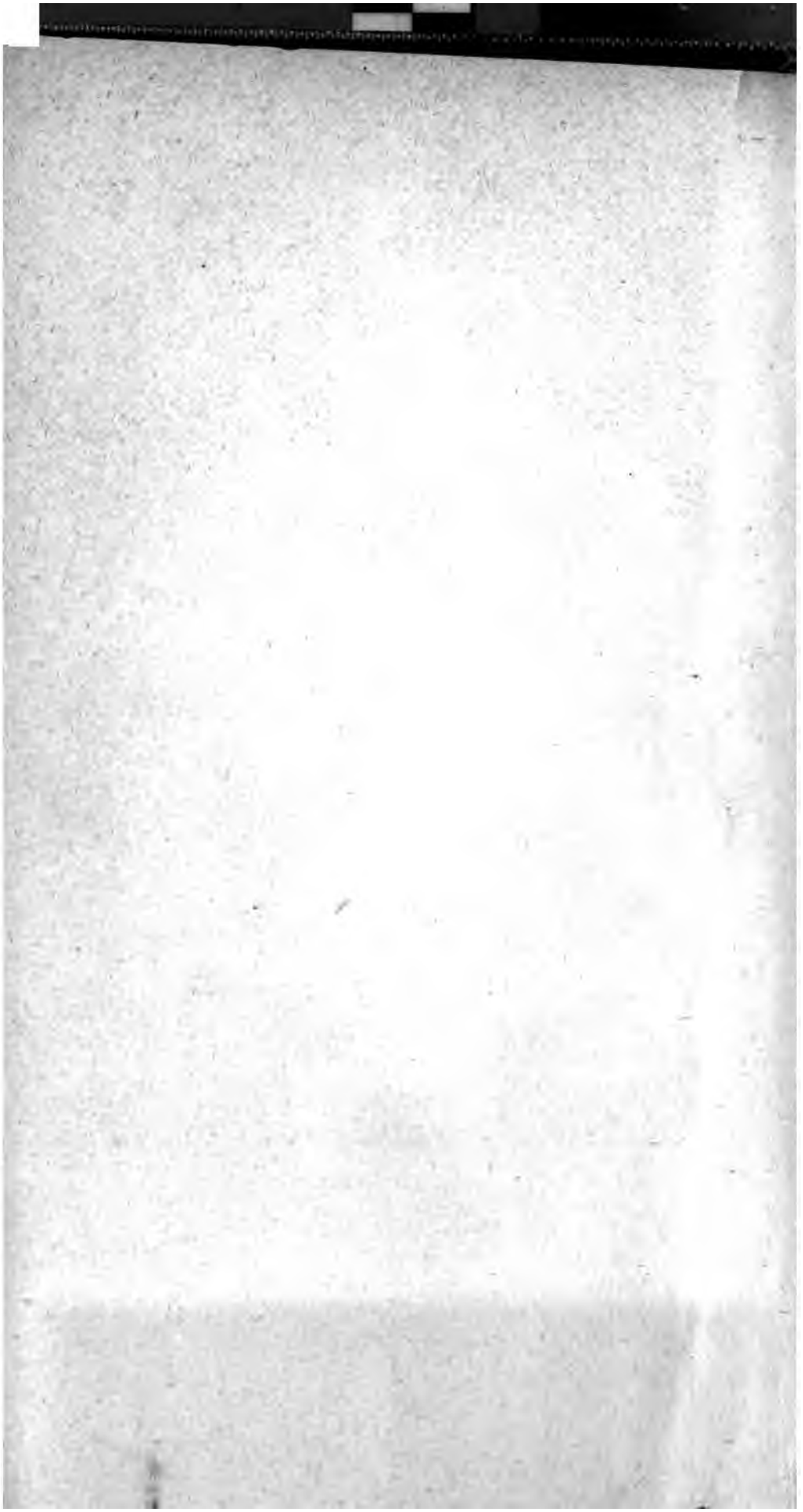

MORRIS'S

HUMAN ANATOMY

SIXTH EDITION

MORRIS'S

HUMAN ANATOMY

A COMPLETE SYSTEMATIC TREATISE
BY ENGLISH AND AMERICAN AUTHORS

EDITED BY

C. M. JACKSON, M. S., M. D.

PROFESSOR AND DIRECTOR OF THE DEPARTMENT OF ANATOMY,
UNIVERSITY OF MINNESOTA

ELEVEN HUNDRED AND SIXTY-FOUR ILLUSTRATIONS
FIVE HUNDRED AND FIFTEEN PRINTED IN COLORS

SIXTH EDITION, REVISED AND LARGELY REWRITTEN

PHILADELPHIA
P. BLAKISTON'S SON & CO.
1012 WALNUT STREET

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For arrangement of subjects and authors see page ix

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EDITOR'S PREFACE TO THE SIXTH EDITION

One criticism upon most of the current text-books of human anatomy is that they are too extensive for the beginner. Much precious time is wasted by him in floundering through a mass of details which obscure the fundamental facts. And yet it is important to have these details conveniently accessible for both present and future reference. To meet this difficulty, the attempt is made in this edition to discriminate systematically in the use of sizes of type. The larger type is used for the more fundamental facts, which should be mastered first, and the smaller type for details. While it has been found difficult to apply this principle uniformly through the various sections, it is hoped that the plan, even though but imperfectly realized, will prove useful to the beginner.

In the illustrations of the bones, as heretofore, the origins of muscles are indicated by red lines, the insertions by blue lines, and the attachments of ligaments by dotted black lines.

Each of the various sections has been throughly revised, and some of them entirely rewritten. The previous section on Morphogenesis is now entitled Developmental Anatomy. It has been rewritten by Prof. R. E. Scammon, and its scope extended so as to include both prenatal and postnatal changes, thus bridging the gap between embryology and adult gross anatomy. The section on Skin and Mammary Gland has been separated from the Glands of Internal Secretion, the former being rewritten by Prof. Charles R. Stockard and the latter by Prof. J. F. Gudernatsch. The spleen, formerly included with the ductless glands, was also revised for the present edition by Dr. Gudernatsch, but has been transferred to its more appropriate position under the Lymphatic System.

Each author is alone responsible for the subject-matter of the article following his name. Care has been exercised on the part of the editor, however, to make the whole uniform, complete and systematic.

As to nomenclature, the Anglicised form of the BNA has been continued, excepting those cases where the Latin form is adopted into English (e.g., most of the muscles), and rare cases where the BNA term seems undesirable. As a rule, the Anglicised form where first used is followed by the BNA Latin term *in brackets*, except where the two are practically identical. For convenience of reference, some of the commoner synonyms of the old nomenclature are also added in parenthesis.

The fourth edition of Morris's Anatomy was the first general text-book of anatomy in English to adopt the BNA. During the past few years the merit of this system of nomenclature has become so widely recognized that it is now very generally accepted among the English-speaking nations. Lack of space forbids the enumeration of the many advantages of this system, not the least of which is the reduction of some 30,000 anatomical terms (including synonyms) to 5000. The comparatively few defects of the BNA will doubtless be remedied by revision.

In addition to the bibliographical references scattered throughout the text, a brief list is given at the close of each section. These brief lists of carefully selected references are intended merely as a guide to put the student 'on track' of the original literature.

Due credit has been given throughout the book wherever illustrations have been taken, or modified, from other works. Special acknowledgement should be made of our indebtedness to the works of Toldt, Rauber-Kopsch, Poirier and Charpy, Henle and Spalteholz.

In the present edition many new figures have been added, and in addition a large number of the older figures have been improved or replaced. For the generosity of the publishers in this connection, and for the hearty coöperation of the contributors in the revision of the various sections, the editor desires to express his deep indebtedness.

C. M. JACKSON.

MINNEAPOLIS.

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INTRODUCTION

By C. M. JACKSON, M.S., M.D.

PROFESSOR OF ANATOMY, UNIVERSITY OF MINNESOTA

ANATOMY, as the term is usually employed, denotes the study of the structure of the human body. Properly, however, it has a much wider significance, including within its scope not man alone, but all animal forms, and, indeed, plant forms as well; so that, when its application is limited to man, it should be termed human anatomy. *Human anatomy*, then, is the study of the structure of the human body, and stands in contrast to, or rather in correlation with, *human physiology*, which treats of the functions of the human body, the two sciences, anatomy and physiology, including the complete study of man's organization and functional activities.

In the early history of the sciences these terms sufficed for all practical needs, but as knowledge grew, specialization of necessity resulted and new terms were from time to time introduced to designate special lines of anatomical inquiry. With the improvement of the microscope a new field of anatomy was opened up and the science of *histology* came into existence, including the portion of anatomy which deals with the minuter details of structure. So, too, the study of the development of the body gradually assumed the dignity of a more or less independent study known as *embryology*, and the study of the structural changes due to disease was included in the science of *pathology;* so that the term anatomy is sometimes limited to the study of the macroscopic structure of normal adult organisms.

It is clear, however, that the lines of separation between anatomy, histology, embryology, and pathology are largely arbitrary. Microscopic anatomy necessarily grades off into macroscopic anatomy; the development of an organism is a progressive process and the later embryonic or fetal stages shade gradually into the adult; and structural anomalies lead insensibly from the normal to the pathological domains. Furthermore it is found that in its individual development the organism passes through stages corresponding to those of its ancestry in evolution; in other words, ontogeny repeats phylogeny. A comprehensive study of anatomy must therefore include more or less of the other sciences. Since an appreciation of the significance of structural details can be obtained only by combining the studies of anatomy (including histology) and embryology, and since, further, much light may be thrown on the significance of embryological stages by comparative studies, anatomy, embryology, and comparative anatomy form a combination of sciences by which the structure of an organism, the significance of that structure, and the laws which determine it are elucidated. For this combination it is convenient to have a single term, *morphology*, a word meaning literally the science of form.

In morphological comparisons the term *homology* denotes similarity of structure, due to a common origin in the evolution of organs or parts; while *analogy* denotes merely physiological correspondence in function. Thus the arm of man and the wing of a bird are homologous, but not analogous, structures; on the other hand, the wing of a bird and the wing of an insect are analogous, but not homologous. *Serial homology* refers to corresponding parts in successive segments of the body.

Nomenclature.—Formerly there was much confusion in the anatomical nomenclature, due to the multiplicity of names and the lack of uniformity in using them. Various names were applied to the same organs and great diversity of usage prevailed, not only between various countries, but also even among authors of the same country. Recently, however, a great improvement has been made by the general adoption of an international system of anatomical nomenclature. This system was first adopted by the German Anatomical Society at a meeting in Basel, in 1895, and is hence called the Basel Nomina Anatomica, or briefly, the BNA. The BNA provides each term in Latin form, which is especially desirable for international usage. Each nation, however, is expected to translate the terms into its own language, wherever it is deemed preferable for

everyday usage. Thus in the present work the Anglicised form of the BNA is generally used. Where not identical, however, the Latin form is added once for each term in a place convenient for reference, and is designated by enclosure in brackets [ ]. Where necessary the older terms have also been added as synonyms.

The Commission by whom the BNA was prepared included eminent anatomists representing various European nations. The work of the Commission was very thorough and careful, and extended through a period of six years. Among the guiding principles in the difficult task of selecting the most suitable terms were the following: (1) Each part should have one name only. (2) The names should be as short and simple as possible. (3) Related structures should have similar names. (4) Adjectives should be in opposing pairs. A few exceptions were found necessary, however.

On account of its obvious merits, the BNA system has been generally adopted throughout the civilized world, and the results are very satisfactory. Comparatively few new terms have been thereby introduced, over 4000 of the 4500 names in the BNA corresponding almost exactly to older terms already in use by the English-speaking nations. Certain minor defects have been criticized; but these are outweighed by the advantages of this uniform system.

Abbreviations.—Certain frequently used words in the BNA are abbreviated as follows: a., arteria (plural, aa., arteriæ); b., bursa; g., ganglion; gl., glandula; lig., ligamentum (plural, ligg., ligamenta); m., musculus (plural, mm., musculi); n., nervus (plural, nn., nervi); oss., ossis (or ossium); proc., processus; r., ramus (plural, rr., rami); v., vena (plural, vv., venæ).

Terms of position and direction.—The exact meaning of certain fundamental terms used in anatomical description must be clearly understood and kept in mind. In defining these terms, it is supposed that the human body is in an upright position, with arms at the sides and palms to the front.

The three **fundamental planes** of the body are the sagittal, the transverse and the frontal. The vertical plane through the longitudinal axis of the trunk, dividing the body into right and left halves, is the *median* or *midsagittal* plane; and any plane parallel to this is a *sagittal* plane. Any vertical plane at right angles to a sagittal plane, and dividing the body into front and rear portions is a *frontal* (or coronal) plane. A plane across the body at right angles to sagittal and coronal planes is a *transverse* or *horizontal* plane.

Terms pertaining to the front of the body are *anterior* or *ventral;* to the rear, *posterior* or *dorsal;* upper is designated as *superior* or *cranial;* and lower as *inferior* or *caudal.*

The term *medial* means nearer the midsagittal plane, and *lateral*, further from that plane. These terms should be carefully distinguished from internal (inner) and external (outer), which were formerly synonymous with them. *Internal*, as now used (BNA), means deeper, i. e., nearer the central axis of the body or part; while *external* refers to structures more superficial in position. *Proximal*, in describing a limb, refers to position nearer the trunk; while *distal* refers to a more peripheral position.

Adverbial forms are also employed, e. g., anteriorly or ventrally (forward, before); posteriorly or dorsally (backward, behind); superiorly or cranially (upward, above); and inferiorly or caudally (downward, below).

It should also be noted that the terms ventral, dorsal, cranial and caudal are independent of the body posture, and therefore apply equally well to corresponding surfaces of vertebrates in general with horizontal body axis. On this account these terms are preferable, and will doubtless ultimately supplant the terms anterior, posterior, superior and inferior.

The discrimination in the use of several similar terms of the BNA should also receive attention. Thus *medianus* (median) refers to the median plane. *Medialis* (medial) means nearer the median plane and is opposed to lateral, as above stated. *Medius* (middle) is used to designate a position between anterior and posterior, or between internal and external. Between medialis and lateralis, however, the term *intermedius* is used. Finally, *transversalis* means transverse to the body axis; *transversus*, transverse to an organ or part; and *transversarius*, pertaining to some other structure which is transverse.

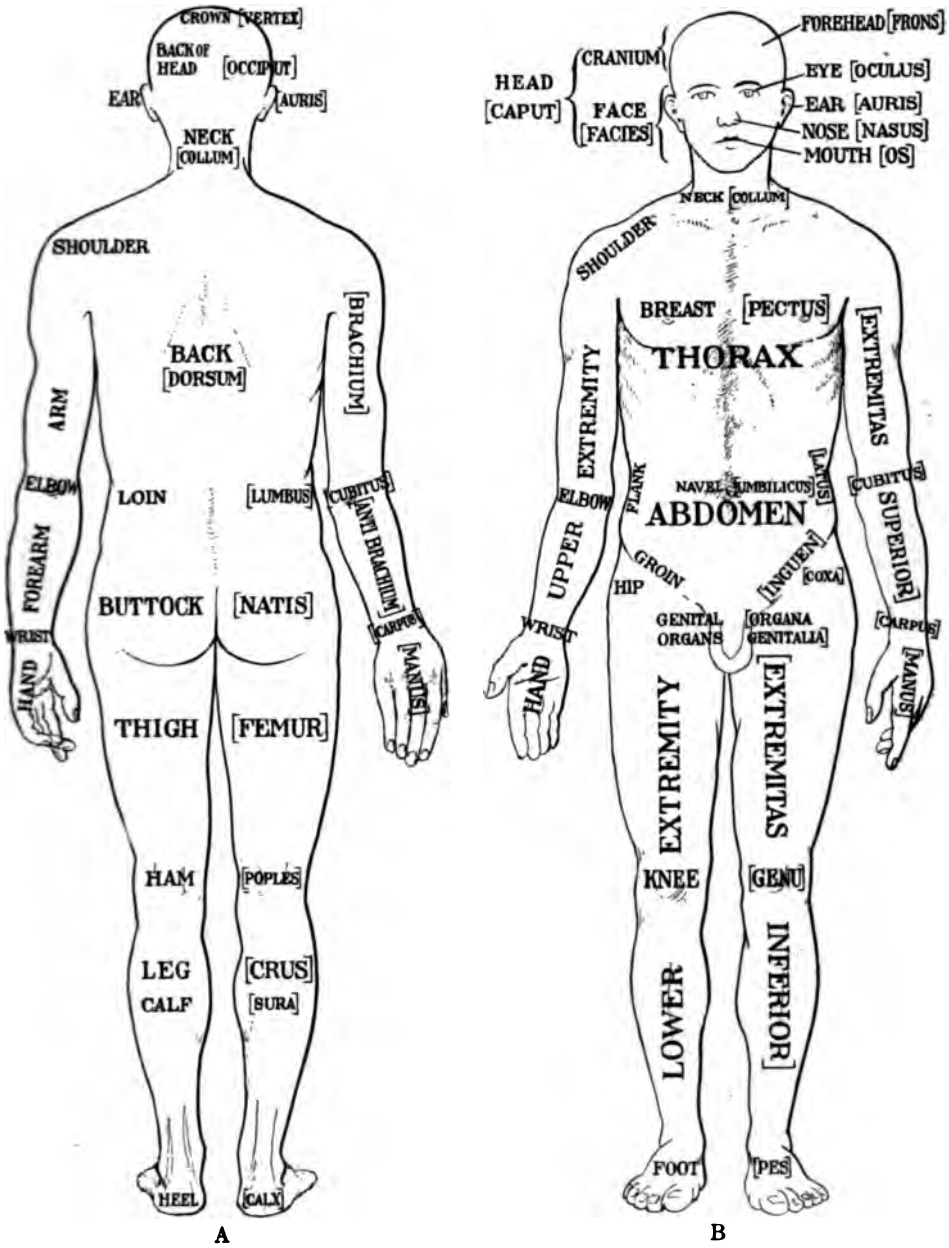
Parts of the body.—The primary divisions of the human body (fig. 1) are the head, neck, trunk and extremities. The *head* [caput] includes *cranium* and *face* [facies]. The *neck* [collum] connects head and trunk. The *trunk* [truncus] includes *thorax, abdomen*, and *pelvis*. The *upper extremity* [extremitas superior] includes *arm* [brachium], *forearm* [antibrachium], and *hand* [manus]. The *lower extremity* [extremitas inferior] includes *thigh* [femur], *leg* [crus], and *foot* [pes].

Each of the parts mentioned has further subdivisions, as indicated in fig. 1. The cranium includes: *crown* [vertex]; *back* of the head [occiput]; *frontal* region [sinciput], including *forehead* [frons]; *temples* [tempora]; *ears* [aures], including *auricles* [auriculæ].

The face includes the regions of the *eye* [oculus], *nose* [nasus], and *mouth* [os], the subdivisions of which will be given later under the appropriate sections.

The thorax includes: *breast* [pectus]; *mammary gland* [mamma]; and *thoracic cavity* [cavum thoracis]. The *back* [dorsum] includes the vertebral column [columna vertebralis]. The abdomen includes: *navel* [umbilicus]; *flank* [latus]; *groin* [inguen]; *loin* [lumbus]; and the *abdominal cavity* [cavum abdominis]. The

FIG. 1.—PARTS OF THE HUMAN BODY. A, Posterior view. B, Anterior view.



pelvis includes: *pelvic cavity* [cavum pelvis]; *genital organs* [organa genitalia], *buttocks* [nates], separated by a cleft [crena ani] at the *anus*. The *hip* [coxa] connects the pelvis with lower extremity.

In the lower extremity, the thigh is joined to the leg by the *knee* [genu]. The foot includes: *heel* [calx]; *sole* [planta]; *instep* [tarsus]; *metatarsus*; and five *toes* [digiti I–V], including the *great toe* [hallux] and *little toe* [digitus minimus].

The upper extremity is joined to the thorax by the *shoulder*. The arm is joined to the forearm at the *elbow* [cubitus]. The hand includes: *wrist* [carpus]; *metacarpus*, with *palm* [vola or palma] and *back* [dorsum manus]. The five *fingers* [digiti I–V] include: *thumb* [pollex], *index* finger [index]; *middle* finger [digitus medius] *ring* finger [digitus annularis] and *little* finger [digitus minimus].

Organ-systems.—Each of the various parts of the body above outlined is composed of various *organs*, and the groups of related organs make up *organ-systems*.

The various organ-systems are treated as special branches of descriptive anatomy. The study of the *bones* is called *osteology;* of the *ligaments* and *joints*, *syndesmology* (or arthrology); of the *vessels*, *angiology;* of the *muscles*, *myology;* of the *nervous system*, *neurology;* and of the *viscera*, *splanchnology*. Further subdivisions are also made. The viscera, for example, include the *digestive* tract, *respiratory* tract, *urogenital* tract, etc.

Tissues and cells.—The body, as above stated, has various parts, each of which may be subdivided into its component systems and organs. A further analysis reveals a continued series of structural units of gradually decreasing complexity. Thus each organ is found to consist of a number of *tissues* (epithelial, connective, muscular or nervous). Finally, each tissue is composed of a group of similar units called *cells* which are the ultimate structural units of the body. The body may therefore be regarded as composed of myriads of cell units, organized into units of gradually increasing complexity, very much as a social community is composed of individuals organized into trades, municipalities, etc.

Most of the individual tissues can be recognized by their gross appearance. In fact, the principal tissues were first demonstrated by Bichat through skilful dissection, maceration, etc., and without the aid of the microscope. The cellular structure of the tissues was later discovered by Schwann in 1839.

Each cell is composed of a material called *protoplasm*, a viscid substance variable in appearance and exceedingly complex in chemical composition. It readily breaks down into simpler chemical compounds, whereby energy (chiefly in the form of heat and mechanical energy) is liberated. It has also the power of absorbing nutritive material to build up and replace what was lost. Its decomposition results from stimuli of various kinds, and hence it is said to be irritable. The mechanical energy which it liberates is manifested by its contractility, especially in the muscle cells. It excretes the waste products produced by its decomposition. Each cell has the power, under favorable conditions, of reproducing itself by division. Protoplasm presents, in short, all the forms of activity manifested by the body as a whole; and indeed, the activities of the body are the sum of the activities of its constituent cells.

In the protoplasm of each cell is a specially differentiated portion, the *nucleus*. The nucleus plays an important part in regulating the activities of the *cytoplasm*, the general protoplasm of the cell body. The nucleus differs from the cytoplasm both structurally and chemically, and contains a very important substance, *chromatin*, which during cell division is aggregated into a definite number of masses called *chromosomes*. Further details concerning the cells and tissues may be found in the text-books of cytology and histology.

In earlier days human anatomy was almost entirely a descriptive science, but little attention being paid to the significance of structure, except in so far as it could be correlated with physiological phenomena as they were at the time understood. In recent years attention has been largely paid to the morphology of the human body and much valuable information as to the meaning of the structure and relations of the various organs has resulted. Since the form and structure of the body are the final result of a series of complicated developmental changes, the science of embryology has greatly contributed to our present knowledge of human morphology, and, accordingly, an account of some of the more important phases of morphogenesis and developmental anatomy will form a fitting introduction to the study of the adult.

References.—*General:* For looking up the literature upon any anatomical topic, the best guide in general is the Jahresbericht über die Fortschritte der Anatomie und Entwicklungsgeschichte, which contains classified titles and brief abstracts of the more important papers in gross anatomy, histology and embryology. Other useful aids are the Index Medicus and the catalogue of the Surgeon General's Library of the War Dep't. (Washington, D. C.). The latter two contain titles only, but cover the whole field of medicine. The Concilium Bibliographicum also provides a convenient card-index system of references for the biological sciences, including Anatomy. For *nomenclature:* His, Archiv f. Anat., 1895 (BNA system); Barker, Anatomical Nomenclature; Eycleshymer, Anatomical Names. *Cells and tissues:* Wilson, The Cell; Hertwig, Zelle und Gewebe (also English transl.); Schaefer, Microscopic Anatomy (in Quain's Anatomy, 11th ed.); Heidenhain, Plasma und Zelle; Kölliker, Gewebelehre; Prenant, Bouin et Maillard, Traité d'Histologie.

SECTION I

DEVELOPMENTAL ANATOMY

REWRITTEN FOR THE SIXTH EDITION

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THE life history of man, in common with most higher organisms, is characterized by continuous change and presents a cycle in which may be recognized the succeeding phases of growth and differentiation, maturity, and old age or senescence. In man nearly one-third of the traditional span of life is required for the body to reach its full size and differentiation. This portion of the human life cycle may be called the developmental period, and the study of the structure of the body and its changes in this time may be termed developmental anatomy.

Divisions of the developmental period.—The developmental period is divided by the incident of birth into prenatal and postnatal epochs and in these a number of more or less arbitrarily defined subdivisions may be recognized. The divisions of the developmental period are shown on the following table. In this scheme puberty is regarded only as a transition point between later childhood and adolescence. The length of the developmental period and of its several subdivisions varies greatly with sex, race, environment, and physical constitution. A distinction is often drawn between the anatomic or physiologic age of the individual, as indicated by the degree of physical development of the body, and the calendar or chronologic age. As females pass through most of the transitions of the developmental period a little earlier than do males the physiologic age of girls is usually somewhat greater than that of boys of the same calendar age.

DIVISIONS OF THE DEVELOPMENTAL PERIOD IN MAN

Prenatal life

Period of the ovum.
From fertilization to the close of the second week of prenatal life.

Period of the embryo.
From the close of the second week to the close of the second (lunar) month.

Period of the fetus.
From the close of the second (lunar) month to birth at 10 lunar months.

Birth

Postnatal life

Period of the newborn (Neonatal period).
From birth to the close of the second (postnatal) week.

Infancy.
From 2 weeks to the close of the first year or until the habitual assumption of the erect posture (usually in the thirteenth or fourteenth month).

Childhood

Early childhood (Milk-tooth period).
From 1 to 6 years.

Middle childhood.
From 6 to 9 or 10 years.

Later childhood (Prepuberal period.
From 9 or 10 years to 12–15 years in females and 13–16 years in males.

Puberty
Fourteenth year in females. Sixteenth year in males. (According to American data.)

Adolescence.
From puberty to the last years of the second decade in females and to the first years of the third decade in males.

Growth and differentiation.—The changes which characterize the developmental period do not take place at the same time or at equal rates in all regions of the body, for each organ and part has its own peculiar life cycle. In a few

organs, such as the mesonephros of the embryo, this cycle is very short. Other organs persist during childhood and then decline, while the great majority continue, with varying degrees of change, throughout postnatal life.

The characteristic life cycle of the various organs depends upon the changes in the structural units which compose them and, in the last analysis, upon the growth and differentiation of their constituent cells. Each cell has a definite life cycle, an early period of rapid and vigorous changes, later periods of differentiation and maturity, followed by stages of degeneration and death. This cycle of cell changes is termed *cytomorphosis*. The length of life cycle of the various types of cells in the body differs greatly, some of the blood cells living probably a month or less while certain brain cells may survive throughout postnatal life. The growth of cells may take place either by the enlargement (hypertrophy) of individual cells or by the multiplication (hyperplasia) of cells by mitosis. Cell division is necessary for continued cell growth for otherwise the cell would soon reach a size where its surface would be inadequate (for nutritive, respiratory and excretory purposes) to its mass. In general, however, cell division is most active in the early embryonic periods, during which the cells remain small. Later, cell division diminishes or ceases, and growth is due chiefly to the enlargement of cells already present. The growth of the structural units of organs also follows this general rule, the production of new units being confined mainly to fetal and early postnatal life.

While the functional and structural differentiation of cells and structural units may take place during the period of their rapid multiplication these processes are usually partially disassociated and the phase of active differentiation comes some time after the period of most active growth.

THE EARLY DEVELOPMENT OF THE EMBRYO

The germ-cells and fertilization.—The period of development in man, as in the great majority of multicellular animals, is inaugurated by the process of fertilization which consists of the union of the male germ-cell or spermatozoon with the female germ-cell or ovum.

The ovum and spermatozoon are differentiated, by the process of maturation, from certain more primitive germ-cells set aside from the general body or somatic cells at an early period in development. In maturation both the ovum and spermatozoon undergo profound nuclear changes and each becomes highly specialized in form and structure for its part in the fertilization process.

The ripe spermatozoon or sperm is a slender lance-like structure 0.05 or 0.06 mm. long (fig. 3).

The ripe human ovum or egg-cell is a spheroidal body whose greatest diameter is approximately 0.1 mm. (fig. 2). It contains a nucleus about 0.02 mm. in diameter which is generally slightly eccentric in position. Suspended in the protoplasm of the cell-body are numerous droplets and granules which are presumably reserve food substances. The ovum is bounded by a delicate vitelline membrane.

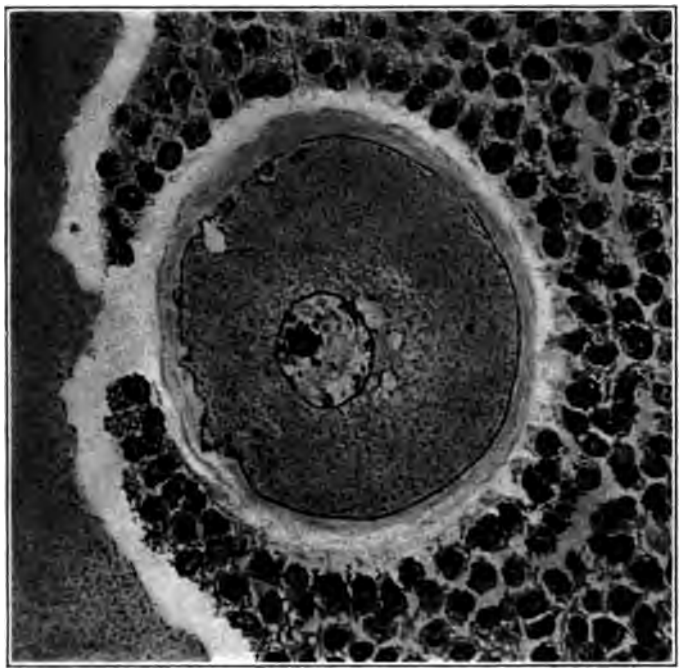
Fertilization has not been observed in man but it has been studied in detail in several mammals and it is most probable that the process is essentially the same in all higher forms. After escaping from the ovary through the rupture of the Graafian follicle the ovum enters the ostium of the uterine tube and passes down the lumen. The union of the ovum with the spermatozoon probably takes place in most cases during this process.

Segmentation of the ovum.—The fertilized ovum is converted into a solid ball of much smaller cells by a series of cell-divisions. This process is known as segmentation and the mass of cells resulting from it is called the *morula*. Like fertilization, segmentation has not been observed in man and our concepts of the process in the human species are based upon observations on the ova of lower animals. It is probable that the first segmentation divisions are equal but that the later ones are quite irregular. The morula which results from them is a solid body at first but an eccentrically placed cavity soon appears within it and the structure is differentiated into an outer shell, the *trophoblast*, and a cluster of cells termed the *inner cell-mass*. The inner cell-mass is broadly attached to the inner surface of the trophoblast and the cavity between the two is filled with fluid and bridged by delicate cellular strands, the *magma reticulare*.

It is probable that after fertilization approximately ten days are required for the ovum to reach this stage of development. During this period the ovum has left the uterine tube and has come to rest on the inner surface of the uterus. The uterine epithelium in contact with the ovum is destroyed, presumably

through the activity of the cells of the trophoblast, and the ovum sinks into the uterine mucosa and is inclosed by it. Until this implantation takes place the ovum is an independent organism dependent upon its own scanty reserve food supply for nourishment. Consequently it grows little if any during this period. With implantation, however, the ovum becomes, in a fashion, a parasite upon the maternal organism from which it derives its nourishment throughout

FIG. 2.—MATURE OVUM, WITH FOLLICULAR CELLS, OF A WOMAN 36 YEARS OLD. (After Thompson.) ×500.



the remainder of the fetal period. With the establishment of this relation the ovum enters on a period of extremely rapid growth.

Formation of the embryonic disk.—Two spaces now appear in the inner cell-mass, an upper one, the amniotic cavity and a lower one, the yolk-sac cavity. These are separated by a plate of cells, the *embryonic disk*. At the same time a distinct layer of cells is differentiated on the outer surface of the cell-mass. This

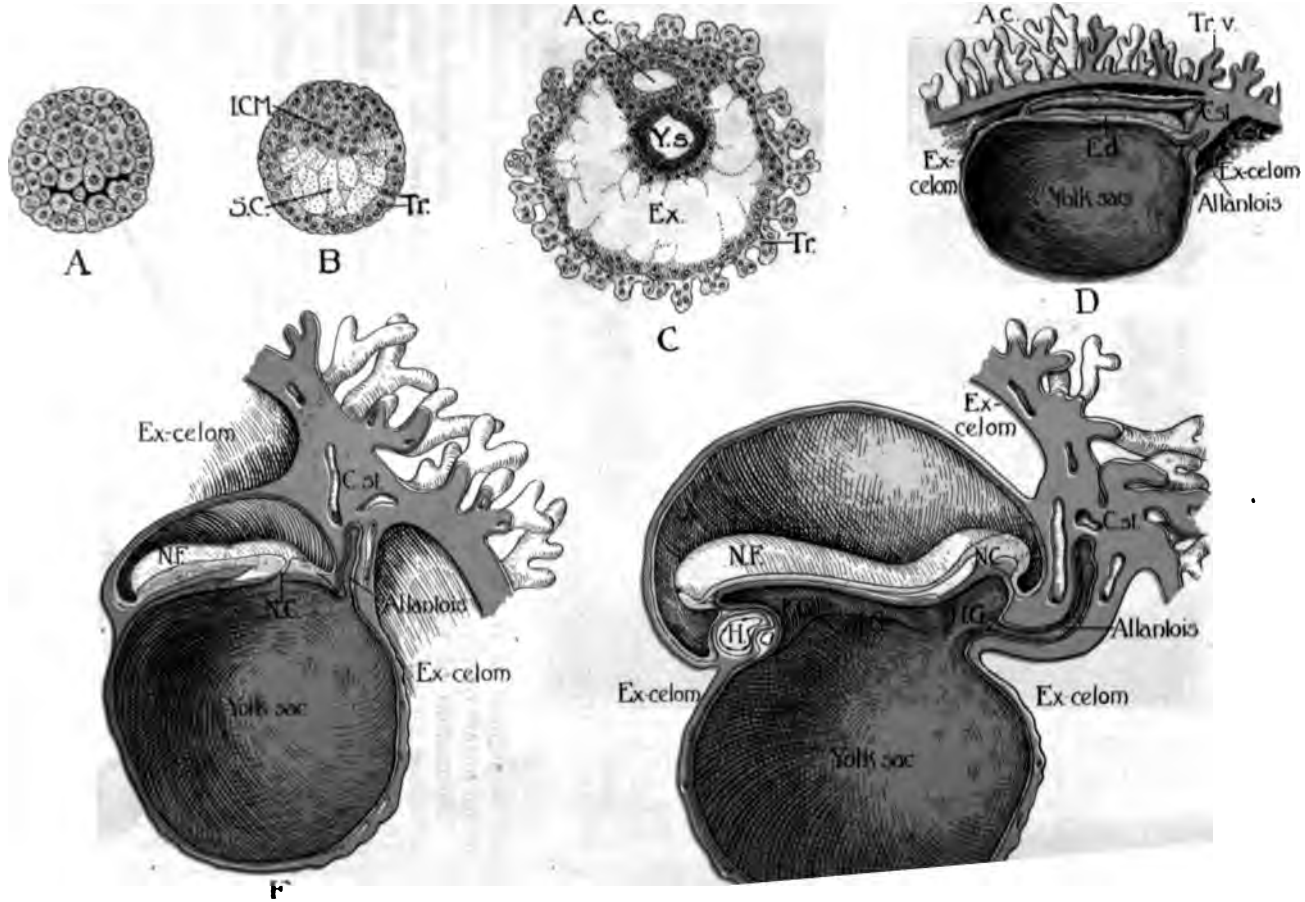
FIG. 3.—MATURE SPERMATOZOA.

A, frontal view showing broad surface of the head: B, anterior portion in side view. (After Broman.) ×2500.

layer is the extraembryonic mesoderm. It is probably formed in part from the cells of the inner cell-mass and the trophoblast and in part from the magma reticulare. The extraembryonic mesoderm forms a complete lining about the original cavity of the morula and this space is now termed the *extraembryonic celom*. As the extraembryonic celom is established the magma reticulare disappears and the connection between the inner cell-mass and the trophoblast is reduced to a short bridge of extraembryonic mesoderm, the connecting stalk (fig. 4).

FIG. 4.—A SERIES OF DIAGRAMS ILLUSTRATING THE LATER CHANGES IN THE OVUM AND THE FORMATION OF THE EMBRYO. (Based on the figures of Broman, Brödel, Dandy, Eternod, Lewis, Miller and Streete.)

A, morula (hypothetical). B, differentiation of the inner cell-mass and trophoblast (hypothetical). C, formation of the amniotic cavity, yolk-sac and extraembryonic celom. D, formation of the embryonic disk. E and F, formation of the archenteron and neural canal. A.c., amniotic cavity. C.st., connecting stalk. E.d., embryonic disk. Ex., extraembryonic celom. F.G., foregut. H., heart. H.G., hindgut. I.C.M., inner cell-mass. N.C., neurenteric canal. N.F., neural folds. S.C., segmentation-cavity. Tr., trophoblast. Tr.v., trophoblastic villi. Y.s., yolk-sac.

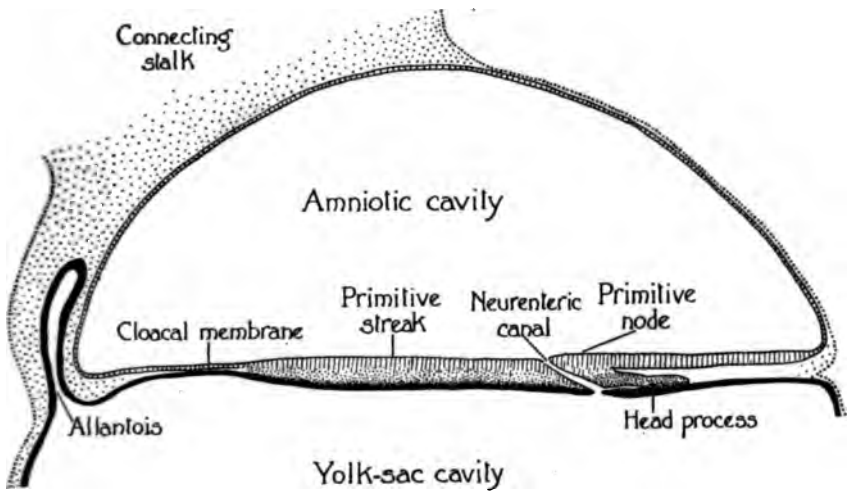


Our interest is centered in the embryonic disk, for the embryo is entirely a product of this structure: the remainder of the ovum gives rise to the supporting or nourishing structures for the developing embryo or else disappears comparatively early in prenatal life.

The embryonic disk in embryos of the third week is an oval plate having a maximum diameter of about 0.2 mm. It consists of three sheets of cells called the germ layers. The upper layer or ectoderm forms the floor of the amniotic cavity and becomes continuous with the walls of the amnion at the margins of the embryonic disk. The lower layer or entoderm forms the roof of the yolk-sac and is continued as the walls of this structure at the periphery of the embryonic disk. The middle layer or mesoderm forms an incomplete plate between the ectoderm and entoderm. At the margins of the embryonic disk it becomes continuous with the extraembryonic mesoderm which covers the outer surface of the inner cell-mass.

The subsequent history of the embryo is essentially that of the differentiation and the disposition of the germ-layers. Their contributions to the adult body are as follows:

FIG. 5.—DIAGRAM OF A LONGITUDINAL SECTION THROUGH THE LONG AXIS OF THE EMBRYONIC DISK AT THE TIME OF FORMATION OF THE PRIMITIVE STREAK AND NEURENTERIC CANAL. (Based in part on the figures of Ingalls and Streeter.)



From the ectoderm are formed:

The central and peripheral nervous system, the epithelial internal ear, the lens, iris and retina of the eye. The epithelial portion of the skin and its appendages.

The lining of the buccal, nasal, and a part of the pharyngeal cavities; the enamel of the teeth; the salivary glands.

The lining of the anal canal; the lining of the vestibule and a portion of the urethra in the male, with associated glands.

The anterior lobe of the hypophysis cerebri; the pharyngeal hypophysis. The paraganglia.

From the entoderm are formed:

The lining epithelium of the digestive tract, with the exception of the mouth, a part of the pharynx, and the anal canal; the parenchyma of the digestive glands, pancreas and liver. The lining of the larynx, trachea, bronchi and lungs.

The lining of a portion of the bladder; the lining of the female urethra and a part of the male urethra, with associated glands.

The parenchyma of the thyroid and parathyroid glands; the reticulum and the thymic corpuscles of the thymus.

From the mesoderm are formed:

The skeletal and muscular structures and the connective tissues of the body.

The vascular system; the lymphoid and sanguifactive organs.

The serous membranes.

The genital glands and their ducts and accessory structures. The kidneys, ureters and the greater part of the bladder.

The dentine and cementum of the teeth.

The cortex of the suprarenal glands.

Early changes in the embryonic disk.—The first indications of the establishment of the embryo on the germinal disk appear early in the third week. At this

time the ectoderm and entoderm in the posterior part of the longitudinal axis of the disk fuse forming a band of cells known as the primitive streak. The primitive streak is indented by a dorsal primitive groove (fig. 6). It terminates anteriorly in an enlargement, the primitive node, and from the node a mass of cells, the head-process, extends forward in the midline, fusing below with the entoderm of the yolk-sac in this region. A narrow channel, the neurenteric canal, pierces the primitive node and connects the amniotic cavity with the yolk-sac cavity. The neurenteric canal is continuous with a cleft in the head-process termed the head-process canal (fig. 5). As these changes take place on the germinal disk a small tubular outgrowth, the allantois, arises from the posterior end of the roof of the yolk-sac and grows upward, behind the amnion, into the connecting-stalk.

The primitive groove, the primitive streak, the primitive node, neurenteric canal, and head-process are ephemeral structures which may be regarded as representing a highly modified process of gastrulation in the human embryo. The primitive streak and node and the head-process join the mesoderm laterally and presumably contribute cells to this germ-layer. The head-process also gives rise to a longitudinal rod of cells, the notochord, which forms the median

FIG. 6.—DORSAL VIEW OF THE EMBRYONIC DISK AND YOLK-SAC OF AN EMBRYO OF THE EARLY PART OF THE THIRD WEEK. (After Streeter.)

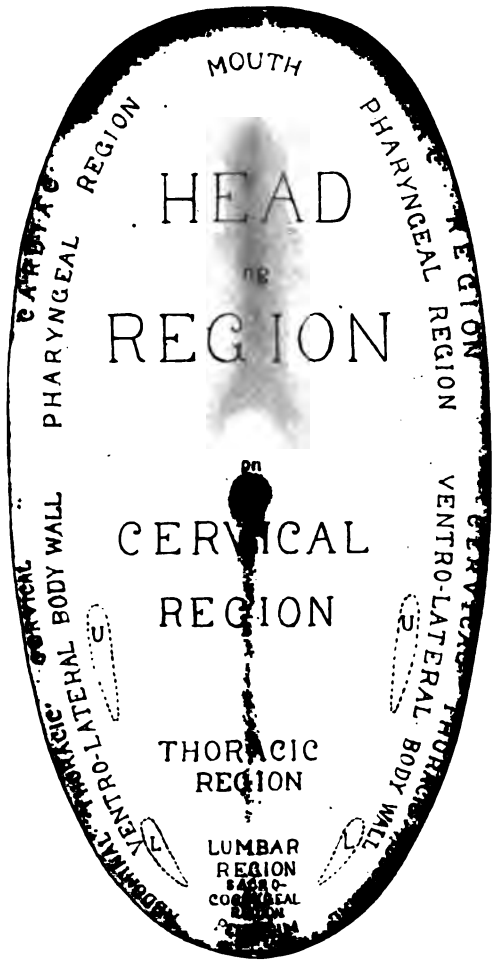
longitudinal axis of the embryo and is subsequently associated with the skeleton; possibly its ventral part is incorporated in the entoderm of the yolk-sac. With this distribution of its material the head-process disappears as a separate structure. The primitive streak becomes relatively shorter with the growth of the embryo anterior to it and the consequent migration backward of the primitive node. After the third week it is no longer recognizable. The neurenteric canal is normally obliterated in the third week.

The topography of the embryonic disk.—Although only slight signs of differentiation are visible on the surface of the embryonic disk in the third week it is possible to map out upon it more or less definite areas corresponding to all of the various regions of the future body, as shown in fig. 7. Beginning anteriorly, the head region is relatively enormous in size, occupying the entire area in front of the primitive node and forming about half of the entire disk. The cervical, thoracic, lumbar, and sacrococcygeal regions appear successively smaller, approaching the posterior end ('tail-bud') of the primitive streak. It is also a striking fact that the future dorsal region of the body wall, corresponding to the central portion of the disk, along each side of the midline, is now larger than the ventrolateral regions, which occupy a relatively narrow zone around the periphery of the disk.

Early changes in the germ layers.—The definitive embryo is formed by the rapid growth of the dorsal region of the embryonic disk and by a series of folds and cleavages of the germ-layers of this area. The **ectoderm** plays a most active part

in these early transformations. Shortly after the primitive streak is established, the ectoderm along the midline of the embryonic disk is thickened into a neural plate which extends from the primitive node to the anterior end of the disk. The lateral margins of the plate grow rapidly and rise from the surface of the disk as a pair of longitudinal neural folds or ridges which bound a shallow neural groove (figs. 8 and 12*A*). The neural plate is converted into the *neural tube* by the further growth of the neural ridges which fold over the neural groove and fuse in the midline. This process begins in the future cervical region and extends forward and backward from this level (fig. 12*A*). The extreme anterior and

FIG. 7.—TOPOGRAPHY OF THE EMBRYONIC DISK. Diagram of relations at the length of about 1 mm. ng, neural groove. pn, primitive node. pp, primitive pit. U, upper limb. L, lower limb.



posterior ends of the tube remain open for a time as the anterior and posterior neuropores. With their subsequent closure the walls of the tube are completed and its cavity is entirely separated from the amniotic cavity. The neural tube gives rise to the brain, spinal cord, and retinæ and optic nerves. Its further history is considered in connection with the nervous system.

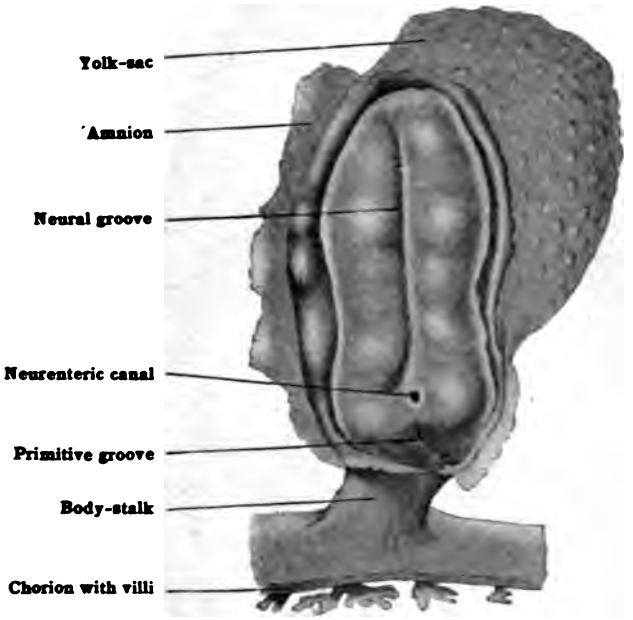
The ectoderm which covers the periphery of the embryonic disk is carried over the dorsal surface of the neural tube with the infolding of the neural ridges. It forms the external covering of the embryo.

The entoderm.—As the neural plate is formed from the ectoderm on the upper surface of the embryonic disk, the entoderm lying below this region is folded into the primitive digestive tube or *archenteron*. In embryos of the latter part of the third week three divisions, the *foregut*, the *hindgut*, and the *midgut* may

be recognized in this structure (figs. 4*E*, 4*F*). The midgut is a shallow groove still broadly connected with the yolk-sac, the foregut is a pocket-like projection from the midgut extending forward under the anterior part of the neural plate, and the hindgut is a similar but shorter projection which extends into the caudal region of the developing embryo.

With the further growth of the archenteron the foregut and hindgut become considerably elongated and the connection of the midgut with the yolk-sac is reduced to a short, wide yolk-stalk. In this process the upper part of the posterior wall of the yolk-sac is incorporated in the floor of the hindgut, and the allantois now takes origin from this part of the archenteron instead of the yolk-sac. The later history of the entoderm will be considered in connection with the development of the digestive and respiratory tracts.

FIG. 8.—HUMAN EMBRYO 1.54 MM. LONG. Viewed from above, the roof of the amniotic cavity having been removed. (Minot, after Graf Spee.)



The mesoderm.—The mesoderm of the human embryo appears to have a dual origin being formed primarily from the extraembryonic mesoderm of the inner cell-mass and secondarily from the primitive streak, primitive node, and head-process. After the formation of the notochord the mesoderm takes the form of a pair of plates which lie on either side of the longitudinal embryonic axis and which are continuous laterally with the extraembryonic mesoderm covering the amnion and yolk-sac. Behind the primitive node these plates fuse with the primitive streak across the midline of the embryonic disk but anterior to the node they are separated by a medial space which contains the notochord (figs. 9, 10.)

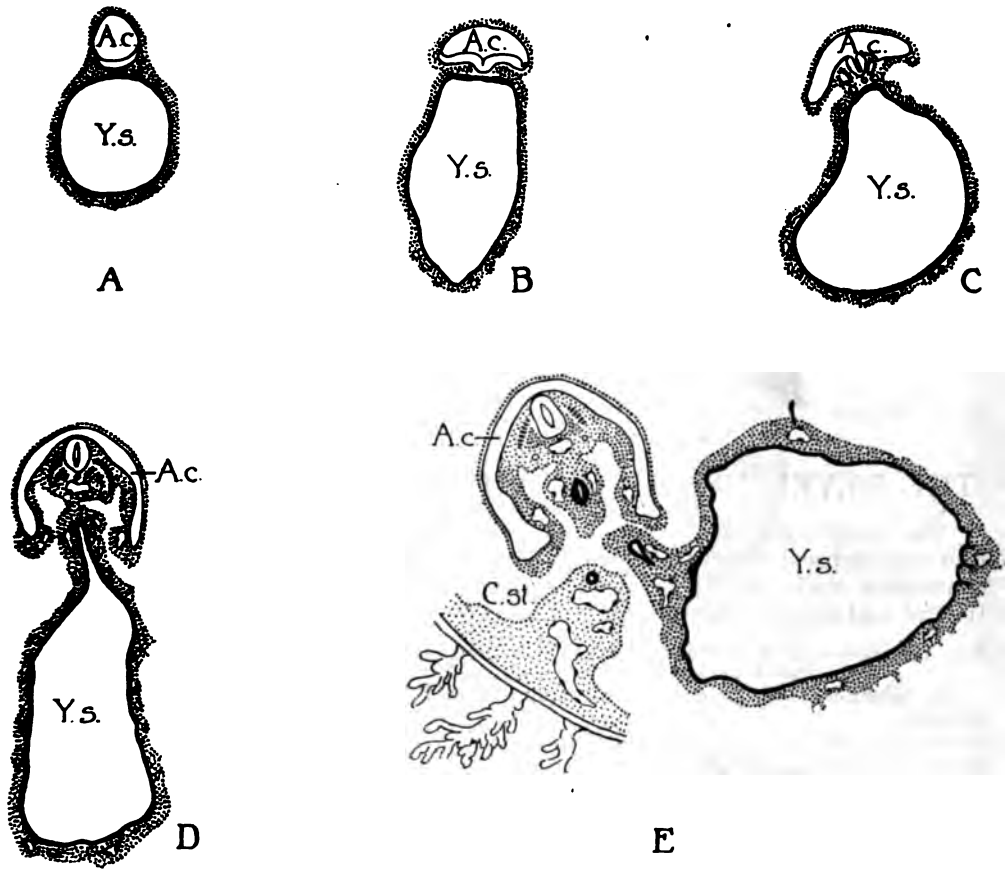
Some of the later changes in the mesoderm are shown in fig. 10. Each plate of mesoderm is divided by a longitudinal groove into three parts. These are (1) a narrow medial strip, the medial or paraxial mesoderm, (2) the intermediate mesoderm which forms a slender cord lying beneath the longitudinal groove, and (3) a broad band of lateral mesoderm. The *medial mesoderm* is subdivided by a series of transverse clefts into a row of blocks or segments known as the *mesodermic somites*. At the same time the lateral mesoderm splits into an upper (outer) or somatic layer and a lower (inner) or splanchnic layer. The space between these two layers is the embryonic body cavity or *celom*. It becomes continuous with the extraembryonic celom at the lateral margins of the embryonic disk.

The appearance of the mesodermic somites marks the beginning of metamerism, the arrangement of the body in successive segments or metameres. The somites form first in the occipital region and rapidly differentiate in the craniocaudal direction. In embryos 7 or 8 mm. in length about 40 pairs of somites can be distinguished.

The anterior end of the *medial mesoderm*, which is continued into the head region, does not undergo segmentation in the human embryo. From it are formed the cranial bones, certain of the muscles of the head and connective tissue.

FIG. 9.—CROSS-SECTIONS OF A SERIES OF YOUNG HUMAN EMBRYOS. All drawn at the same magnification. (Slightly modified from Graf Spee.)

A, embryo of the middle of the third week. B, embryo of the end of the third week. C, embryo of the early part of the fourth week. D, embryo of the latter part of the fourth week. E, embryo of the fifth week. A.c., amniotic cavity. C.st., connecting stalk. Y.s., yolk-sac. The mesoderm is indicated in stipple.

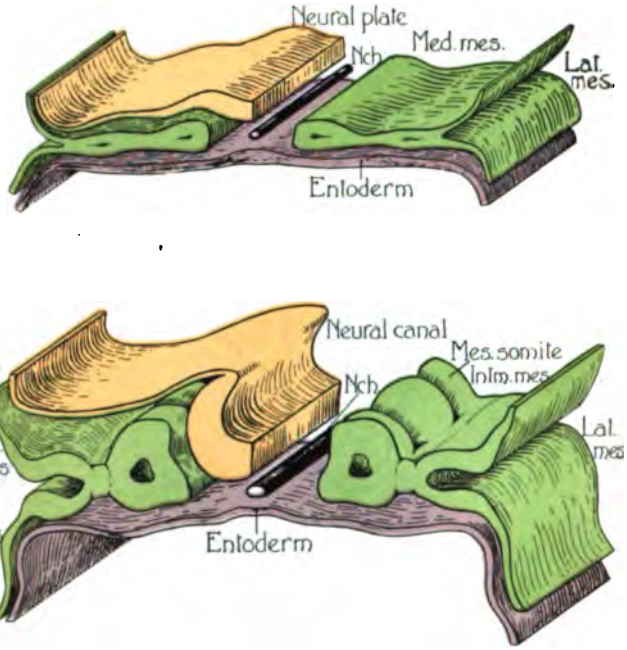


A small cavity, the *myocele* appears in the center of each somite and the wall separates into an upper lateral part, the *dermomyotome*, and a lower medial part, the *sclerotome*. From the dermomyotomes are formed the voluntary muscles of the trunk, neck, and a part of the head; while the sclerotomes take part in the development of the axial skeleton. Probably both parts of the somite contribute cells to the mesenchyma which forms the connective tissue of the body wall, and the supporting structures and voluntary muscles of the limbs.

The greater part of the *intermediate mesoderm* is also divided into segments or *nephrotomes* (corresponding to the somites), portions of which form the transitory uropoietic organs, the pronephros and mesonephros. The posterior part of the intermediate mesoderm remains unsegmented as the nephrogenic cord which is later involved in the development of the permanent kidney.

The *lateral mesoderm* shows no evidences of segmentation. The lateral cavities which are formed between its upper and lower layers soon lose their connection with the extraembryonic body cavity and fuse in the midline, forming the general celom to be described later.

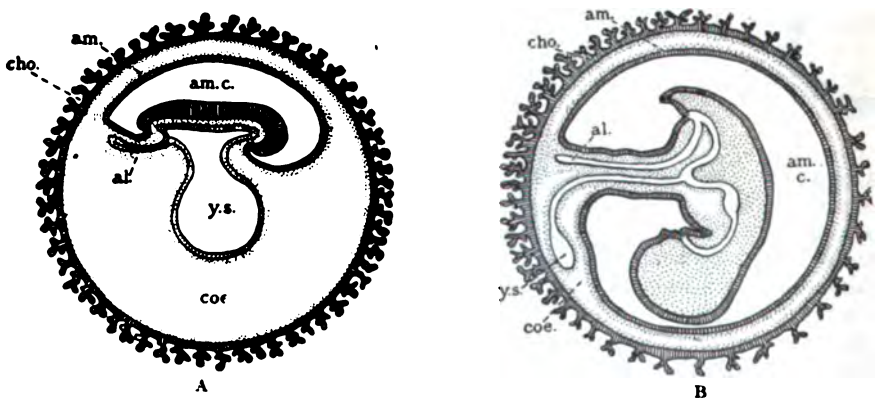
FIG. 10.—STEREOGRAMS ILLUSTRATING THE EARLY CHANGES IN THE MESODERM. Intm.mes., intermediate mesoderm. Lat.mes., lateral mesoderm. Nch., notochord. Sm.mes., somatic layer of lateral mesoderm. Sp.mes., splanchnic layer of lateral mesoderm. Ectoderm, yellow; mesoderm, green; entoderm, red.



THE DEVELOPMENT OF THE EXTERNAL BODY-FORM

The early transformations of the germ-layers convert the embryonic disk into a cylindrical structure which is only partially connected with yolk-sac and connecting stalk (fig. 11). The cylindrical body wall now encloses two tubes (neural and enteric) with a longitudinal axis (notochord) between them, and is

FIG. 11.—DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE EMBRYONIC MEMBRANES AND THE FORMATION OF THE UMBILICAL CORD. (After Lewis.) al., allantois. am., amnion. am.c., amniotic cavity. cho., chorion. coe., celom. Y.s., yolk-sac.

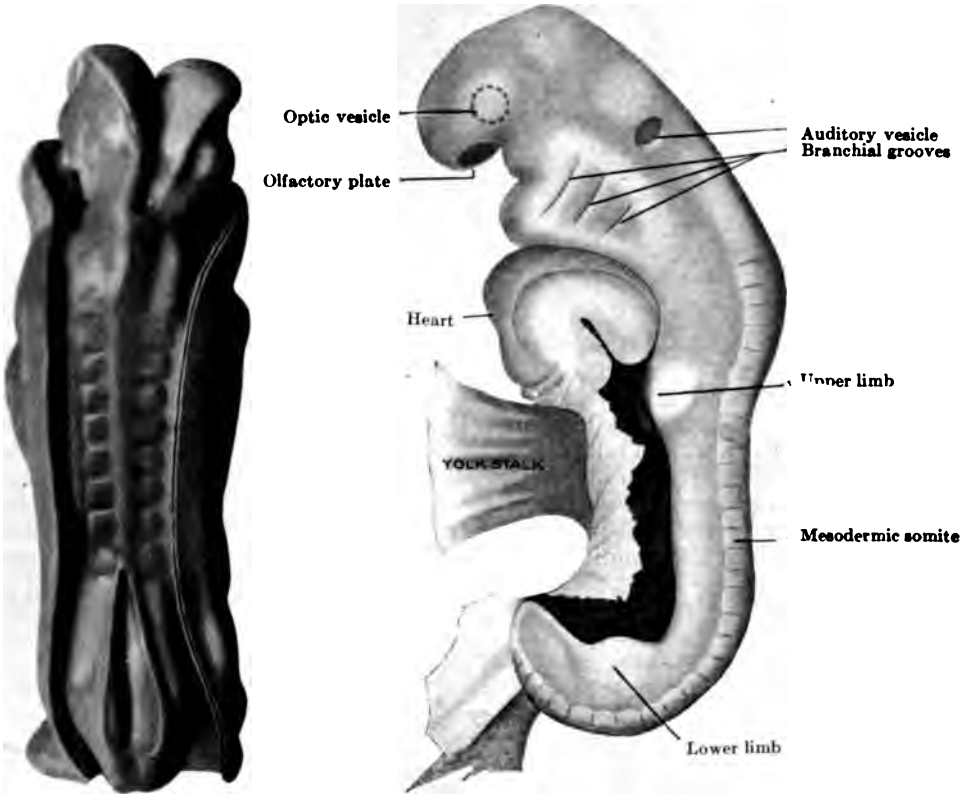


covered by an outer layer of skin-ectoderm which is continuous along the sides of the embryo with the ectoderm of the amnion. The head is relatively large and is separated from the disk below it by a deep head fold. The caudal end

of the embryo is prolonged into a short tail-bud which is also marked off from the disk by a shallow tail-fold. The middle portion or trunk is still widely connected with the disk, but its boundaries are indicated by distinct lateral folds.

The embryo becomes further separated from the other structures derived from the inner cell-mass by the deepening of the head, tail, and lateral folds; and its connection with these structures is reduced to a slender *umbilical cord.* This cord contains the allantois and yolk-stalk (with their surrounding mesoderm) and is covered by the ectoderm which is reflected from the amnion upon the external surface of the embryo.

FIG. 12.—A, HUMAN EMBRYO 2.11 MM. LONG. (FROM A MODEL BY ETERNOD.) B, HUMAN EMBRYO 4.2 MM. LONG, SHOWING THREE BRANCHIAL GROOVES. (After His.)



Coincident with these changes, the longitudinal axis of the embryo is modified by the formation of a series of flexures or bends. The head is flexed on the trunk first by an anterior cephalic flexure, and soon after by a more posterior cervical flexure, and the caudal part of the trunk and the tail are bent downward in a semicircular curve (fig. 12B). Later the rapid growth of the dorsal region throws the entire body into a partial spiral (coiled either to the right or left) so that its outline, when seen in lateral view, may be almost circular (fig. 13).

The ventral part of the body increases in size very rapidly in the second fetel month through the great growth of the contained viscera. With this growth the axis of the trunk is straightened and the cervical flexure partially e liminated The cephalic and caudal flexures are never completely obliterated, although the latter is obscured by the growth of the lower limbs; and the external evidences of the former are masked by the subsequent changes in the proportions of the head and face.

A well marked tail appears which in embryos 7 to 8 mm. long may be nearly one-sixth as long as the body. Regression of the tail structure begins in the sixth week and by the ninth week it has usually entirely disappeared.

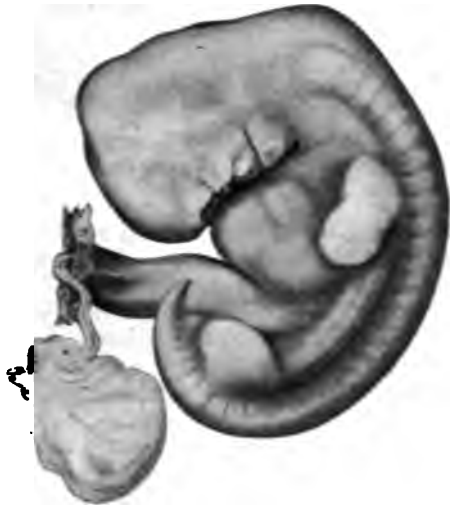
Deveploment of the head and neck.—The head is divisible from an early stage, into a neural portion including the brain, eyes and internal ears with their

supporting structures, and a facial or visceral part which contains the anterior termination of the digestive-respiratory tract. The growth and differentiation of these two portions are quite dissimilar. The neural portion is by far the larger in the young embryo and this predominance is never completely lost although it is greatly reduced during both fetal and postnatal life by the growth of the accessory structures of the mouth, nose and pharynx.

FIG. 13.—HUMAN EMBRYO 4.02 MM. LONG. (After Hochstetter.)

In the fourth and fifth weeks the visceral portion of the head undergoes marked external changes. A median *oral sinus* or embryonic mouth is formed on the ventral surface, and anterior to the sinus a pair of small ***nasal pits***. The nasal pits are bounded laterally by lateral nasal processes; and a broad medial process separates them and extends downward forming the middle part of the upper boundary of the oral sinus. The remainder of the margin of the oral sinus is formed from the mandibular and maxillary processes of the first branchial

FIG. 14.—HUMAN EMBRYO 11.5 MM. LONG. (After Minot.)

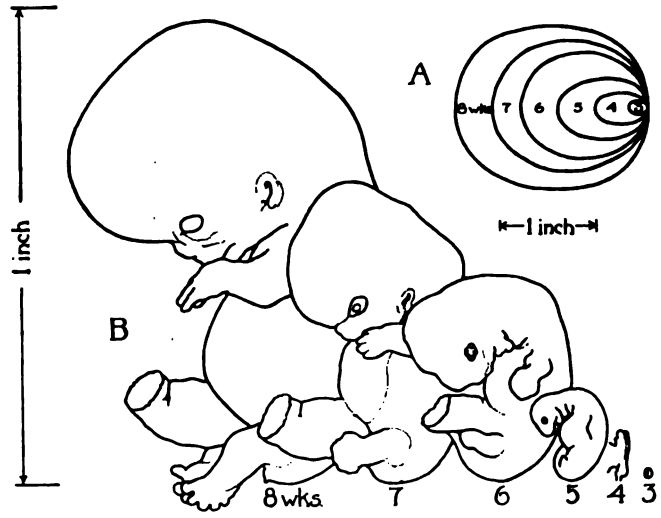


arch, the maxillary processes forming the lateral thirds of the upper boundary and the mandibular processes the entire lower margin. The maxillary and medial nasal processes are separated for the time by shallow lacrimal grooves (figs. 13, 14 and 17).

The margins of the sinus are completed by the coalescence of the mandibular processes below and the fusion of the maxillary and medial nasal processes above. The definitive *nose* is formed by the fusion of the lateral and medial nasal proc-

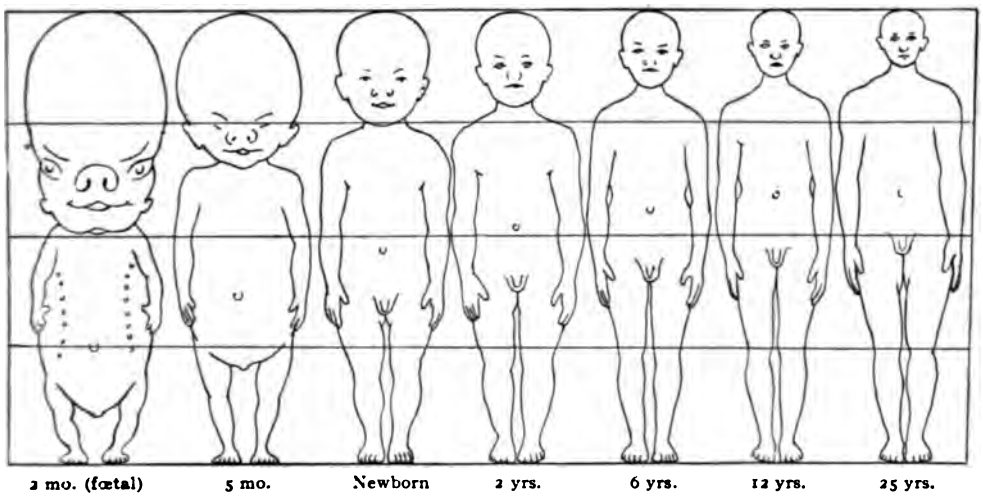
esses at the lower margins of the nasal pits and the subsequent growth of the medial process, particularly in the midline above the nares. The later development of the external features of the face is illustrated by the series of outlines in fig. 18.

FIG. 15.—A, OUTLINES OF AVERAGE HUMAN OVA FROM 3 TO 8 WEEKS OLD, ONE-HALF NATURAL SIZE. B, OUTLINES OF HUMAN EMBRYOS FROM THE THIRD TO THE EIGHTH WEEK, ENLARGED 2.5 TIMES. (After Evans.)



As these changes take place in the facial region the lateral surfaces of the neck are indented by a series of four (paired) *branchial* (visceral) *grooves* which are separated by the *branchial arches*. The upper part of the first of these grooves is deepened to form the *external auditory meatus*, the margins being elevated to form the *auricle*. The region corresponding to the second, third, and fourth grooves becomes depressed, forming the *cervical sinus* which soon closes over and normally disappears.

FIG. 16.—FIGURES ILLUSTRATING THE CHANGES IN PROPORTIONS DURING PRENATAL AND POSTNATAL GROWTH. (After Stratz.)

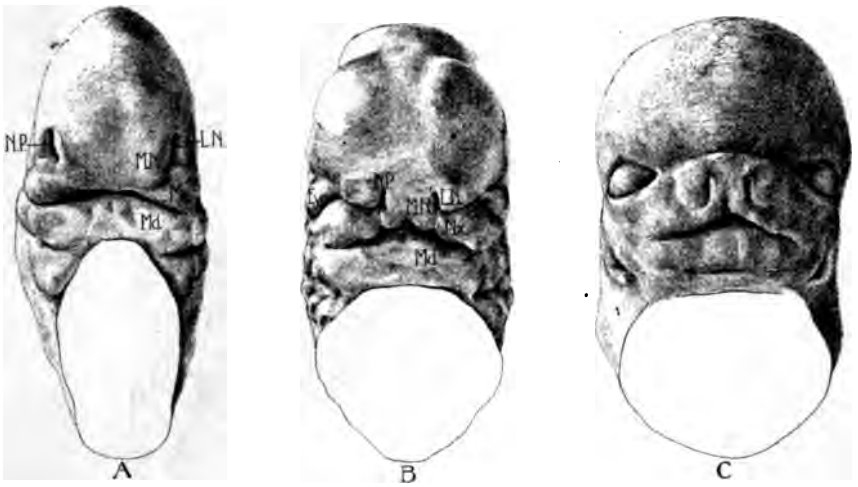


Development of the trunk.—In the young embryo the trunk appears as a cylindrical body flattened from side to side and exhibiting externally the modeling of the viscera contained within it. In fetal life, with the development of the skeleton and trunk musculature and the rounding of the visceral mass, it takes on an ovoid form largest at the level of the umbilicus and almost circular in cross section. In spite of the changes in the form and relative proportions of the

contained viscera, the relative proportions of the trunk remain almost unchanged from the close of the third fetal month until birth. In the early part of infancy, also, there is little change in the form of the trunk, but after the assumption of the erect posture there is a reduction of the relative anteroposterior diameter of both the thoracic and abdominal regions accompanied by a decrease in the relative size

FIG. 17.—DEVELOPMENT OF THE FACE IN THE SECOND FETAL MONTH. (From a series of models made in the Department of Embryology of the Carnegie Institution.)

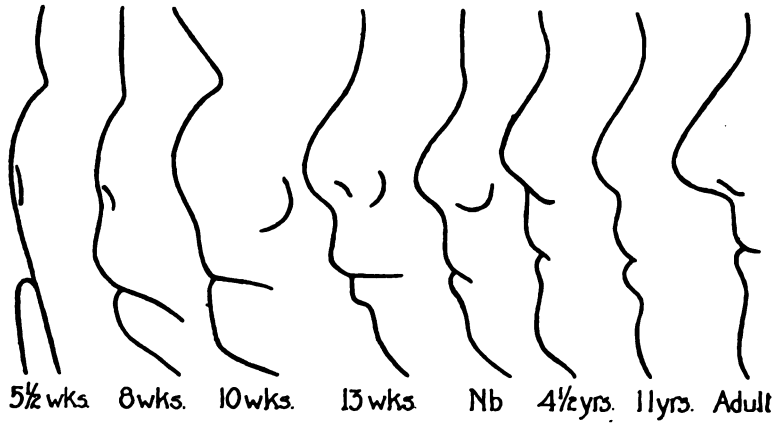
L.N., lateral nasal process. Md., mandibular process. M.N., medial nasal process. N.P., nasal pit. Mx., maxillary process.



of the umbilical region and a relative increase in the lumbar region. These changes continue throughout childhood and early adolescence.

Development of the extremities.—The limbs appear about the third week of fetal life as short ridges which project from the lateral surfaces of the cranial and caudal ends of the trunk. Each ridge is differentiated into a limb-bud in which may be recognized a flattened distal segment representing the hand or

FIG. 18.—A SERIES OF PROFILES ILLUSTRATING THE CHANGES IN THE FORM AND PROPORTIONS OF THE FACE IN THE DEVELOPMENTAL PERIOD. (After Peter.)



foot, and a rounded proximal segment representing the remainder of the limb. The latter is again divided by a slight constriction into a distal part, corresponding to the forearm or leg, and a proximal part corresponding to the arm or thigh. The digits are formed as radiating ridges on the lateral surfaces of the hand and foot segments. As these ridges grow more rapidly than the bodies of these segments they soon project beyond their margins as definitive fingers or toes.

The axes of the limbs undergo three main changes in position in their early development. At first the limb-buds project outward at right angles to the

FIG. 19.—DEVELOPMENT OF THE UPPER EXTREMITY. (After Retzius.)

A, anterior limb-bud of an embryo 12 mm. long. B, anterior limb-bud of an embryo 15 mm. long. C, anterior limb-bud of an embryo 16 mm. long. D, forearm and hand of an embryo 25 mm. long. E, hand of a fetus 52 mm. long. All ×6.

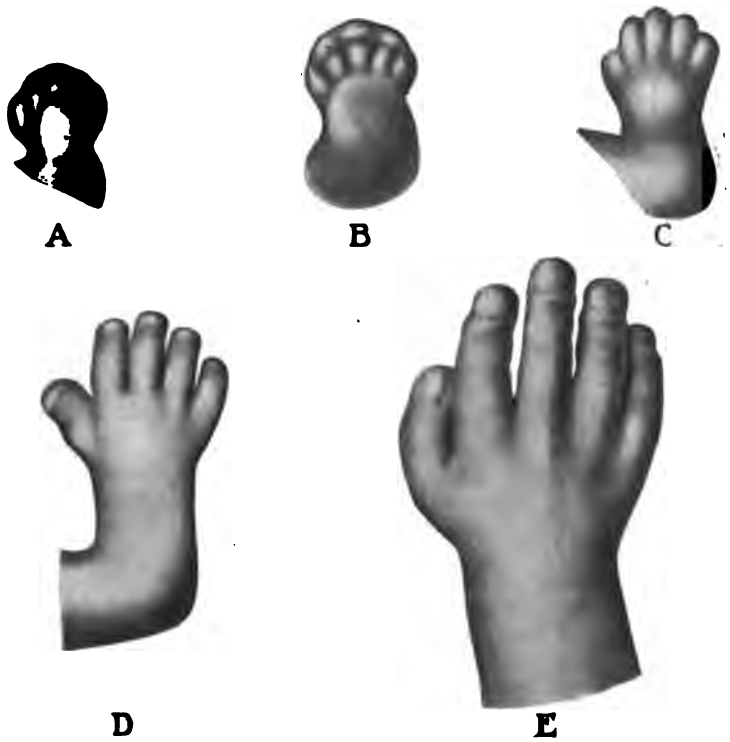
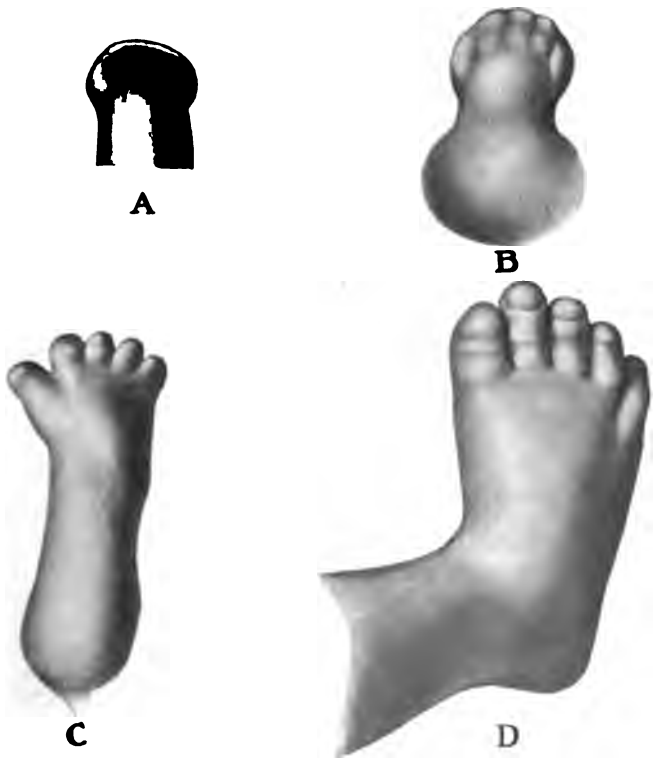


FIG. 20.—DEVELOPMENT OF THE LOWER EXTREMITY. (After Retzius.)

A, Posterior limb-bud of an embryo 17 mm. long. B, posterior limb-bud of an embryo 19 mm. long. C, leg and foot of an embryo 25 mm. long. D, foot of a fetus 52 mm. long. All ×6.



lateral surface of the body. Later they are bent caudally and ventrally so that their former ventral surfaces face medially. And finally each limb is rotated about its long axis through an angle of approximately 90 degrees. This rotation takes place in opposite directions in the arm and leg. The arm is turned outward so that the thumb comes to lie on the lateral (outer) margin of the limb and the palm faces ventrally (in supination), while the leg rotates inward and the great toe comes to lie on the medial margin of the limb, and the plantar surface of the foot faces dorsally.

In embryonic life the development of the arm precedes that of the leg and it is not until after birth that the lower extremity exceeds the upper one in length. In postnatal life the lower limb increases in length more rapidly than the upper; at about two years their length is equal and in the adult the lower limb is about one-sixth longer than the upper. The adult relations of the different segments of the limbs (arm, forearm and hand, and thigh, leg and foot) are practically established early in prenatal life although there is some reduction in the relative length of the hand and height of the foot in the postnatal period.

THE GROWTH OF THE BODY AND ITS PARTS

Growth of the body in weight.—The diameter of the ripe human ovum is approximately 0.1 mm. Consequently, if the egg-cell is considered as a perfect sphere, its volume is about 0.0000005 cc. and its weight, assuming the specific gravity to be 1.0, is about 0.0000005 gm. If the average weight of the body in the third decade be considered as 65 kilos (about 143 pounds) we may estimate the total increment in the body-weight during the developmental period at about 130 billion-fold. Considered from this point of view almost all of the weight increment takes place in prenatal life, for in this period the body increases in mass about 6.5 billion times while from birth to maturity the gain is but twenty-fold. From the standpoint of absolute growth, on the other hand, the body acquires about 5 per cent. of its adult weight before birth and about 95 per cent. thereafter. The growth of the body in weight is indicated in the following tables.

Growth in length.—Growth in length has certain characters in common with growth in weight although the relative lineal increase of the body in the developmental period is obviously much smaller than the relative growth in mass.

At the end of the first fetal month the length of the embryo is approximately 0.25 cm. This is increased 10-fold in the second fetal month but thereafter the relative rate of growth becomes progressively slower. The period of most rapid absolute growth in length is in the fourth fetal month, during which there is a gain of about 8 cm. (from 10 cm. in the twelfth week to 18 cm. in the sixteenth). After this there is a gradual decline in the absolute as well as the relative rate of lineal increase.

PRENATAL GROWTH IN LENGTH AND WEIGHT

Age in lunar months	Crown-rump or sitting height (Mall), cm.	Crown-heel or standing height (Mall), cm.	Weight at end of month, grams	Ratio of increase to weight at beginning of month
0	(diameter of ovum = 0.1 mm.)		(Ovum = 0.0000005 g.)	
I	0.25	0.25	0.004	7999.99
II	2.5	3.0	2.0	499.0
III	6.8	9.8	24.0	11.0
IV	12.1	18.0	120.0	4.0
V	16.7	25.0	330.0	1.75
VI	21.0	31.5	600.0	0.82
VII	24.5	37.1	1000.0	0.67
VIII	28.4	42.5	1600.0	0.60
IX	31.6	47.0	2400.0	0.50
*X	33.6	50.0	3200.0	0.33

* 270 days (Mall).

AVERAGE PHYSICAL MEASUREMENTS OF AMERICAN CHILDREN IN THE FIRST FOUR YEARS OF POSTNATAL LIFE. (Based in part on the figures of Crum and Taylor.)

Age	Sex	Weight, pounds	Height, inches	Chest girth, inches	Head girth, inches
Birth	Boys	7.3	20.5	13.0	14.0
	Girls	7.1	20.0	12.9	13.8
6 months	Boys	18.0	26.5	17.4	17.4
	Girls	16.7	25.9	17.1	17.1
12 months	Boys	21.9	29.4	18.6	18.5
	Girls	20.7	28.9	18.1	18.0
18 months	Boys	24.6	31.7	19.1	19.1
	Girls	23.4	31.1	18.6	18.5
2 years	Boys	27.1	33.7	19.5	19.4
	Girls	26.4	33.4	19.4	19.0
3 years	Boys	32.2	37.1	20.6	19.9
	Girls	30.5	36.7	20.4	19.4
4 years	Boys	35.9	39.5	21.1	20.1
	Girls	33.7	39.0	20.4	19.7

GROWTH IN RELATIVE VOLUME OF THE PARTS OF THE BODY.
In per cent. of the total body volume.

	Head and neck	Trunk	Arms	Legs
Second fetal month	45	50	3	3
Sixth fetal month	37	40	8	15
Birth	27	49	9	15
Two years	22	50.5	9	17.5
Six years	15	51	9	25
Maturity	7	53	10	30

The growth in length in fetal life is indicated in a preceding table (p. 20) and by the upper curve in fig. 21. The age of the fetus may be estimated from its standing height by 'Hasse's rule'; namely: that before the fifth month the age in fetal months is equal to the square root of the total (standing or crown-heel) height, while after the fifth month the age equals one-fifth of the standing height in cm. This give approximate results except for the first 2 months.

The length of the body at birth usually falls between 48 and 52 cm. (approximately 19 to 21 inches). The birth-length, like the birth-weight, is influenced by sex, race, and a number of other factors. In the neonatal period there is often a slight decrease in length due to changes in bodily proportions in the recovery from the molding effects of birth.

The curve of postfetal growth in length is a sinuous one similar to the curve of postnatal weight increase and the same phases may be recognized in it. Length increases about 30 per cent. (15 cm. or 6 inches) in the first six months and about 50 per cent. (25 cm. or 10 inches) in the first year (fig. 22). During early and middle childhood the lineal increase is very slow, averaging only about 6 or 7 cm. per year. The prepuberal length increase, like the weight increase, begins earlier in girls than in boys and is completed sooner. The body increases approximately 3.3 times in length during the postnatal developmental period. Growth in length usually ceases at about 18 years in females and soon after 20 in males.

FIG. 21.—CHART OF THE AVERAGE GROWTH IN LENGTH AND WEIGHT IN FETAL LIFE. (Based on the data of Mall, A. W. Meyer and Jackson.)

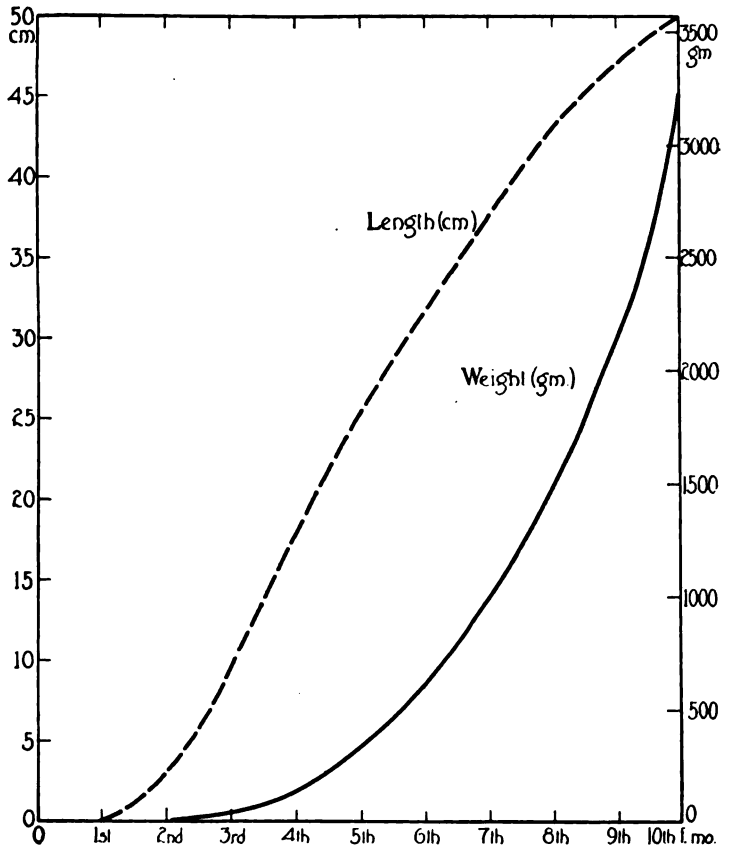
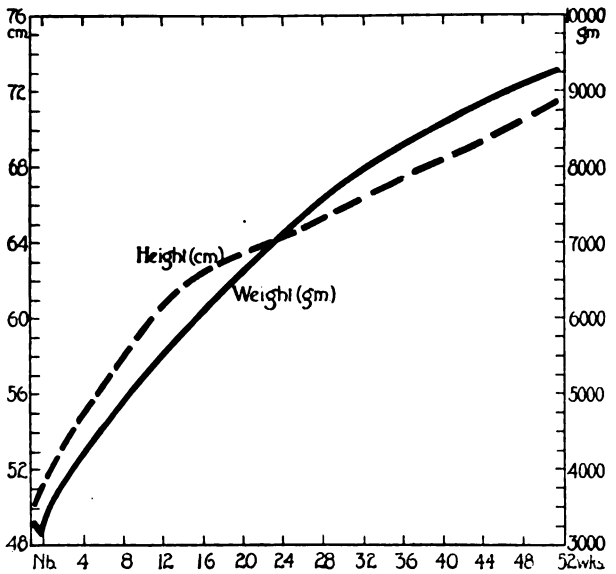


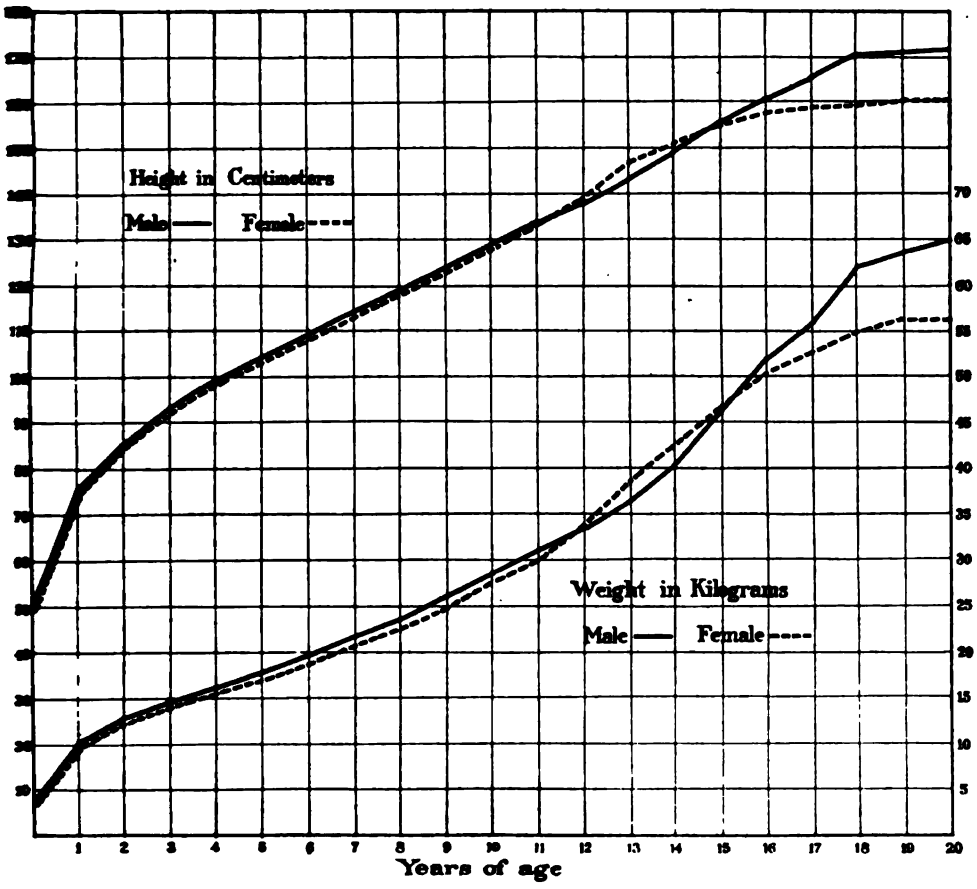
FIG. 22.—CHART OF THE AVERAGE GROWTH IN HEIGHT AND WEIGHT IN THE FIRST YEAR (Bedvel.)



The relation between the length and the weight of the body changes greatly in the developmental period. In later fetal life and early infancy the mass of the body is much greater in proportion to its length than at any subsequent time. The decline in relative weight begins about the middle of the first year and continues until after puberty. Thereafter there is a period of relative mass increase which may continue throughout maturity. During infancy and childhood females are relatively lighter than males but after puberty they are relatively heavier.

The surface area of the body in the developmental period.—The metabolism of the body is greatly influenced by the relation of its surface or cutaneous area to its mass or volume, and this relation is greatly altered in the course of postnatal

FIG. 23.—CHART SHOWING AVERAGE POSTNATAL GROWTH IN HEIGHT AND WEIGHT. (After Stratz.)



development. The surface area of the average newborn child is about 2500 square cm. (400 square inches). This is doubled in the first year and is tripled in the middle of childhood. There is a period of rapid increase in surface area before puberty and the total gain between birth and maturity is about 7-fold. But the weight of the body increases approximately 20-fold in this time and there is consequently a great reduction in the ratio of surface area to mass or volume (from over 800 square cm. of surface area per kilogram of body weight in the newborn to less than 300 square cm. per kilogram in the adult.)

The relative growth of the parts of the body.—Growth and differentiation do not take place at the same time or rate in the various parts of the body and the changes in proportions which occur in the developmental period are dependent on this lack of uniformity. While each part passes through its own cycle of changes these changes as a whole tend to follow what is known as the *law of developmental direction;* for it is generally found that development (including

growth and differentiation), in the long axis of the body, appears first in the head region of the body and progresses toward the tail region and similarly development in the transverse plane begins in the mid-dorsal region and progresses lateroventrally (in the limbs proximodistally).

Some of the changes in the proportions of the body and the relative size of its several parts are indicated in figs. 15 and 16 and in a preceding table (p. 21). The *head* is the largest part of the body in earlier stages, forming about one- alf of the body in the second fetal month, about one-quarter at birth, and from 6 to 8 per cent. in maturity. The *trunk* as a whole remains of about the same relative size throughout the developmental period (45 to 50 per cent.) although the thoracic portion reaches its maximum in the earlier stages and the pelvic portion not until adolescence. The *lower limbs*, like the pelvis, develop slowly, forming about 3 per cent. of the body at the end of the period of embryo, about 15 per cent. at birth and reaching about 30 per cent. in the adult. The *upper limbs* also form about 3 per cent. of the body weight at the close of the embryonic period. They increase to 8 or 9 per cent. at birth and maintain thereafter about the same relative size.

These changes cause a great increase in the relative weight and volume of the caudal or lower part of the body; and with them the *midpoint* of the body (between crown and sole) is gradually shifted from the upper margin of the thorax at the end of the embryonic period to a level slightly above the umbilicus at birth, and to the level of the crest of the pubis in the adult. The center of gravity is also shifted caudally from the cervical region in the embryo to the point where the inferior vena cava pierces the diaphragm at birth, and to a point just in front of the sacral promontory in the adult.

The relative growth of systems.—There is a marked difference in the growth of the various systems of the body. The *skeleton* grows comparatively slowly during the greater part of prenatal life but increases much more rapidly in the last two fetal months. At birth it forms from 15 to 20 per cent. of the body. Its postnatal growth apparently proceeds with that of the body as a whole, the total increase in weight between birth and maturity being about twenty-fold. The *musculature* also grows rather slowly in the young embryo but increases to about 25 per cent. of the body at birth and to 40 or 45 per cent. in the adult. The blood-vessels apparently also increase in relative weight after birth. The *central nervous system*, on the other hand, is relatively enormous in the young embryo, decreasing from about 25 per cent. of the body in the second fetal month to about 15 per cent. at birth and to between 2 and 2.5 per cent. in the adult. Data for the peripheral nervous system and the skin are somewhat scanty and rather unsatisfactory, but it is evident that both undergo a considerable reduction in relative weight in the postnatal developmental period. The *visceral group* (as a whole) shows a slow but steady decrease in relative weight after the embryonic period, forming about 15 per cent. of the body weight in the second month, about 9 per cent. in the newborn, and from 5 to 7 per cent. in the adult.

Growth of organs.—While in general the individual organs follow the course of growth of the visceral group, each organ has its own characteristic scheme of relative growth. As a rule, after its appearance in embryo, each organ increases more or less rapidly to a maximum relative size, after which, although increasing in absolute size, it decreases in relative size through subsequent prenatal and postnatal life to maturity.

Curves of the absolute growth of the various organs in the period of the fetus all appear much alike, showing an initial period of slow increase followed after the fifth month by a terminal phase of rapid growth. This uniformity is lost at birth and most of the major organs, on the basis of the course of their postnatal growth, can be classified in 4 main groups—splanchnic, nervous, genital and lymphoid (fig. 24).

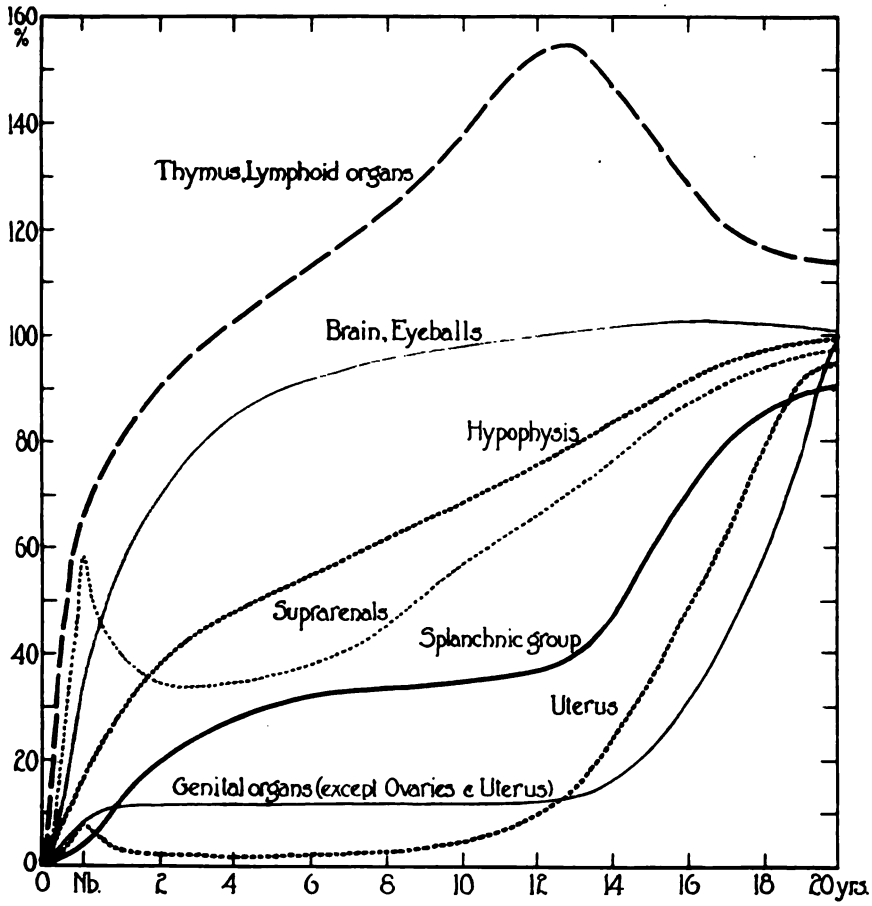
The *splanchnic group* includes the digestive, respiratory, urinary organs, the thyroid gland, the heart, and the spleen. These organs increase rapidly in weight in infancy and the first part of early childhood. In the latter part of early childhood and in middle childhood they grow quite slowly. They enter on a second phase of rapid growth in the prepuberal period, and this is followed by a terminal phase of slow increase in adolescence. In general the growth of the organs of this group is similar to the growth of the body as a whole.

The *nervous group* includes the brain, spinal cord, and eyeballs. These structures grow very rapidly in infancy and have completed over 90 per cent. of their postnatal increase by the close of early childhood.

The organs of the *genital group* (all genital organs with the exception of the ovaries and uterus) grow very slowly until the prepuberal period, when they enter on a phase of rapid increase which extends into or through adolescence.

The structures of the *lymphoid group* (excluding the spleen but including the thymus) are large at birth, grow rapidly until puberty, and then decline in absolute weight.

FIG. 24.—CHART ILLUSTRATING THE COURSE OF GROWTH OF THE VARIOUS TYPES OF ORGANS. The growth of the various organs is calculated in per cent. of their adult weight.



The organs which do not fall under any of the preceding categories are the suprarenal glands, the ovaries, the uterus and the hypophysis. Their growth is considered in connection with their development in the following sections.

THE SKELETON

The skeleton, including the bones, cartilages, ligaments, and joints, is derived from the mesoderm. The process is inaugurated by the formation, in the future skeletal regions, of masses of thickened mesenchyma known as scleroblastema. The hard parts of the skeleton, the bones and cartilages, arise in the more condensed parts of the scleroblastema while the joints are formed from the intervening portions. The majority of the thickened scleroblastemal masses are differentiated into cartilage. Certain of these cartilages persist throughout life while a few may be converted at a later time into fibrous tissue. But by far the greater number are replaced by bone during the later development of the skeleton.

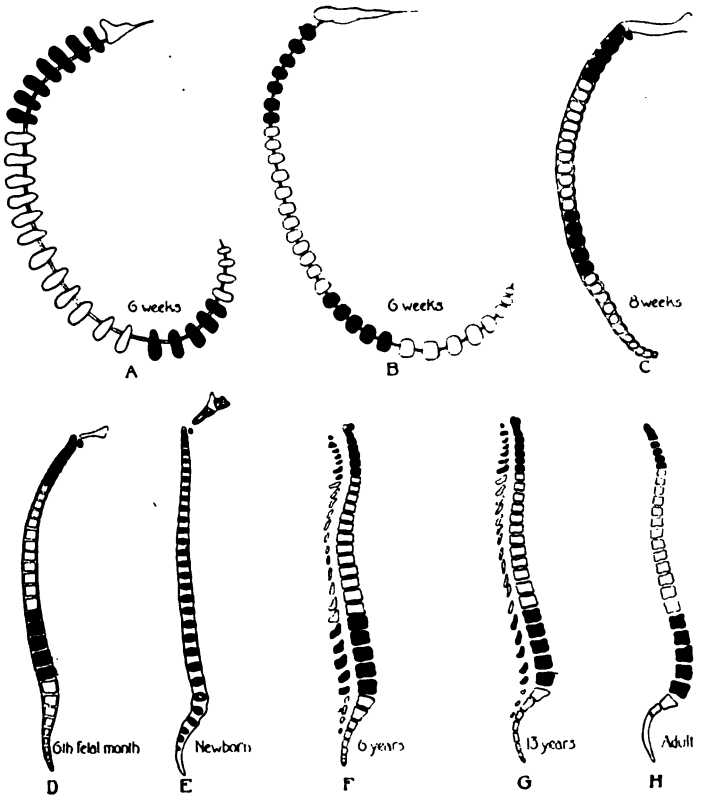
Most of the bones of the body arise through the replacement of previously formed bodies of cartilage by bony material, while a smaller number are formed directly in the membranous scleroblastema. The former are known as cartilaginous or replacement bones and the latter

are termed membranous or investment bones. All the bones of the extremities, the bones of the spinal column and thorax, the auditory ossicles, the hyoid bone, and the greater part of the bones of the base of the skull are cartilaginous bones. The bones of the face and the greater part of the vault of the skull are membranous bones. Certain of the skull bones are formed partly in membrane and partly in cartilage.

The **process of ossification** begins in discrete foci which are known as centers of ossification. These centers are formed from time to time throughout the developmental period, the first appearing in the clavicle in embryos of the sixth week and the last, in the epiphyses of the vertebral column, in the third decade of postnatal life. Over eight hundred centers are formed in the body and of these slightly more than half appear after birth.

Almost all bones of the adult are formed from one or more centers of ossification; the relation of the total number of bones in the mature skeleton to the total number of centers being approximately as 1 to 3. The ossification centers of all bones of the body with the exception

FIG. 25.—MEDIAN SAGITTAL SECTIONS OF THE VERTEBRAL COLUMN AT VARIOUS AGES ILLUSTRATING THE DEVELOPMENT OF THE NORMAL SPINAL CURVATURES. Cervical and lumbar vertebræ indicated in black. (Based in part on the figures of Bardeen, Williams and Cunningham.)



of those of the carpus, tarsus, skull, and sternum, may be divided into two general classes, the primary and secondary. The primary centers which form the greater part of the bone almost always appear before birth. Such centers, when located in long bones, are known as diaphyses. The secondary centers or epiphyses are, with one or two exceptions, formed during postnatal life. A further consideration of the nature of diaphyses and epiphyses will be found in the section on Osteology (p. 82).

As the formation of new centers and the fusion of older ones proceeds at unequal rates during the first two decades, the number of separate bone masses in the body varies from year to year during this period. The **number of bones** in the average newborn child is 270. This number is reduced in the first 2 or 3 years of life through the fusion of primary centers which are present before birth. From this time until puberty, however, the number increases steadily through the formation of epiphyses and the ossification of the carpus and tarsus. In the fourteenth year there are about 350 separate bony masses in the body. After puberty the number again increases rapidly until nearly the middle of the third decade. Often it is not until middle life that the number of bones is reduced to the usual quota of 206, excluding the smaller sesamoids.

The spinal column.—In the latter part of the first month the notochord is surrounded by a sheath of mesenchyme in which may be recognized segmentally arranged masses which represent the vertebræ and are formed from the sclerotomes of the mesodermic somites. Dorsal prolongations from these masses grow up on either side of the neural tube forming the arches

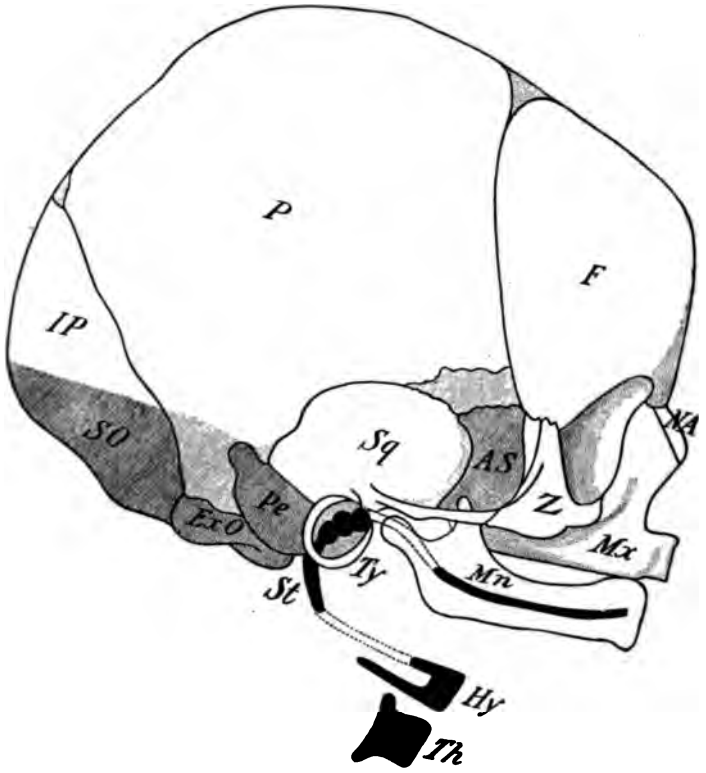
of the vertebræ, and at the same time lateral outgrowths appear which represent the various lateral projections of the vertebræ including the costal processes.

In the second and third fetal months the cervical and sacral regions form the greater part of the vertebral column (fig. 25). At birth the cervical part forms approximately one-fourth, the thoracic part one-half, and the lumbar part one-fourth of the entire movable spine. In the adult the thoracic portion continues to form approximately one-half of the free vertebral column, but the lumbar portion is increased to about one-third, and the cervical portion is reduced to one-fifth or one-sixth of the whole. It is probable that in most cases these proportional postnatal changes take place in the first 3 years.

During the first fetal month the vertebral column shows a pronounced ventral *flexion*. From this time until birth the free portion gradually becomes straighter while the sacral portion first becomes straighter and later acquires a second ventral curve. In the newborn child the free column forms a single gentle curve with an anterior (ventral) concavity extending from

FIG. 26.—DIAGRAM SHOWING THE CATEGORIES TO WHICH THE BONES OF THE SKULL BELONG. (After McMurrich.) The unshaded bones are membrane bones, the heavily shaded represent the chondrocranium, while the black represents the branchial arch elements.

AS, alisphenoid. ExO, exoccipital. F, frontal. Hy., hyoid. IP, interparietal. Z, zygomatic. Mn, mandible. Mx, maxilla. NA, nasal. P, parietal. Pe, periotic. SO, supraoccipital; Sq, squamosal; St, styloid process; Th, thyroid cartilage; Ty, tympanic.



the first cervical to the last lumbar vertebra, while the sacrum is directed somewhat posteriorly. The cervical curve appears when the infant begins to lift its head but neither at this time nor later does it become a fixed flexure. The lumbar curve appears as the child assumes the upright posture. It forms very slowly and throughout childhood and adolescence it may be effaced by stretching the spine. Later the lumbar curve is fixed, in a measure, by the anterior thickening of the lower lumbar vertebræ and the intervertebral disks between them. This process begins in later childhood and continues slowly until maturity. For further details on the curvatures, see p. 97.

The cartilaginous vertebræ are formed by the appearance of centers of chondrification of the blastemal vertebræ. There are four of these centers for each vertebra, two lateral ones which soon fuse in the body, and one for each side of the vertebral arch. The ossification of the vertebræ is considered in the section on **Osteology.**

The material between the vertebral masses is later converted into the outer portions of the intervertebral disks; and the segments of the notochord which occupy these regions form the nuclei pulposi. The vertebral portions of the notochord degenerate.

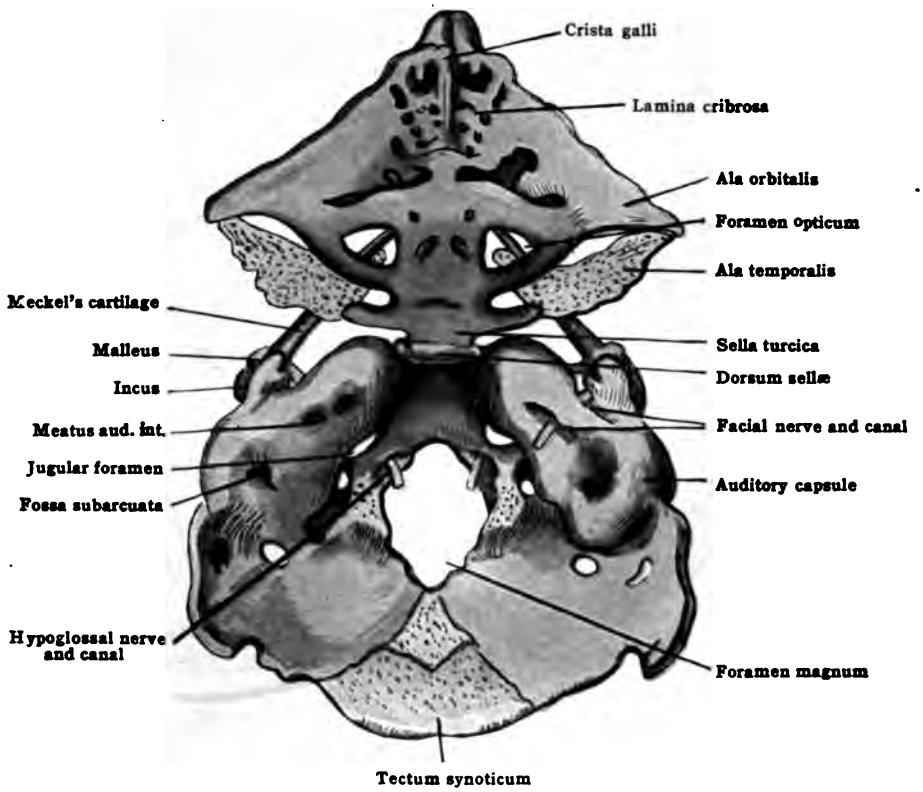
The *length* of the movable or free vertebral column (cervical, thoracic, and lumbar vertebræ) at the end of the second fetal month is about 2 cm. This is more than doubled in the third month, nearly quadrupled in the fourth, and increased almost 10-fold by birth when the average length is almost 20 cm. (8 in.). Between birth and maturity the movable vertebral column increases in length between 2 and 2.5 times, about two-thirds of this growth being accomplished

before puberty. After the second fetal month the vertebral column forms from 40 to 45 per cent. of the total length of the skeleton.

Development of the skull.—The bones of the skeleton of the head may be divided into three main categories (fig. 26): (1) the group of cartilage bones developed mainly in the base of the skull around and anterior to the cephalic portion of the notochord and about certain of the organs of sense; (2) the membrane bones which form the vault of the skull and the framework of the upper part of the face; and (3) the cartilage bones which have their origin from the cores of the branchial arches. The distinction between these three parts of the head skeleton is often imperfect, for their parts overlap and fuse during development and the relations between them are constantly shifted and modified.

In the skull, as in the other parts of the skeleton, three stages, the blastemal or membranous, the chondrogenous, and the osseogenous, may be recognized although they overlap considerably and do not proceed at the same rate in all parts of the head skeleton.

FIG. 27.—MODEL OF THE CHONDROCRANIUM OF A HUMAN FETUS 8 CM. IN LENGTH. Cartilage in blue. Viewed from above. (After O. Hertwig.)



Toward the end of the first month the brain is enclosed in a membranous sac formed by the condensation of the surrounding mesenchyma. The basal portion of this sheath forms a thickened plate which surrounds the cephalic portion of the notochord and projects forward beyond its anterior termination. The occipital portion of this plate is greatly expanded and is connected with the fibrous capsules around the developing internal ears. The anterior part of the plate extends forward into the nasal region.

The formation of the *chondrocranium* in the basal portion of the cranial blastema begins early in the second month and is practically complete by the close of the third (fig. 27). The caudal or occipital portion of the chondrocranium forms almost a complete ring around the foramen magnum and extends laterally about the base of the posterior part of the brain. Lying anterior to the occipital portion of the skull on either side are the cartilaginous auditory capsules. The contiguous borders of the occipital portion of the skull and the auditory capsules are partly fused, but lacunæ in this region indicate the position of the future hypoglossal and jugular foramina and transmit the structures which pass through these openings in the adult skull. A median bar of cartilage, which represents the basilar portion of the occipital bone and the body of the sphenoid, passes forward from the anterior margin of the foramen magnum and terminates in an expanded frontonasal plate. Two pairs of processes arise from this median mass. The posterior (alisphenoid) represents a part of the greater wing of the sphenoid and the anterior clinoid processes. The latter fuse with the frontonasal plate enclosing the optic foramina. The medial portion of the frontonasal plate extends forward into the nasal region forming the fundament of the ethmoid bone and a part of the nasal capsule. The lateral portions (orbitosphenoid) spread over the eyes and represent the lesser wings of the sphenoid.

The *visceral elements of the skull* are derived from cartilages formed in the branchial arches. That of the first arch is known as Meckel's cartilage. It extends from the outer surface of the auditory capsule through the mandibular process to the ventral median line. The upper portion of Meckel's cartilage is differentiated into two parts which form two of the auditory ossicles, the malleus and the incus. The lower part is enclosed in a sheath of membrane bone which forms the mandible (fig. 28). All of this part of the cartilage disappears with the exception of its medial tip which is probably involved in the formation of the mental protuberance. The upper portion of the cartilage of the second or hyoid arch forms a portion of the stapes and a part of the styloid process of the temporal bone while its lower segment gives rise to the lesser cornu and a part of the body of the hyoid bone. The upper portions of the third, fourth

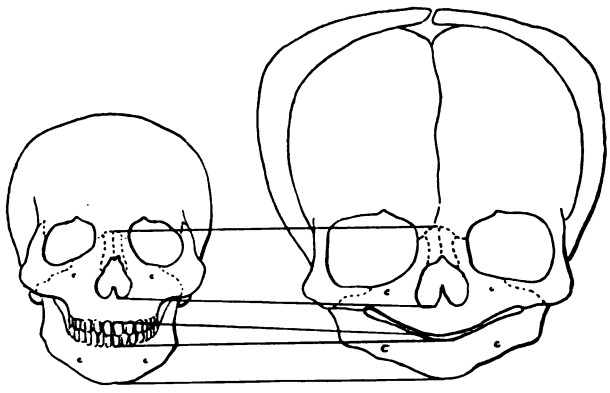
FIG. 28.—MANDIBLE SHOWING RELATIONS OF MECKEL'S CARTILAGE IN A HUMAN FETUS OF 8 CM. CROWN-RUMP LENGTH. (After Kollmann.)

and fifth arches form no permanent structures. The lower part of the third arch gives rise to the greater cornu and a part of the body of the hyoid bone, and the lower parts of the fourth and fifth arches are involved in the formation of the thyroid cartilage.

The further history of the ossification of the bones of the head will be found in the section on **Osteology.**

Growth of the skull.—The most striking characteristic of the fetal skull is the great predominance of the neural over the visceral portion. During the period of the chondrocranium the base of the cranium is large as compared with the roof or vault but with the growth of the cerebral hemispheres the vault becomes increasingly prominent. In early stages of development the occipital region forms by far the largest part of the cranium. Later the parietal portion enters on a period of rapid growth and becomes the predominant region, and finally in the last fetal months the frontal region becomes the center of most vigorous expansion.

FIG. 29.—SKULLS OF THE NEWBORN AND ADULT. Drawn to the same face height to illustrate the relative proportions of the facial and neural skeleton at birth and in maturity. (After Holl.)



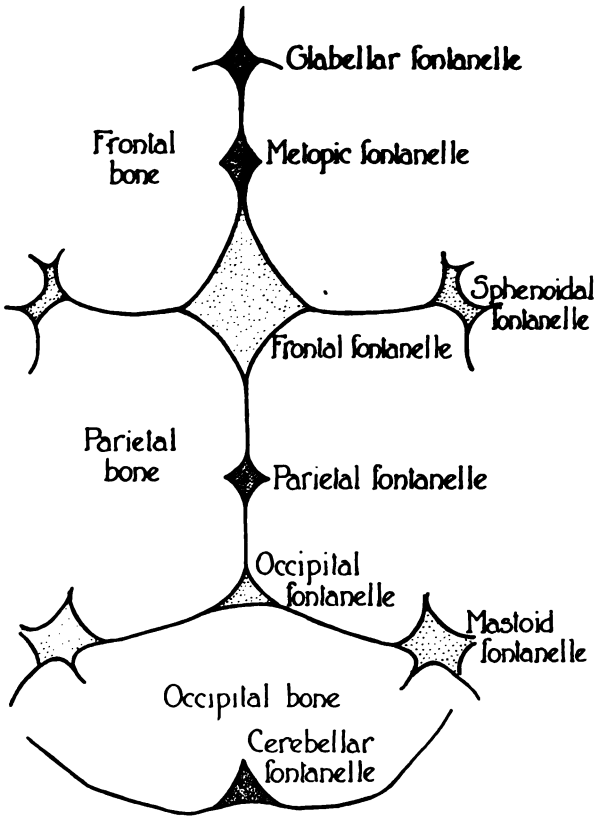
At birth the skull is large as compared with the rest of the skeleton. The neural portion is still much larger than the visceral or facial, the relation between the two being as 8 to 1 as compared with the ratio of 2.5 to 1 in the adult (fig. 29). The vault in comparison with the base of the cranium is also much larger than in later life.

The bones of the cranial vault are quite thin and are separated by narrow strips of membrane which are expanded at the angles of the parietal bones into areas of some size which are known as *fontanelles*. Theoretically fontanelles may be formed at any point on the calvarium which is equidistant from three or more contiguous centers of ossification. There are some 26 such points on the vault of the skull and constant or occasional fontanelles have been found in most of these locations. Two median and single fontanelles (the frontal and occipital), and two lateral and paired fontanelles (the sphenoidal and mastoid), are commonly present at birth. Their positions are shown in figs. 30 and 188–190. Besides these constant fontanelles, numerous accessory ones may be present. The more important ones, the parietal, cerebellar and metopic fontanelles, are all located along the sagittal suture.

The involution of the frontal fontanelle usually begins some months after birth generally completed early in the second year. The occipital fontanelle is generally clc the end of the first trimester. The sphenoidal fontanelle commonly closes in the first 6 1 and the mastoid fontanelle between 12 and 18 months after birth. The obliteration fontanelles takes place by the progressive ingrowth of the edges of the bone which bound but occasionally separate ossification centers may arise within them and form indep bones which occupy all or part of the original space.

The skull as a whole grows less in postnatal life than the other divisions of the sk the neural portion increasing in volume about 5 times and the facial portion about 1 Between birth and maturity the *cranial capacity* rises from 400 to 1500 c.c. and the hor circumference of the skull from about 32 cm. to 48 or 50 cm. Most of this growth take in the first two or three years after birth (fig. 31). The postnatal growth of the skull is associated with the growth of other structures of the head and particularly with those brain and eyeballs, the teeth and paranasal sinuses, and certain of the larger muscles.

FIG. 30.—DIAGRAM OF THE CALVARIUM AT BIRTH, SHOWING THE POSITIONS OF THE CO: AND THE MORE IMPORTANT ACCESSORY FONTANELLES. Constant fontanelles sha light stipple, accessory fontanelles in heavy stipple.



structures influence the growth of the skull at different periods: the brain and eyeballs i in infancy and early childhood, the teeth and paranasal sinuses mainly in middle an childhood, and the muscles mainly in adolescence.

During infancy all parts of the skull grow rapidly, the cranial capacity increasin 400 cc. at birth to 700 cc. at 6 months and over 1000 cc. at 18 months. The face grow more rapidly than the cranium in this period, the ratio between the two being reduced to 8 at birth to 1 to 6 in the second year. Most of the early growth of the face is due expansion of the orbits, which accomplish over half of their postnatal growth in the first 2 but there is also a marked growth of the maxillæ and mandible in connection with the de ment of the deciduous dentition.

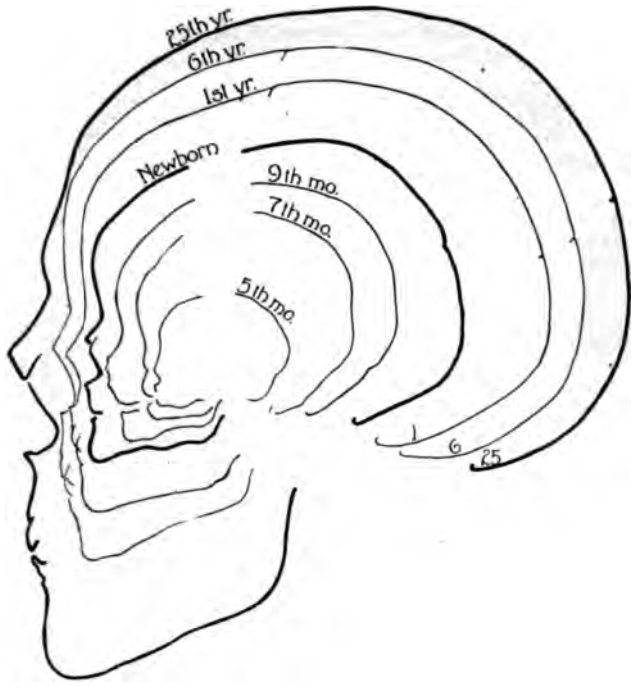
From 2 to 7 years the growth of the skull is continued, although less rapidly than in in The cranium expands slowly, the vault growing more than the base. The facial skeleton more rapidly than the neural portion and by 5 years the ratio between them is 1 to 5. of the growth is in the lower part of the face and is due to the expansion of the dental and the development of the maxillary sinuses.

In middle and later childhood the skull grows little, aside from the lengthening of t which accompanies the establishment of the permanent dentition. In adolescence the of the skull again increases. The cranium enlarges slightly in all diameters, mainly t the increase in the thickness of the bones of the vault, and the face completes its growt

the full development of the paranasal sinuses and the upper and lower dental arches. As a rule these later changes are more extensive in the male than in the female skull.

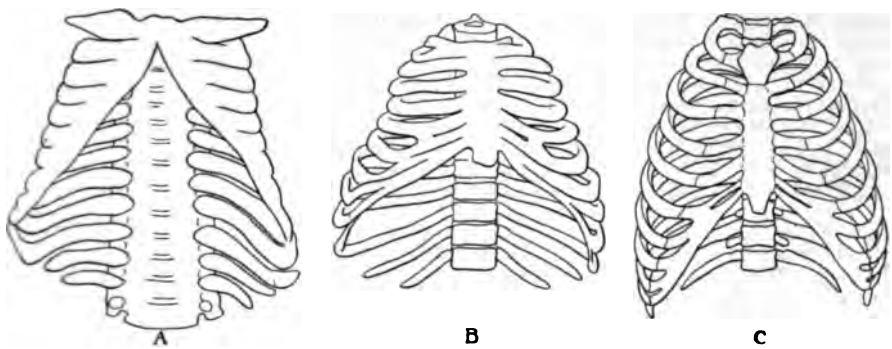
The thorax.—The formation of the thorax is first indicated in the blastemal period by the development of the costal processes of the thoracic vertebræ. These structures represent the future ribs. They assume a rod-like form and rapidly grow ventralward in the thoracic body

FIG. 31.—TRACINGS OF MEDIAN SAGITTAL SECTIONS OF THE SKULL AT DIFFERENT AGES, ILLUSTRATING THE RATE OF GROWTH OF THE CRANIUM. (Based on the figures of Corrado and Welcker.)



wall. Their distal ends unite craniocaudally, forming longitudinally directed sternal bands on either side of the ventral midline. The fundament of the unpaired sternum is formed by the side-to-side union of these bands, together with a small mass (the episternum) which is derived from a band of thickened mesenchyma connecting the sternal ends of the developing clavicles.

FIG. 32.—ANTERIOR VIEWS OF THE SKELETAL THORAX.
A, of an embryo 15 mm. long. (After Müller.) B, of a newborn child. C, of an adult. All drawn to the same absolute size.



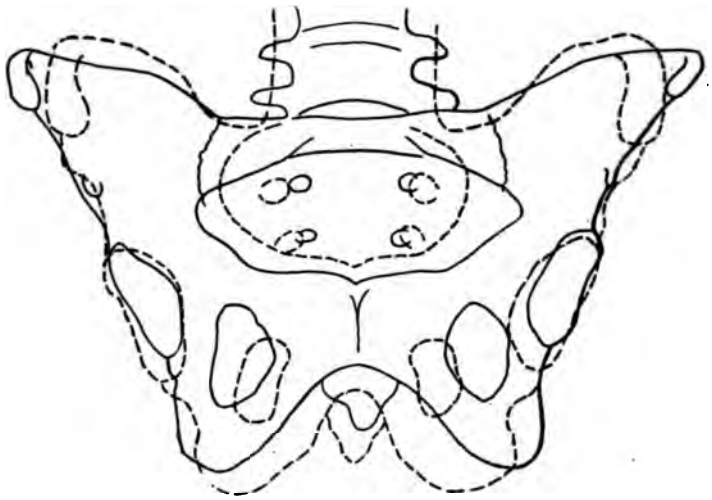
Some of the later changes in the *form of the thorax* are shown in figs. 32, A, B and C. In early stages the thorax is conical and is nearly circular in cross-section. At the time of their origin the ribs lie parallel with one another and are almost horizontal, but they soon incline downward (figs. 44, 45). After birth and particularly after the erect posture is assumed there is a progressive reduction of the relative anteroposterior diameter of the thorax and its base is relatively contracted. These changes are possibly due in part to the effect of gravity on the viscera and to the reduction in relative size of the organs of the upper abdominal region.

The postnatal growth of the thorax, as determined by external measurements, particularly of the horizontal chest circumference, seems to follow the course of the growth of the body in height and weight. There is a period of rapid increase in infancy and a part of early childhood, a period of slow growth in middle childhood, followed by a phase of rapid growth in prepuberty and perhaps early adolescence, and finally a terminal period of slow increase to maturity.

The pelvis.—The pelvis is formed in part from the fixed vertebræ of the sacrum and coccyx, which are developed around the lower portion of the notochord, and in part from the blastemal ossa coxæ which are developed from the proximal portions of the mesenchymal cores of the lower limb-buds. These elements are not closely associated at the time of their differentiation and the complete pelvic girdle with definite fundaments of the pubic symphysis and the sacroiliac articulations is not established until about the end of the second month. In early fetal life the pelvis is relatively small. After the third month all of the pelvic diameters grow at approximately the same rate and there are no great changes in the shape of the pelvis from this time to birth.

The *pelvis of the newborn* differs from that of the adult in a number of particulars (fig. 33). It has a distinctly conical form and its length is greater in proportion to the transverse and conjugate diameters. The pelvic cavity is relatively as well as absolutely much smaller than in the adult. The superior aperture approaches a circle more closely than in later life, although

FIG. 33.—DRAWING OF ANTERIOR VIEWS OF THE PELVES OF AN ADULT MALE AND A MALE NEWBORN DRAWN TO THE SAME ABSOLUTE SIZE AND SUPERIMPOSED. Adult pelvis in solid line, newborn pelvis in broken line. (After Merkel.)



even at birth the transverse diameter is greater than the conjugate. The dimensions of both the lesser pelvic cavity and the inferior aperture are smaller in proportion to the superior aperture than at maturity. The sacrum forms a greater portion of the pelvic circumference and is less depressed between the ilia. The sacral promontory is less marked, but a second prominence may be indicated at the level of the linea terminalis. There is little indication of the sacral concavity. The acetabula are very large and shallow at birth while the obturator foramina are relatively small. The pelvis is more vertical in position than later, the plane of the superior aperture forming an angle of 80° in the horizontal as compared with 50° to 60° with the adult, while the long axis of the symphysis pubis is more nearly perpendicular.

During the first 2 years of life the pelvis grows rapidly in all dimensions. This growth is continued at a slower rate from 2 to 5 years, but there is comparatively little increase between 5 and 10 years. There is a second period of more rapid growth in later childhood and adolescence, and by the end of the second decade the pelvis has almost obtained its adult dimensions, although many of the pelvic epiphyses do not unite with the main bones until the twenty-fifth year.

Until the infant assumes an erect position, the pelvis changes but little in form. As this position becomes habitual, the sacrum descends between the ilia and the promontory is definitely established. With this there is a relative expansion of the ala of the ilia, an increase in the pubic angle and a bending of the sacrum backward. The increase in the transverse diameter of the pelvis is brought about mainly by the growth of the sacrum and the posterior parts of the ilium. Growth also takes place along the line of apposition of the three divisions of the os coxæ in the acetabulum, but there is probably comparatively little growth, at least in males, at the symphysis pubis. The pelvic growth which occurs after puberty is practically all epiphyseal.

Sexual differences in the pelvis appear about the sixth fetal month, mainly in the form of differences in the pubic angle and the shape of the ilia. The pelvis of the newborn male is larger than that of the female, the sacrum is relatively wider, the ilia less vertical, the pubic angle more acute and the acetabula shallower and more horizontal. The sexual differences of the newborn pelvis, aside from those of size, are usually masked in the early period of rapid

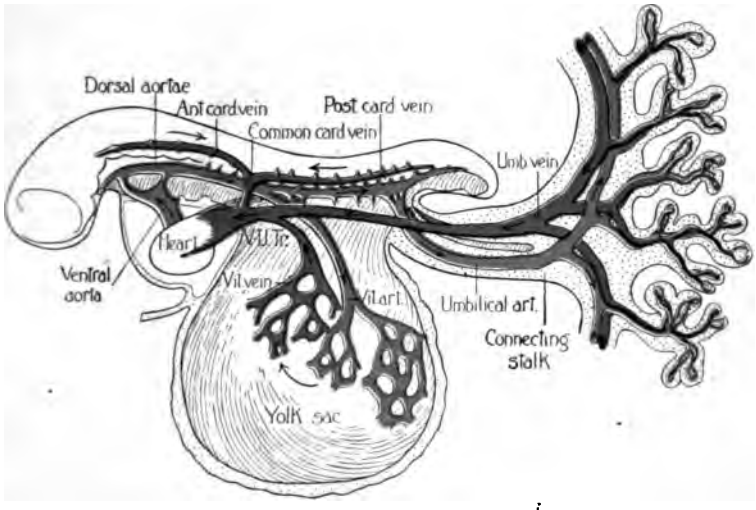
growth and do not reappear until the prepuberal period. During the first decade the pelvic measurements of boys are usually larger than those of girls, but after this time the dimensions of the female pelvis are generally the greater.

THE VASCULAR SYSTEM

In this section the consideration of the vascular system will be limited to a description of the establishment and course of the early embryonic circulation, an account of the fully established circulation of the late fetus, and the changes in the circulatory system at birth; including an outline of the general growth of the vascular structures. The morphologic changes by which the various segments of the embryonic circulatory system are transformed to the adult structures are described in connection with the VASCULAR SYSTEM (pp. 668 and 724).

In man and the higher mammals the development of the vascular system is extremely precocious, due to the small amount of food substances stored in the ova of these forms and the consequent necessity of a system of vessels which can draw nourishment and oxygen from the maternal circulation and distribute them to the tissues of the embryo.

FIG. 34.—DIAGRAM OF THE CIRCULATION OF A YOUNG HUMAN EMBRYO. (Based in part on the figures of Watt and Brödel.)



Fundaments of the first vessels in man appear in the form of cords, cellular strands, and cysts in the extraembryonic mesoderm at a stage preceding the establishment of the embryo on the germinal disk. These structures are organized into two sets of anastomosing cords; one, the umbilical or allantoic, which is associated with the connecting stalk, allantois, and the trophoblast; and the other, the vitelline, which spreads out in the mesoderm of the yolk-sac. Trunks formed from these networks pass, in the mesoderm, to the margin of the germinal disk. As the tubular embryo is formed from this structure, they enter the developing body either as definite trunks or as capillary plexuses, and form the framework of the embryonic vascular system.

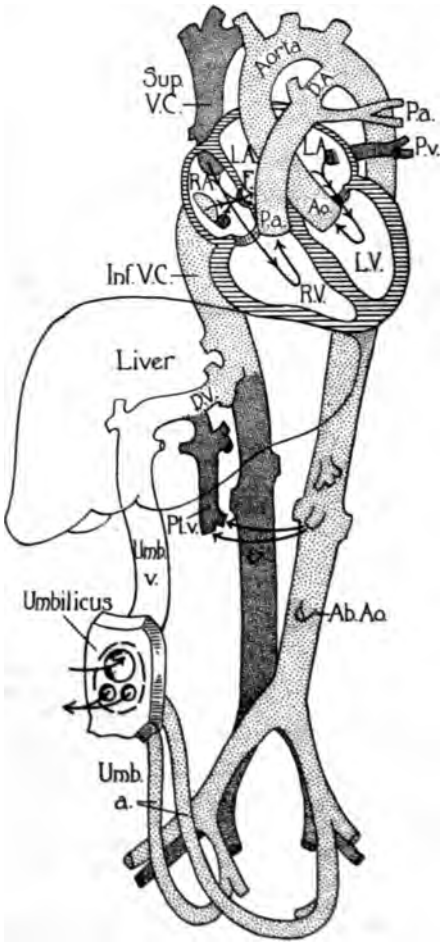
The course of the embryonic circulation.—The form of the circulatory system in the young embryo is illustrated by fig. 34. The blood from the capillaries of the chorion (the modified trophoblast) passes to the embryo through the paired umbilical or allantoic veins. Before entering the embryo these vessels are joined by the vitelline veins which collect the blood from the yolk-sac. These vessels form the vitelline-umbilical trunks (V.U.Tr.) which enter the body, on either side, in the splanchnic mesoderm below the foregut and join in the tubular heart, which is formed from them. From the heart the ventral aortæ pass below and then around the anterior part of the foregut and gaining its dorsal surface run backward as the paired dorsal aortæ. The dorsal aortæ give off the vitelline arteries (Vit. art.) which return blood to the capillaries of the yolk-sac and finally terminate in the umbilical or allantoic arteries which run to the chorion through the connecting stalk and end in the chorionic capillaries. The dorsal aortæ also give rise to a number of segmentally placed arterial sprigs which supply the tissues of the embryo. The blood from these vessels is collected by venules which empty into longitudinal venous trunks, the anterior and posterior cardinal veins. The cardinal veins on either side drain into a short common cardinal vein (duct of Cuvier) which opens into the posterior part of the heart-tube in common with the vitelline-umbilical trunks.

The umbilical veins are the nourishing vessels of the embryo, since they carry blood from the chorionic capillaries where it has received oxygen and food-stuffs (by osmosis) from the maternal circulation. These substances are absent from the vitelline veins, since the yolk-sac of the human embryo contains no reserve food material. Theoretically, at least, there is a mixture of arterial blood from the umbilical vessels and venous blood from the common cardinal veins in the posterior end of the heart; but the actual difference between the arterial and venous blood in the young embryo is probably very slight since the volume of the blood-stream is relatively large and the rate of circulation presumably very rapid.

The fetal circulation.—The course of the blood in the late fetus is shown in diagrammatic fashion in figs. 35 and 586. The pure or arterial blood from the placental capillaries enters the body by the single umbilical vein, and passes through this vessel to the liver where it is joined by a branch of the portal vein carrying venous blood. The blood from the sinus formed by the union of these two vessels passes through the *ductus venosus* which joins with the inferior vena cava (either directly or through the left hepatic vein). As the vena cava is carrying blood from the capillaries of the lower part of the body there is a further mixture of venous and arterial blood at this point. The stream of mixed blood now passes through the terminal portion of the vena cava and enters the caudal portion of the right atrium. The superior vena cava also enters the right atrium, bringing back venous blood from the head and superior extremities. The opening of the superior vena cava with its valves is so placed that the stream from this vessel is directed toward the *foramen ovale* between the right and left atria.

FIG. 35.—DIAGRAM OF THE FETAL CIRCULATION.

Ab.Ao., abdominal aorta. Ao., ascending aorta. D.A., ductus arteriosus. D.V., ductus venosus. F., foramen ovale. Inf. V.C., inferior vena cava. L.A., left atrium. L.V., left ventricle. P.a., pulmonary arteries. Pt.v., portal vein. P.v., pulmonary veins. R.A., right atrium. Sup.V.C., superior vena cava: Umb.a., umbilical arteries. Umb.v., umbilical vein.



Despite this anatomical arrangement, however, experimental evidence indicates that the blood of the inferior and superior venæ cavæ is completely mixed in the right atrium. The blood from the right atrium flows in part into the left atrium, where it is joined by a small stream of venous blood, returning from the lungs through the pulmonary vein. It then passes into the left ventricle and thence to the systemic circulation through the arch of the aorta. A portion of the blood from the right atrium passes into the right ventricle and through it to the pulmonary artery. A small part of this stream is diverted to the right and left pulmonary arteries to supply the lungs, but the main current passes through the *ductus arteriosus* (Botalli) to pass into the descending arch of the aorta, joining the stream from the left ventricle which has come through the aortic arch. The blood passing through the aorta continues downward through this vessel, and such as remains after supplying the aortic branches flows into the umbilical arteries and thence back to the capillaries of the placenta.

Several *peculiarities of the fetal circulation* which are particularly striking may be enumerated. But one vessel in the body of the fetus, the umbilical vein, carries strictly arterial blood, and this vessel supplies no part of the body directly, except a small portion of the liver. The blood entering the right atrium from the inferior vena cava has already received venous mixtures from three sources (the portal vein, the inferior vena cava, and the vena azygos major). There is a complete mixture of blood from the superior and the inferior vena cava in the right atrium and a further addition of venous blood from the pulmonary vein in the left atrium. Thus the circulating blood of the fetal body is throughout mixed, venous and arterial. Its efficiency under these conditions probably depends: (1) on its very large quantity compared with the volume of the fetus; (2) on the rapidity of its circulation; and (3), on the relatively slow rate of catabolism (and hence slight amount of waste products) in the fetal organism.

The establishment of the adult circulation.—The change from the fetal to adult type of circulation is brought about by the closure of the fetal blood-passages, the umbilical vessels, the ductus venosus, the ductus arteriosus, and the foramen ovale. In this closure two processes can be recognized; the physiologic occlusion, which takes place immediately after birth, and the anatomical obliteration which occur days, months, or even years later. With the establishment of respiration the ductus arteriosus collapses, and all the blood from the pulmonary artery is forced through the branches of these vessels into the capillary bed of the lungs. This leads to an increased flow from the pulmonary veins into the left atrium and pressure in this chamber rises so that the valve of the foramen ovale is forced against the margin of the interatrial septum and the communication between the two chambers is interrupted. At the same time, with the tying of the umbilical cord, or in most cases even with the simple interruption of this structure, the fetal ends of the umbilical arteries and veins are contracted and their lumina obliterated. With this change, blood no longer flows through the umbilical vein and the current of blood through the ductus venosus ceases.

The actual obliteration of the fetal blood-passages rarely begins in the first fortnight of postnatal life. The obliteration of the ductus venosus is brought about through the interruption of its epithelial lining and invasion of its lumen by the connective tissue of the tunica media and tunica interna. The vessel is generally completely closed by the end of the first month. Obliteration of the ductus arteriosus takes place in much the same way, generally in the first half year of postnatal life, but sometimes not before the close of the first year. The occlusion of the foramen ovale is apparently brought about by the proliferation of connective tissues in the valve and at the margin of the foramen, through the mechanical irritation of these structures by friction in the movements of the heart. At the close of one year the foramen is obliterated in about one-half of all cases, but the opening remains patent to the probe in nearly one-third of adult hearts. The obliteration of the umbilical arteries and vein begin shortly after birth with the organization of the thrombus at the cut end of the vessel; but the process is not complete throughout the intra-abdominal portion of these vessels until several weeks after birth. For changes in the umbilicus, see p. 1403.

The growth of blood-vessels.—In the young embryo the blood-vessels have very thin walls and their caliber is relatively enormous; that of the dorsal aorta, for example, is nearly one-fifth the transverse diameter of the body in the third week. In fetal and postnatal life the blood-vessels continue to increase in absolute diameter even to very old age, but their relative diameter is steadily reduced, at least until maturity. In the developmental period, the different vascular trunks constantly adjust to the changing volumes of the areas which they supply and to modifications in the caliber of vessels which drain from them. Thus the arterial trunks to the head increase in size during the period of rapid growth of this part while those of the lower limbs grow slowly in early life but increase rapidly when these members enter a period of active growth. And the abdominal aorta undergoes an actual decrease in diameter for a period after birth when the umbilical arteries which drain it are obliterated.

The walls of arteries in the fetal period are relatively thicker, compared with the diameters of their lumina, than in postnatal life; but their absolute thickness increases slowly to an advanced age. In fetal life the growth of the walls of arteries takes place almost entirely in the tunica media and tunica externa, the tunica interna remaining almost unchanged from the fourth fetal month until birth. After birth, however, the relative growth of the interna is much more rapid than that of the other coats. Apparently there is little growth of the tunica media after puberty although the interna increases throughout postnatal life.

There are but few observations on the growth of vessels in length, but these seem to indicate that the lineal growth of blood-vessels is closely correlated with the lineal growth of adjacent structures.

Growth of the heart.—In the second fetal month the heart forms about 3.6 per cent. of the body. The relative weight decreases to about 0.7 per cent. at the close of fetal life. With the great increase in the weight of the body in the first year the relative heart-weight drops to about 0.5 per cent., and from this time there is very slow decrease until the middle years of adult life when the average relative weight of the heart is 0.4 to 0.45 per cent. It should be remembered that during fetal life the heart not only sends the blood through the capillaries of the body but also through those of the fetal portion of the placenta. The relation of the weight of the heart to the combined weight of the body and placenta in the latter fetal months is not far from the adult ratio of heart-weight to body-weight (0.47 to 0.45 per cent.).

The growth in absolute weight of the heart in postnatal life follows the course of the visceral group of organs. The birth-weight of the organ (20 to 25 grams) is doubled in the first year, tripled in 4 years and increased 6 to 8-fold by puberty. The total postnatal gain in absolute heart-weight is usually about 12-fold.

The mass of the walls of the various chambers of the heart is distinctly modified in the developmental period. The atria form a considerably larger proportion of the heart-weight in the fetus than in the adult, the reduction in their relative weight taking place mainly in early infancy. In the fetal period the weight of the right ventricle is equal to or greater than that of the left. But the additional work which falls to the left ventricle after the separation of the

systemic and pulmonary circulations at birth causes this portion of the heart to grow so rapidly that by the close of the first year it is nearly twice the weight of the right ventricle.

The lymphoid and sanguifactive organs.—The first *blood-cells* of the human embryo are differentiated in connection with the developing blood-vessels of the yolk-sac: but the liver soon becomes a seat of blood-formation and remains a sanguifactive organ until birth. The *bone-marrow* appears as the primary marrow cavities are formed in the course of the ossification of the different bones, and since the first ossification centers do not appear until the sixth week there is little differentiation of bone-marrow until after the period of the embryo. The *spleen* appears in the fifth week as a thickening of the layers of splanchnic mesothelium of the dorsal mesogastrium, the splenic pulp being differentiated from a mass of dense mesenchyma formed by the proliferation of cells from the splanchnic layer of the region. The fundaments of lymph-glands appear in the third month as collections of lymphoid cells about plexuses of lymphatic capillaries. The formation of lymph-glands continues through fetal life and probably for an indefinite time after birth. For development of the lymphatics in general, see LYMPHATIC SYSTEM, p. 739.

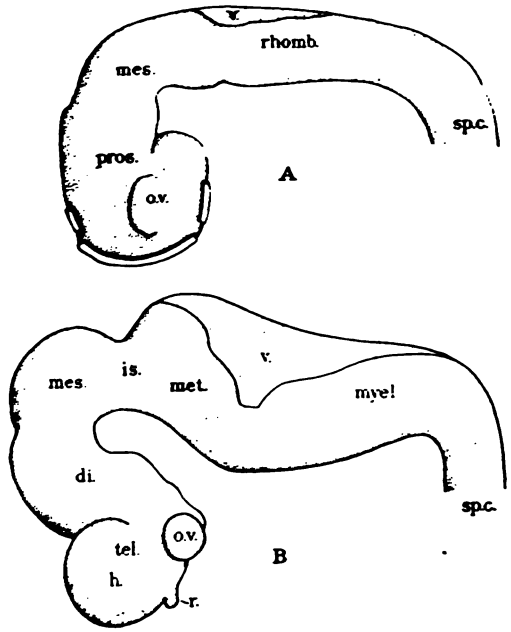
The growth of lymphoid tissue has been considered in connection with the growth of organs. It is characterized by a relatively great amount of lymphoid tissue at birth, an increase in absolute amount until about puberty and a subsequent decline in amount both absolute and relative (fig. 24). The spleen, however, does not follow this course. It is relatively small in early fetal life but increases in the latter part of the period, forming about 0.3 per cent. of the body at birth. During postnatal life it declines in relative weight, forming less than 0.2 per cent. of the body in the adult. The increase in the absolute weight of the spleen in postnatal life follows the course of the splanchnic group of organs.

THE NERVOUS SYSTEM

The early development of the brain.—Even before the neural plate is folded into the neural tube it is differentiated into an anterior expanded portion which represents the brain and a narrower posterior part which represents the spinal cord. As the anterior part of the plate becomes tubular it is further divided by grooves into three swellings or vesicles, the forebrain, midbrain, and hindbrain (figs. 36A and B). As these chambers differentiate, the axis of the

FIG. 36.—A, THE BRAIN OF A 4.0 MM. HUMAN EMBRYO. (From Lewis, after Bremer.) B THE BRAIN OF A 10.2 MM. EMBRYO. (From Lewis, after His.)

Except the isthmus, is., the principal subdivisions of the brain are indicated by prefixes of the term encephalon. sp.c., spinal cord. h., hemisphere. o.v., optic vesicle. r., rhinencephalon. v., roof of the fourth ventricle.



cephalic portion of the tube is bent first at the level of the midbrain (the cephalic flexure) and soon after at the juncture of the hindbrain at the cord (the cervical flexure). The floor of the middle portion of the hindbrain is curved ventrally at a much later time, forming the third or pontine flexure. For further details and figures of the early development of the brain, see pp. 11, 790.

Before the forebrain is completely closed it is expanded transversely forming lateral outpouchings, the optic vesicles. Each optic vesicle forms a distal optic cup which produces the retina of the eye, while its proximal optic stalk remains attached to the forebrain as the optic

nerve. The point of attachment of the optic stalks marks the line of division of the forebrain into two secondary vesicles, an anterior telencephalon and a posterior diencephalon. Somewhat later a second pair of lateral outpouchings are formed from the walls of the telencephalon dorsal to the optic evaginations. These are the cerebral vesicles. They form the cerebral hemispheres and (secondarily) the olfactory lobes and tracts. The diencephalon forms a smaller part of the forebrain. Its floor is depressed posterior to the optic stalks, forming the embryonic infundibulum from which are differentiated the posterior lobe of the hypophysis, the mammillary bodies, the tuber cinereum, and the infundibulum of the adult. The lateral walls of the diencephalon are thickened forming the thalamus and geniculate bodies. The roof becomes membranous anteriorly to form the epithelial layer of the tela chorioidea; posteriorly it forms the pineal body.

The walls of the mesencephalon become greatly thickened, their dorsal portion forming the corpora quadrigemina and their ventral portions the greater part of the cerebral peduncles (crura cerebri).

Three secondary divisions can be recognized in the hindbrain or rhombencephalon: (1) a narrow isthmus, which is continuous with the mesencephalon anteriorly; (2) a short middle segment, the metacephalon; and (3) a large posterior portion, the myelencephalon. The isthmus changes little in form in later development. It is represented in the adult by a portion of the brain-stem which includes the anterior medullary velum, and parts of the brachium conjunctivum (superior cerebellar peduncles) and of the cerebral peduncles. The metencephalon forms an expanded and thickened ring of the brain-tube immediately behind the isthmus. Its dorsal part forms the cerebellum and its ventral portion the pons. In early stages the myelencephalon forms a widely expanded chamber with a membranous roof and a thick floor which is continuous with the cord without any sharp line of demarcation. The myelencephalon becomes the medulla oblongata, a part of the roof forming the posterior medullary velum.

The spinal cord.—In the young embryo the spinal cord extends to the extreme caudal end of the body; but with the regression of the tail in the latter part of the second fetal month there may be recognized an anterior or trunk portion which will form the definitive spinal cord, and a posterior or caudal segment which undergoes partial involution, forming the filum terminale. The distinction between these two portions is definitely established before the middle of the third month. The cervical and lumbar enlargements of the cord can be recognized by the end of the third month. For relations at various stages, see figs. 43–48.

The cerebrospinal cavities.—The central lumen of the neural canal is never lost but exists throughout life in a modified form as the central canal of the spinal cord and the ventricles of the brain. The lumen in the lower end of the trunk portion of the spinal cord remains as a chamber of some size, the *ventriculus terminalis*, but in the remainder of the cord it is reduced in relative size through the fusion of the dorsal part of the lateral walls to the minute central canal. In the myelencephalon and the metencephalon the lumen is expanded, forming the fourth ventricle; while in the isthmus and mesencephalon it is reduced to a narrow channel, the Sylvian aqueduct. The third ventricle represents the expanded anterior end of the canal in the forebrain and the lateral ventricles its lateral extensions which are produced with the evagination of the cerebral vesicles, the points of origin of these extensions being represented by the interventricular foramina. The epithelial layers of the choroid plexuses which project into the third and fourth ventricles are formed by the invaginations of the membranous wall of the brain in these regions and the morphologic continuity of the walls of the canal is not interrupted, at least during the embryonic and the early fetal periods. The so-called fifth ventricle (cavum septi pellucidi) has no developmental relation to the cerebrospinal cavities, being formed much later between the apposed medial walls of the hemispheres.

Growth of the central nervous system.—The relative weight of the central nervous system in the developmental period has been considered in connection with the general growth of systems. The absolute weight of the *brain* at the end of the third fetal month is about 3.5 gm. This is increased about 10-fold by the middle of the fetal period and about 100-fold by birth. The weight of the *brain* is more than doubled in infancy and is increased about 3-fold by the close of the first period of childhood. Thereafter the rate of absolute growth is very slow, the adult weight, which is about 3.6 times that of the newborn, being commonly attained by the close of the fifteenth year.

The *spinal cord* weighs about 0.15 gm. at the close of the third fetal month, increasing about 5-fold by the middle of the fetal period and 20-fold by birth. The cord increases about 8-fold in postnatal life, most of this growth taking place in infancy and early childhood. The spinal cord forms about 15 per cent. of the central nervous system in the second fetal month but thereafter it forms a decreasing proportion until birth when it is less than 1 per cent. In postnatal life, on the other hand, this ratio gradually rises to about 2 per cent.

The parts of the brain also show changing relations in relative size during the developmental period. The *brain-stem* follows the course of the cord, forming a larger proportion of the brain in fetal life, a gradually decreasing proportion in the later part of prenatal life, and a small relative increase after birth. The *cerebellum*, on the other hand, grows very slowly in early fetal life but in the later fetal months enters a period of rapid relative growth which continues through infancy and early childhood. It forms about 3 per cent. of the brain in the third fetal month, about 6 per cent at birth, and about 10 per cent. in maturity. For topography of the developing brain, see figs. 43–48, also fig. 746.

The development of the peripheral nerves.—When the neural tube separates from the surface ectoderm there is left between these two structures a narrow plate of ectodermal cells known as the neural crest. These cells give rise to all of the sensory nerves of the cerebrospinal system, with the exception of the optic and olfactory nerves whose development is considered in connection with the sense organs. The motor nerves and the motor portions of the mixed nerves, on the other hand, are all formed as processes from cells located in the ventral or ventrolateral portion of the neural tube. The course of development of the spinal and cranial nerves is described in the section on the NERVOUS SYSTEM.

The eye.—Four elements enter into the formation of the main structures of the eye. These are: (1) the optic vesicle, derived from the lateral wall of the forebrain; (2) the lentic or optic placode, formed by a thickening of the surface ectoderm over the optic vesicle; (3) a zone of surface ectoderm immediately surrounding the lentic placode but which does not share in its thickening; and (4) the head mesenchyma which surrounds the optic vesicle and placode.

The optic vesicle gives rise to the retina (both nervous and pigmented layers), the epithelium covering the posterior surface of the iris and ciliary body and the optic nerve. The lentic placode is converted into a lentic vesicle which later forms the lens. The surface ectoderm immediately surrounding the lentic placode produces the anterior epithelial layer of the cornea, the epithelium of the conjunctiva and the parenchyma of the lacrimal gland. The surrounding mesenchyma forms the sclerotic and choroid coats of the eye and their derivatives. The vitreous body is probably derived in part from the ectodermal and in part from the mesenchymal elements of the eye. The further history of the eye is described in connection with the section on the SPECIAL SENSE ORGANS (p. 1114).

The ear.—As has been previously described (pp. 17, 29), the outer ear is formed from the first branchial groove or cleft, the middle ear is a derivative of the first branchial pouch, and the auditory ossicles are formed from the upper ends of the cartilages of the first and second branchial arches. The inner ear is formed from the otocyst, a closed sac formed from the otic or auditory placode which appears as a thickening of surface ectoderm above the first branchial arch. The development of the ear is considered in more detail in the section on the SPECIAL SENSE ORGANS (p. 1129).

The ear in childhood.—The ear of the newborn and infant differs from that of the adult in several important details. The external auditory meatus is relatively short and straight and there is no true bony meatus. The tympanic membrane is slightly smaller than in the adult, but it acquires its full size in infancy. It is slightly more horizontal in early life. The tympanic cavity and ossicles have reached their full size at birth and the epitympanic recess and antrum are quite as large as in maturity if not larger. The antrum lies entirely above the tympanic cavity and its lateral wall is only about 1 mm. thick. The mastoid process does not develop until after the first year and the mastoid cells usually appear in later childhood. The auditory (Eustachian) tube has about one-half of its adult length at birth but its diameter is quite as great as in maturity. The tube is almost horizontal in the infant, the oblique course of the adult tube being acquired with the growth of the nasopharynx in middle and later childhood. The internal ear has practically its adult dimensions at birth.

The olfactory organ.—The organ of smell is developed from the epithelium of the upper part of the nasal fossæ, whose history is described later in connection with the development of the digestive tract. The olfactory nerve is formed by the processes of specialized cells which remain in the olfactory mucosa. A rudimentary olfactory organ, the *organ of Jacobson*, is represented in the embryo by a pair of small pouches in the nasal septum. These usually disappear in the later part of fetal life.

THE DEVELOPMENT OF THE DIGESTIVE TRACT

Early development.—In the early embryo four main structures may be recognized which play a part in the later development of the digestive and respiratory tracts. These are: (1) the nasal pits and (2) the oral sinus, which are lined with ectoderm derived from the covering of the inferior surface of the head; (3) the archenteron, formed from the entoderm of the roof of the yolk-sac; and (4) the cloacal membrane. These elements form the epithelial linings of the digestive and respiratory tracts and the parenchyma of the glands connected with them. At a later time there is associated with them a considerable amount of mesenchyma which gives rise to the muscular wall and the connective tissue investments of the tubes and to the supporting framework of the associated glands.

Some of the general changes in the development of the digestive tract are shown in figs. 37, 43, 44, 45 and 46. The oral sinus is deepened and its roof gives rise to a median pocket (Rathke's pouch), which later separates and forms the anterior lobe of the hypophysis. At the same time the *buccopharyngeal membrane* separating the sinus from the cephalic end of the pharynx disappears and the ectoderm and entoderm becomes continuous in this region. The foregut is differentiated into an upper expanded pharynx and a lower tubular segment which later forms the esophagus, stomach, and a portion of the duodenum. The *midgut* elongates and its connection with the yolk-sac is reduced to a slender yolk-stalk. The *hindgut* is differentiated into an upper tubular portion and a lower chamber, the *cloaca*. The latter gives origin to the allantois and its floor is formed in part by the cloacal membrane. The cloaca is later divided, in the frontal plane, into a dorsal rectum continuous with the midgut and a ventral urogenital sinus which receives the allantois.

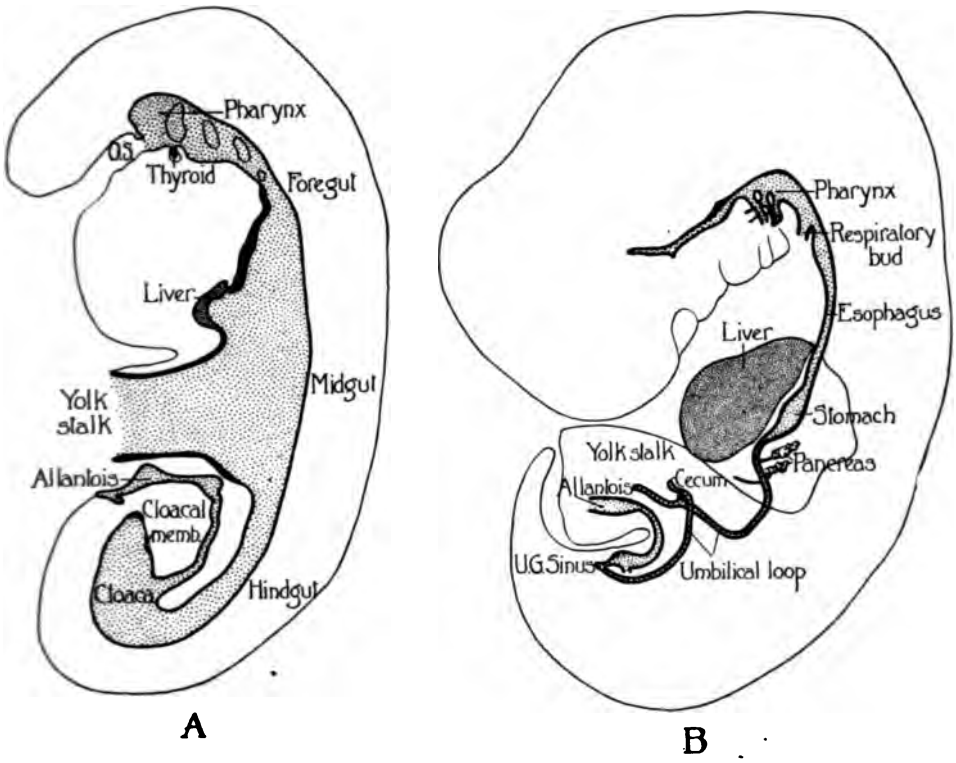
The mouth.—The floor of the embryonic mouth or oral sinus is formed by the inner surfaces of the mandibular processes. The margins of its roof are formed laterally by the maxillary processes and anteriorly by the medial nasal process; and its central portion includes two membranous plates which separate the oral cavity from the *nasal pits* above. These plates soon disappear and the oral sinus communicates with the nasal chambers by paired *primitive choanæ* (fig. 38). The definitive palate is formed by the growth of the paired *palatine shelves* which arise from the medial borders of the maxillary processes and grow toward each other, fusing in the midline. In this manner the upper part of the original oral cavity is left above the palatine shelves, forming the inferior portions of the permanent nasal fossæ. The formation of the boundaries of the mouth has been considered in connection with the development of the face (p. 16). After their establishment they are invaded by ridges of oral epithelium which form the oral vestibule separating the lips and cheeks from the alveolar processes.

The teeth.—The teeth are formed in part from the oral ectoderm and in part from the mesoderm of the cores of the maxillary and mandibular arches. The ectodermal portion arises as

vertical outgrowths from oral epithelium known as dental shelves, which extend into the alveolar processes and lie parallel with and medial to the labial grooves. A series of twenty cup-shaped expansions, the *enamel organs*, form on the free edges of the dental shelves. Each of these covers, in part, a small mass of condensed mesenchyma, the *dental papilla* (figs. 39 and 40).

FIG. 37.—RECONSTRUCTIONS OF THE DIGESTIVE TRACT.

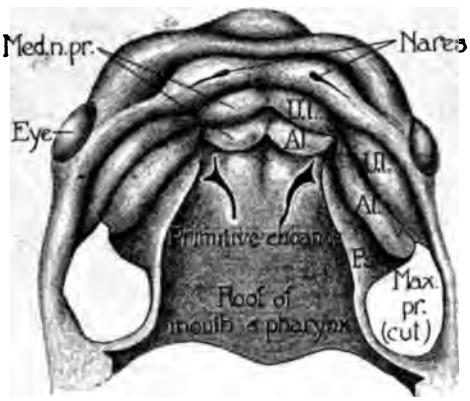
A, of an embryo 2.5 mm. long. (After Thompson and Lewis.) B, of an embryo 10 mm. long. (After Phisalix.)



The enamel organs enlarge rapidly and their connections with the dental shelves are reduced to slender necks. Each organ is differentiated into three parts: (1) a thin outer membrane attached by the neck to the dental shelf; (2) an inner membrane composed of a single layer of

FIG. 38.—RECONSTRUCTION OF THE ORAL REGION OF AN EMBRYO OF THE SECOND MONTH. (From Schaeffer after Kollman and Keith.)

Al., alveolar processes. Max.pr., maxillary process. Med.n.pr., medial nasal process P.s., palatine shelves. U.l., upper lip.

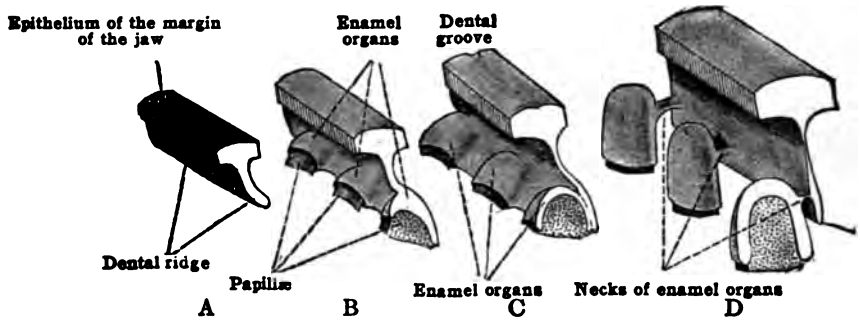


high columnar cells or ameloblasts; and (3) an intervening spongy mass, the enamel-pulp. Coincident with these changes the dental papilla is differentiated into a peripheral layer of columnar cells or odontoblasts, which immediately underlies the inner layer of enamel organ, and a dense central core which is highly vascularized.

The portion of the dental shelves which is not involved in the formation of the deciduous teeth gives rise to a second set of enamel-organs for the permanent dentition.

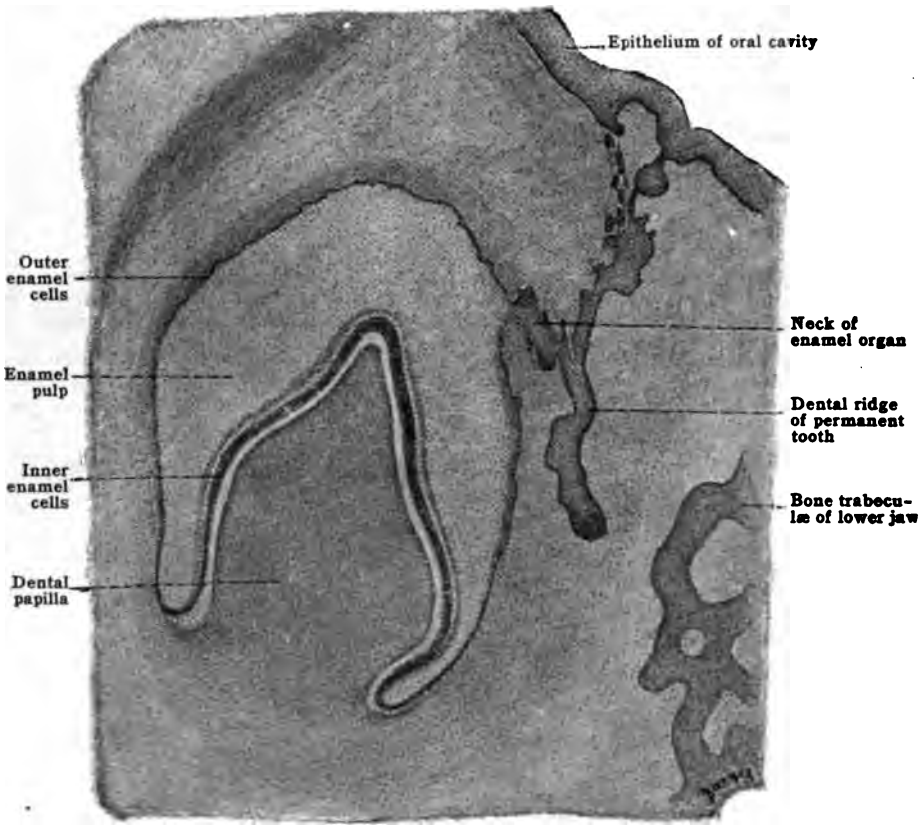
The *calcification* of the teeth begins in the eighteenth fetal week after the crowns are well outlined (fig. 40). The process starts at the crown of the tooth and extends toward the root. Simple teeth, such as the incisors, have single centers of calcification while teeth with two or more cusps have separate centers for each cusp, which soon fuse in a single mass. Calcification

FIG. 39.—DIAGRAMS SHOWING THE EARLY DEVELOPMENT OF THREE TEETH. One is shown in vertical section. (After Lewis and Stöhr.)



takes place in both the ectodermal and the mesodermal parts of the tooth germ. The cells of the inner layer of the enamel organ (ameloblasts) become greatly elongated and a deposit of enamel, in the form of fine globules, appears at their outer margins and gradually fills the cells, converting them into the *enamel-prisms*. The peripheral cells of the dental papilla (odontoblasts) likewise assume a columnar form and a deposit of dentine is laid down between them

FIG. 40.—SECTION SHOWING LATER STAGES OF TOOTH DEVELOPMENT. (After Szymonowicz.)



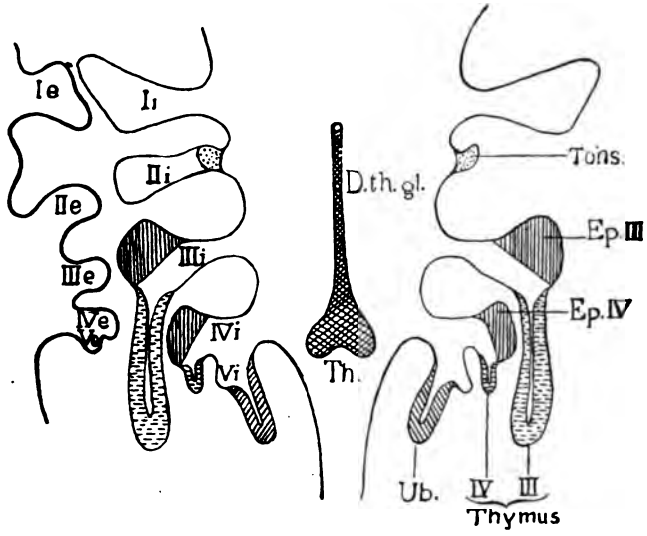
and the ameloblasts. As this material increases the odontoblasts retreat toward the center of the dental papilla, but processes which extend from them remain imbedded in the dentine as the dentinal fibers. The *cementum* which covers the dentine of the root is produced in connection with the surrounding mesenchyma in a manner similar to the formation of membrane-bone. The center of the dental papilla with its blood-vessels, lymphatics and nerves remains as the *pulp* of the tooth.

At the time of birth the germs of all the deciduous teeth and of all the permanent teeth, except the second and third molars, are present, and those of the deciduous teeth and the first permanent molars are partially calcified. The germs of the second permanent molars are formed in the second postnatal month but those of the third molars do not appear until about the fifth year. The later history of the teeth, including the chronology of their eruption, is considered in connection with the digestive tract (p. 1154).

The tongue.—The anterior part of the tongue is formed from a pair of lateral lingual swellings which appear in the floor of the mouth, at the level of the first branchial arch, early in the second month. These fuse together medially, replacing an earlier median swelling in this region, the *tuberculum impar*. The posterior part of the tongue is formed from the medial portion of the second, and possibly the third, branchial arch. The *musculature* of the tongue arises in situ from the thickened mesenchyma of the lingual region but its innervation (by the hypoglossal nerve) as well as its comparative development indicate that it was originally derived from certain of the occipital somites. The epithelium of the tongue is probably partly of ectodermal and partly of entodermal origin, the terminal sulcus indicating the boundary between the two layers.

FIG. 41.—DIAGRAM TO SHOW THE DERIVATIVES OF THE BRANCHIAL POUCHES.

Ie, IIe, IIIe, IVe, Ve, external branchial grooves. Ii, IIi, IIIi, IVi, internal branchial pouches. Tons., palatine tonsil. EpIII, EpIV, parathyroid glands. Ub, ultimobranchial body. Th., thyroid gland. D.th.gl., ductus thyroglossus. (Modified from Keibel and Mall.)



The salivary glands.—The parotid gland is formed from a shelf-like outgrowth of the epithelium at the angle of the mouth between the maxillary and mandibular processes; and the submaxillary and sublingual glands are formed from similar outgrowths from the medial and lateral angles of the grooves between the tongue and lower alveolar processes. The general scheme of the later development of submaxillary and parotid glands and the major portion of the sublingual gland is much the same. Each grows backward as a keel-like flange which becomes detached from the oral epithelium except for a small anterior connection which represents the future ostium of the duct of the gland. The proximal portion of the outgrowth forms the main duct of the gland, the distal expanded portion giving rise, by repeated divisions, to the smaller ducts and alveoli. The minor sublingual mass is developed from a series of separate outgrowths.

The pharynx.—The pharynx forms a considerable portion of the digestive tube in the young embryo. Its relative size undergoes a marked decrease in fetal life, followed by a slower reduction after birth. During infancy and childhood the length of the pharynx increases rapidly while the anteroposterior diameter grows slowly and the width remains almost unchanged. All diameters increase in middle and later childhood but the growth in length is still the most rapid. In adolescence there is a limited growth of all diameters.

During the fourth week four pairs of *branchial* (*pharyngeal*) *pouches* are formed from the lateral walls of the pharynx and a single median outgrowth (the thyroid diverticulum) appears in its floor. The pharyngeal pouches correspond in position to the branchial grooves, which are formed on the external surface of the neck, and are separated by the branchial arches. They give rise to a number of structures which are quite dissociated in later life (figs. 41 and 56).

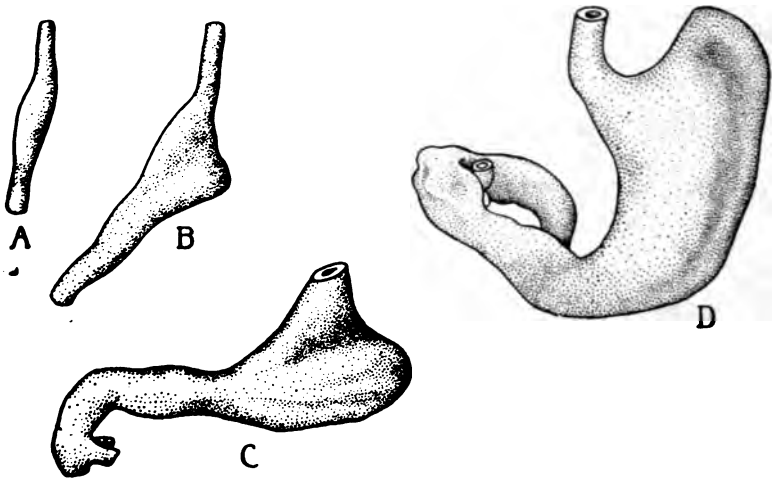
The *first pouch* is directed dorsally and laterally. Its outer extremity is expanded forming the tympanic cavity of the middle ear, while its proximal part is converted into the auditory (Eustachian) tube. A dorsal recess from the *second pouch* forms the tonsillar sinus and the epithelial portion of the palatine tonsil. The histories of the *third* and *fourth pouches* are similar. Both form dorsal and ventral diverticula, the former giving rise to the parenchyma of the parathyroid glands and the latter to the reticulum and thymic (Hassal's) corpuscles

of the thymus. The stalks of these pouches merge in the piriform recess. A pair of small *ultimobranchial bodies*, which possibly represent a fifth pair of pouches, arise from the lateral walls of the pharynx behind the fourth pouches. They form epithelial masses which migrate into the cervical region and are intimately associated with the thyroid. It is improbable that they form any part of this structure but they may give rise to small epithelial masses known as the *glandula insularis cervicalis*.

The palatine tonsils.—About the fourth fetal month solid epithelial buds from the floor of the second pouch invade the surrounding connective tissue. These are later converted into the fossulæ and glands of the palatine tonsil. Lymphoid cells are found in the mesenchymal tissue under the tonsillar epithelium in the sixth fetal month, but definite lymphoid nodules are not present until nearly the time of birth. The postnatal growth of the palatine tonsil is extremely variable. In many cases they reach their highest development in the fifth or sixth year and involution takes place in later childhood. Apparently, in other instances, their growth may continue to puberty or early adolescence. Early in the third fetal month the *plica triangularis* arises from the floor of the pharynx opposite the second pouch and grows upward over a portion of the tonsillar sinus. At the time of birth the plica triangularis forms a fold which surrounds the tonsil, except for a small portion of its posterior border, and covers a part of its free surface. The fusion of the plica triangularis with the walls of the tonsillar sinus is already under way at this time and many specimens show the characteristic subdivisions of the cavity which are found in the adult. In later fetal life and at birth the tonsil lies somewhat higher in the sinus than in later life and its axis is horizontal. The tonsil descends during infancy and its longer axis becomes vertical.

FIG. 42.—DEVELOPMENT OF THE STOMACH.

A, embryo 5 mm. long. B, embryo 8 mm. long (after Broman). C, embryo 10 mm. long. D, embryo 19 mm. long (after Lewis).



The pharyngeal tonsil and bursa.—Early in the second fetal month there appears in the roof of the pharynx a small pouch, the *pharyngeal bursa*, from which there develop a series of radiating folds which extend anteriorly nearly to the nasal openings. In the later fetal months these are invaded by lymphoid tissue and are converted into the *pharyngeal tonsil*. The structure reaches its maximum development in early childhood. Its involution generally begins in the prepuberal period and is completed in early adolescence. The bursa pharyngea is commonly converted into a small closed cyst which remains throughout adult life.

The esophagus.—The esophagus in young embryos is a short tube of relatively large caliber, flattened from side to side. During the early part of the second month it becomes considerably elongated but is reduced in relative diameter and assumes a cylindrical form. At birth the tube is 8 to 10 cm. (3 to 4 in.) in length from the cricoid cartilage to the cardia. Its length is doubled in the first three years and tripled by puberty, but there seems to be little longitudinal growth thereafter.

The stomach.—The stomach appears in the fourth week as a spindle-shaped enlargement of the lower part of the foregut. This is soon subdivided by the *incisura angularis* (or gastric angle) into an upper expanded cardiac and a lower tubular pyloric portion (fig. 42). The fundus develops as an outpouching of the cardiac portion in the latter part of the second month and the gastric canal ('Magenstrasse') is established about the same time. A little later the pyloric portion is subdivided into pyloric canal and antrum. As these changes take place the stomach is bent to the right at the level of the incisura angularis, and the entire organ is rotated from left to right through about 90 degrees. After this time the stomach changes little in form until distended by its contents, either before or immediately after birth, when there is a considerable expansion of the fundus, body and greater curvature.

In early stages, the long axis of the stomach is vertical. With the establishment of the incisura angularis it often becomes transverse or oblique but it commonly returns to the vertical position in late fetal life. With the distension which occurs at birth the long axis again becomes obliquely transverse and this position is usual until the erect posture is habitually assumed,

FIGS. 43, 44, 45, 46, 47 and 48.—A SERIES OF RECONSTRUCTIONS AND DISSECTIONS ILLUSTRATING THE GROWTH AND TOPOGRAPHY OF THE VISCERA IN THE DEVELOPMENTAL PERIOD. All specimens drawn to the same crown-rump length.

Fig. 43, embryo 4.2 mm. long. (Modified from His.) Fig. 44, embryo 11 mm. long. (Modified from Jackson.) Fig. 45, embryo 17 mm. long. (Modified from Jackson.) Fig. 46, fetus 65 mm. long. (Modified from Jackson.) Fig. 47, newborn 51 cm. long. Fig. 48, adolescent. (Based on drawings and casts of His and Symington.) Nervous system, yellow; gastrointestinal tract, red; spleen, blue; Wolffian body, green. All., allantois. Ao., aorta. Bl., bladder. Cl., cloaca. C.V., cardinal veins. E., esophagus. G., genital gland. Ht., heart. I., intestine. K., kidney. L., liver. Lg., lung. Ph., pharynx. Sr., suprarenal gland. St., stomach. U., uterus. W. b., Wolffian body.

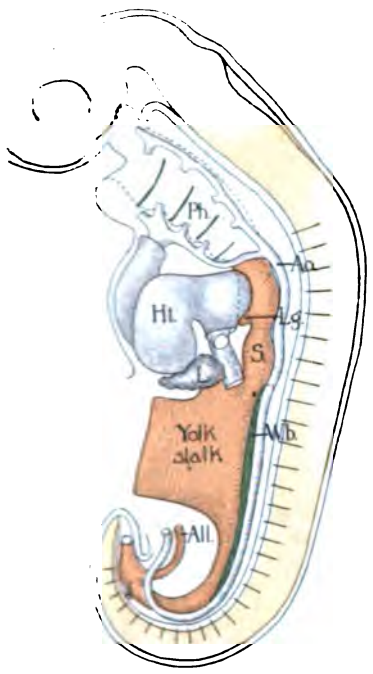


FIG. 43.

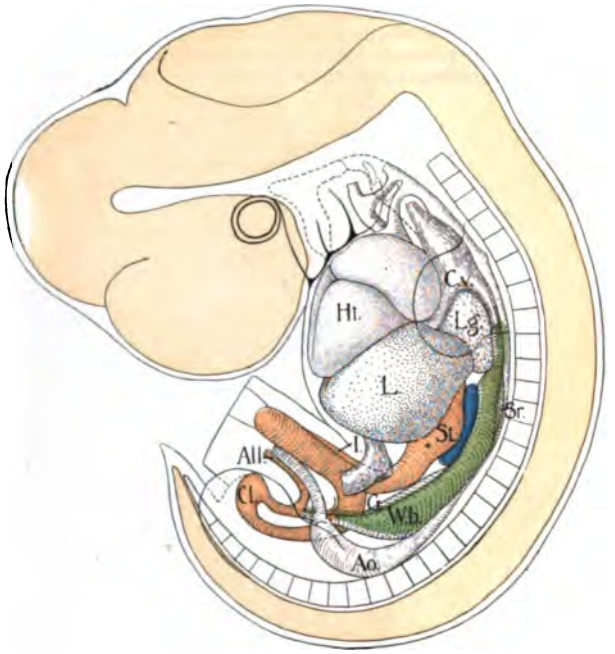


FIG. 44.

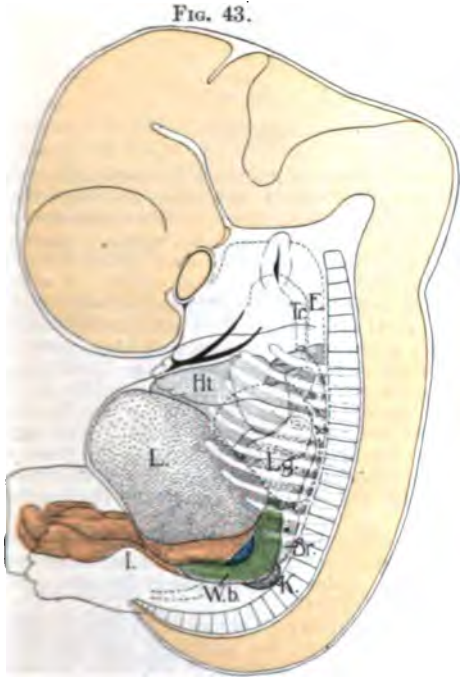


FIG. 45.

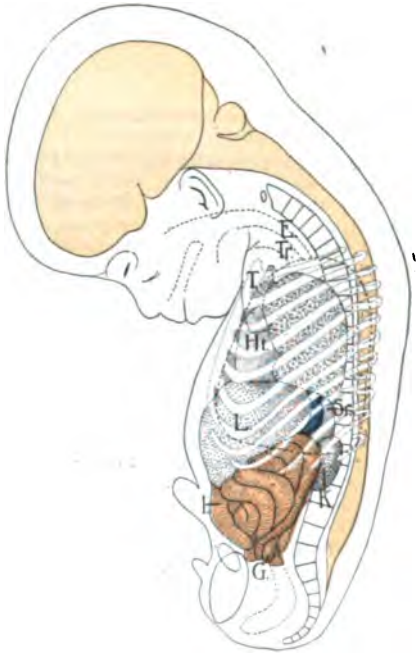


FIG. 46.

when the vertical position again becomes the more common. At the time of its differentiation the stomach lies in the upper part of the thorax but in early fetal life it descends to the upper abdominal region. There is little later change in the positions of the orifices of the stomach but with its subsequent growth in size and changes in form the lower margin gradually descends in the abdomen during the greater part of childhood.

The stomach grows with great rapidity in the latter part of fetal life and this rate is continued in the first trimester of postnatal life. The stomach increases in weight about 24 times between birth and maturity, its postnatal growth following the course of the splanchnic group of organs. The capacity of the stomach at birth is about 30 cc. It rises rapidly to about 90 or 100 cc. at the end of the first month and thereafter increases more slowly to 250 to 300 cc. at the end of the first year.

The development of the intestines.—With the separation of the archenteron from the yolk-sac the intestinal tract is established as a short and relatively straight tube extending from the stomach swelling to the cloaca. This tube in its rapid elongation is thrown into three main or primary loops and a number of secondary ones. The primary loops are: (1) the gastroduodenal loop which forms the upper portion of the duodenum; (2) the enterocolic

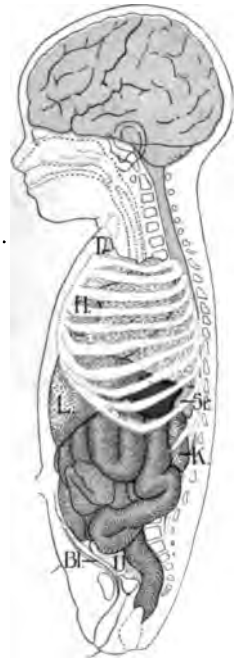


FIG. 47.

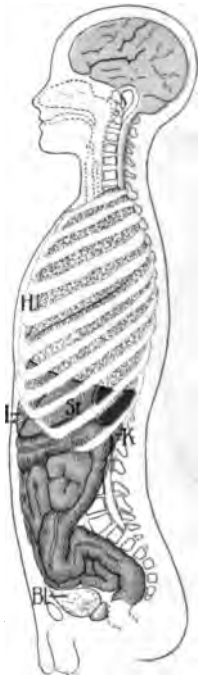


FIG. 48.

or umbilical loop which gives rise to the distal portion of the duodeum, the jejunoileum, and the cecum, ascending colon and a part of the transverse colon; and (3) the left colic loop which forms the remainder of the large intestine. The gastroduodenal loop is short and simple needing no further description. The umbilical loop first lies in the median sagittal plane of the body. It consists of a cranial and a caudal limb and a yolk-stalk arises from its summit which projects into an extension of the body-cavity, the umbilical celom. A slight swelling on the caudal limb marks the position of the cecum and the division between small and large intestines. In its further growth the umbilical loop turns on its axis and its caudal limb is carried first to the left, then anteriorly and later to the right of the proximal one, carrying the cecum with it. The development of the coils of the small intestine (see page 1194) takes place partly in the abdominal and partly in the umbilical celom. During the middle of the fourth month they return rather suddenly to the abdominal cavity and following this the first part of the colon and the cecum pass ventrally over the small intestines to lie in the right hypochondriac region below the liver. Later the cecum descends into the right iliac fossa to a level a little below that occupied in the adult. Its final position is acquired in early childhood after a slight ascent which is probably associated with the postnatal growth of the lumbar region.

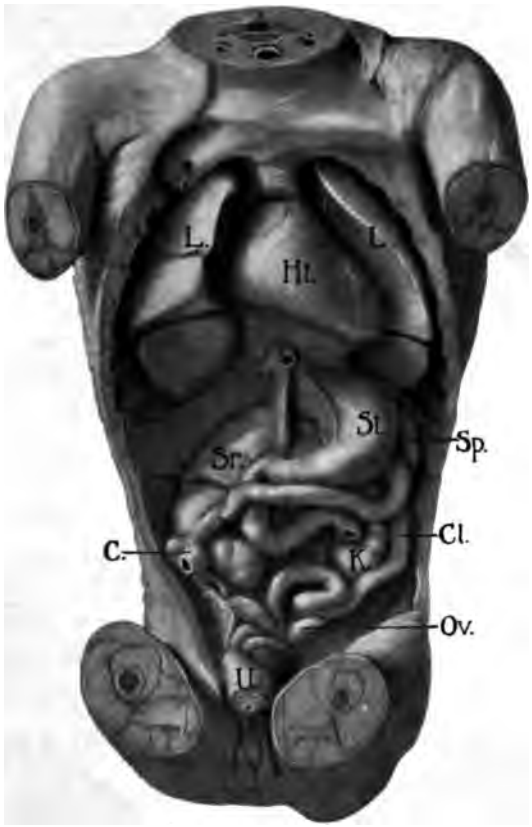
The left colic loop is formed by the bending of the lower part of the intestinal tube to the left side of the abdominal cavity some time after the formation of the other primary intestinal loops. Secondary curves in this loop form the left colic (splenic) and sigmoid flexures. For further details on the development of the intestines, see p. 1204.

The cecum and vermiform process (appendix).—The formation of the swelling which represents the cecum was mentioned above. After the rotation of the umbilical loop the cecal swelling is extended as finger-like projection from the ventral surface of the gut. A small diverticulum which represents the vermiform process arises from the apex of this projection in the third fetal month (fig. 50). The vermiform process grows rapidly, reaching its full rela-

tive length (as compared to the length of the intestine) by the middle of fetal life. In the fourth month the cecal projection is bent at right angles to the main axis of the segment of the intestine from which it arises and the ileocecal valve is formed by invagination of the terminal portion of the walls of the ileum at this point. At birth the cecum is relatively small. Its

FIG. 49.—DISSECTION OF THE THORACIC AND ABDOMINAL VISCERA OF A FETUS OF THE FIFTH MONTH.

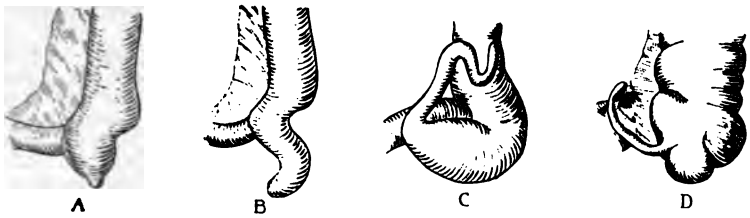
C., cecum. Cl., colon. Ht., heart. K., kidney. L., lungs. Sp., spleen. Sr., suprarenal gland. St., stomach. U., umbilicus. Ov., ovary.



lower end becomes directly continuous with the vermiform process without a sharp line of demarcation and the cecal sacculations are generally absent. The appendix usually lies directly below the cecum at this time, or is bent upward at an acute angle along its medial margin. The development of the cecal sacculations and the formation of a distinct cecal fundus usually takes place in early childhood (generally in the third or fourth year).

FIG. 50.—FOUR STAGES IN THE DEVELOPMENT OF THE CECUM AND VERMIFORM PROCESS. (After Kollmann and Paterson.)

A, embryo at the end of the second month. B, fetus of the third month. C, child ten weeks after birth. D, child of 5 years.

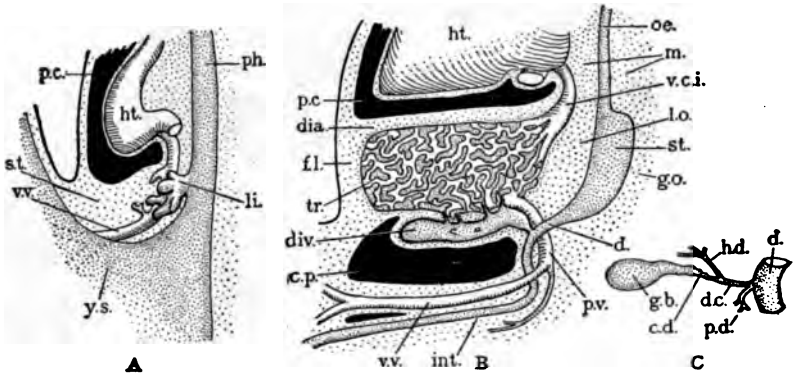


The rectum and anal canal.—The rectum is formed from the dorsal portion of the cloaca which is separated from the urogenital sinus by the formation of the urorectal septum. At the same time the posterior part of the cloacal membrane is separated from the anterior portion and forms the *anal plate* which is later invaginated forming the anal canal. The rectum and anal canal are separated until comparatively late in the development by the *anal membrane* which lies at the level of the future anal valves. A want of rupture of the anal membrane is known as congenital atresia of the anus.

Growth of the intestines.—The growth of the intestines in the early part of prenatal life is very rapid. At birth they form about 1.5 per cent. of the body as compared with 0.75 per cent. in maturity. The absolute length of the intestines at birth is usually between 350 and 400 cm. (12 to 14 feet). The intestinal tract grows about 50 per cent. in length in the first

FIG. 51.—DIAGRAMS OF THE DEVELOPMENT OF THE LIVER. (After Lewis.)

A, the condition in a 4.0 mm. human embryo. B, a 12 mm. pig. C, the arrangement of ducts in the human adult. c.d., cystic duct. c.p., cavity of the peritoneum. d., duodenum. d.c., ductus choledochus. dia., diaphragm. div., diverticulum. f.l., falciform ligament. g.b., gall-bladder. g.o., greater omentum. h.d., hepatic duct. ht., heart. int., intestine. li., liver. l.o., lesser omentum. m., mediastinum. oe., esophagus. p.c., pericardial cavity. p.d., pancreatic duct. ph., pharynx. p.v., portal vein. st., stomach. tr., trabecula. v.c.i., vena cava inferior. v.v., vitelline vein. y.s., yolk-sac.

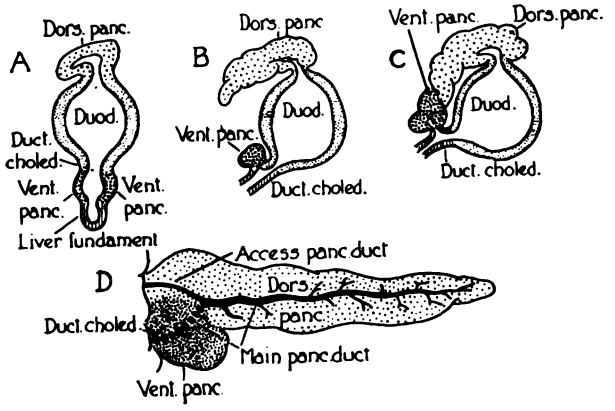


year. Thereafter the increase is much slower, the length in the adult being about 2.5 times that of the newborn.

In the early part of the embryonic period the large intestine forms nearly one-half of the length of the intestinal tract. But by the fourth fetal month it is reduced to about one-fifth of the total length of the intestines and this ratio is maintained throughout the remainder of life, except for a period of increase in the length of the colon in the latter fetal months due to its distension by meconium.

The liver.—The liver arises in the third week as a thickened area in the floor of the posterior part of the foregut (figs. 37A, 43, 51, 62). This area forms a small, thick-walled pouch in which

FIG. 52.—A, B, C, DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE PANCREAS. (After Laguesse.) D, DIAGRAM ILLUSTRATING THE EMBRYONIC CONSTITUENTS OF THE ADULT PANCREAS. (After Charpy.)



may be recognized an anterior hepatic and a posterior cystic portion. The cystic part forms the common bile-duct, the gall-bladder and cystic duct, and probably the main hepatic ducts. The hepatic portion gives rise to a large number of cellular cords which anastomose freely interdigitate with the neighboring veins, and form the parenchyma of the liver. Certain of these cords, which lie close to the developing portal veins, form the minor hepatic ducts. For further details on the development of the liver, see p. 1215 and figs. 918, 963.

The liver grows with great rapidity in the embryonic period forming over 7 per cent. of the body in the second and third fetal months. After this time the relative weight declines to about 4 per cent. at birth, 3 per cent. in childhood and 2.5 per cent. in maturity. The postnatal growth of the liver in absolute weight follows the general course of the splanchnic viscera

and the total increase between birth and maturity is about 13-fold. In fetal life the gall-bladder is small in proportion to the liver, being more or less buried in its substance, but it grows rapidly in infancy and the adult relation between these structures is established by the end of the second year.

The pancreas.—The pancreas (fig. 52) arises in the fourth week from two thickenings of the wall of the posterior part of the foregut. The first of these to appear is the dorsal pancreas which is formed from the roof of the primitive duodenum caudal to the fundament of the stomach. The second or ventral pancreas, which is sometimes a paired structure, arises from the floor of the gut at the cephalic end of the liver-pouch. Both diverticula differentiate into proximal stalks and distal expanded portions, the former forming the main ducts of the gland and the latter giving rise to the minor ducts and alveoli. Both pancreatic diverticula turn to the right in their growth and, passing around the right side of the intestine, come in contact near the point of origin of the ventral pancreas. Later, in connection with the rotation of the intestinal tube, the pancreas is shifted to the left of the duodenum. A fusion of the two elements takes place through the anastomosis of their main ducts. In later life the ventral pancreas is represented by the proximal portion of the main pancreatic duct and the lower part of the head of the pancreas. The remainder of the parenchyma of the gland, the accessory pancreatic duct (when present) and the distal portion of the main duct are derived from the dorsal pancreas. The relation of the pancreas to the primitive mesentery is shown in figs. 918 and 966.

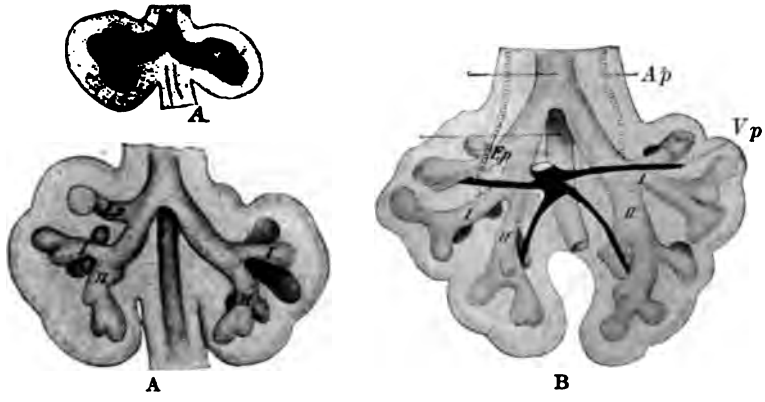
The pancreas grows relatively slowly until the sixth fetal month when it enters on a period of more rapid growth which extends well into the first year of postnatal life. The organ increases in weight nearly 30 times in postnatal life. Its general course of growth is that of the splanchnic group of viscera.

THE RESPIRATORY SYSTEM

Early development of the respiratory system.—The entodermal fundament of the respiratory system arises in the third week as a median groove in the hind part of the floor of the pharynx. The cranial portion of this groove, which represents the larynx, remains attached to the pharynx while the caudal portion grows downward as a respiratory bud which represents the trachea and the lungs (figs. 37B, 43). The free end of the respiratory bud is expanded into a rounded vesicle which immediately bifurcates into right and left branches or lung-buds.

FIG. 53.—RECONSTRUCTION OF THE LUNG OUTGROWTHS OF EMBROYOS OF (*A*) 4.3, (*B*) 8.5., AND (*C*) 10.5 MM.

Ap, Pulmonary artery; Ep, eparterial bronchus; Vp, pulmonary vein; I, second lateral bronches; II, main bronchi.—(His.)



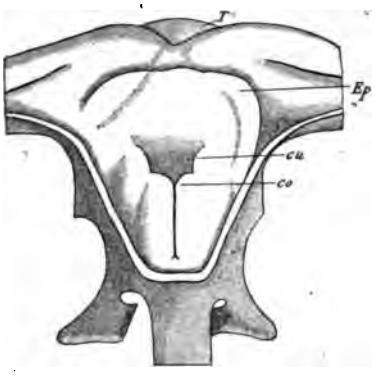
The larynx.—The cranial end of the respiratory groove forms a T-shaped cleft which is bounded anteriorly by a transverse ridge, the fundament of the epiglottis, and laterally by paired arytenoid swellings which represent the cuneiform and corniculate tubercles and the arvepiglottic folds. The epithelial surfaces of the arytenoid swellings soon fuse, forming a plate which obliterates the upper part of the respiratory groove. The cavity of the larynx is reestablished in the second month by the disintegration of the central cells of this plate. The ventricle and ventricular and vocal folds are formed by lateral extensions of the laryngeal cavity in this region.

The **laryngeal cartilages** are differentiated in the mesenchyma surrounding the epithelial tube of the larynx. Their chondrification begins in the second fetal month but is not completed until shortly before birth. The derivation of the thyroid cartilage is considered in connection with the development of the branchial skeleton (p. 29).

The larynx is relatively large in the fetus and newborn. At birth the absolute vertical dimensions are a little less and the transverse dimensions a little more than one-third those of the adult (fig. 55). Three phases can be recognized in the postnatal growth of the larynx: (1) a period of general rapid growth from birth to 2 or 3 years: (2) a succeeding period to prepuberty in which growth proceeds rather slowly although there are some alterations in form: and (3) a second period of rapid growth (most noticeable in males) in later childhood and adolescence. Sexual differences are said to appear in the larynx in the third year and after this time the male larynx is larger than the female. The larynx gradually descends in the neck during the fetal period and childhood.

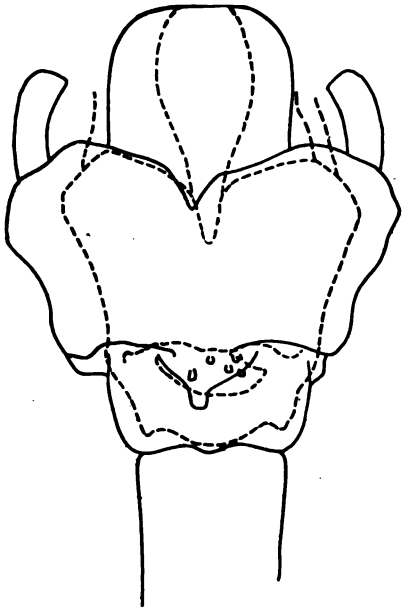
The trachea.—The trachea is formed from the portion of the respiratory bud lying between the laryngeal groove and the lung-buds. The tracheal cartilages and musculature develop in the second month from the mesenchyma surrounding the tube, and the tracheal glands first appear towards the close of the third month. The length of the trachea is nearly tripled between birth and maturity. The diameter of the trachea increases 4 or 5-fold after birth.

FIG. 54.—RECONSTRUCTION OF THE OPENING INTO THE LARYNX IN AN EMBRYO OF TWENTY-EIGHT DAYS. Seen from behind and above, the dorsal wall of the pharynx being cut away. (From McMurrich after Kallius.) co, Cornicular, and cu, cuneiform tubercle. Ep, epiglottis. · T, unpaired portion of the tongue.



The lungs.—The lining of the bronchial tree and the alveoli (air-cells) of the lungs is formed by the repeated division of the lung-buds and their branches (fig. 53). While the terminal branches of the bronchial tree arise from the larger stems by typical dichotomous division the main trunks are formed by monopodial division, straight or but slightly curved while the smaller arise as side branches from them. From an early stage the lung-buds are asymmetrical, the right being larger than the left and directed more caudally. The early branching of the

FIG. 55.—OUTLINE DRAWINGS OF THE LARYNGES OF AN ADULT AND A NEWBORN. Reduced to the same size and superimposed, showing the differences in proportions at birth and in maturity. Adult in dotted line; newborn in solid line.



buds is also dissimilar, the right bud forming two side buds (representing the bronchial ram or the upper and middle lobes), the left bud forming but one (representing the bronchus of the upper lobe).

The formation of alveoli from the tips of the terminal branches of the bronchial tree begins in the sixth fetal month. Their number grows rapidly but they increase little in size before birth. At birth, with the establishment of respiration the alveoli expand vigorously their lining epithelium being reduced from a columnar to a squamous type. Aside from the possible growth of a few air-cells from the walls of the terminal bronchioles there are no new alveoli formed after birth. The size of the alveoli, however, continues to increase throughout life, even to extreme old age.

The visceral *pleura* is formed from the splanchnic mesoderm of the parietal part of the celom which carries the lung-buds as they push their way into this cavity, and the stroma of the lung is probably derived from cells of this layer. The connective tissue of the lung is extremely abundant in the early part of the fetal period but the relative amount is greatly reduced in the last fetal months by the increase in the number of alveoli and still more so by the expansion of the alveoli at birth.

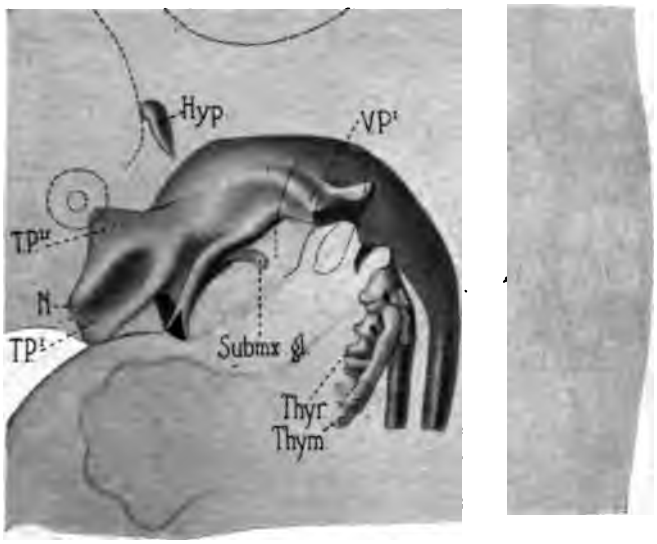
The lungs are formed in the upper cervical region but in their development they descend at first rapidly and then more slowly into the thoracic cavity. There is little change in the position of the lungs in infancy but a slow descent in childhood.

The lungs reach their highest relative weight in the fourth fetal month when they form about 3.3 per cent. of the body. In the newborn they form about 1.7 to 2.0 per cent. and in the adult about 1 per cent. of the body-weight. The growth of the lungs in absolute weight during postnatal life follows the scheme of the splanchnic group of organs.

The nose and paranasal sinuses.—The formation of the nasal pits, development of the external nose, and establishment of the hard palate have already been considered (p. 38). In the early part of the second month the nasal fossæ are represented by the two nasal pits which open to the surface of the face through the embryonic nares (fig. 17) and are separated medially by the primitive nasal septum. They communicate with the oral sinus through the primitive choanæ (fig. 38).

FIG. 56.—LATERAL VIEW OF A MODEL OF THE NOSE AND PHARYNX OF AN EMBRYO OF 6 WEEKS. (After Sudler.)

Hyp., anterior lobe of the hypophysis. N., nasal cavity. Submx.gl., submaxillary gland. Thym., thymus. Thyr., thyroid. T.P^1,. inferior concha. T.P^2,. middle concha. V.P., first branchial (pharyngeal) pouch.



The floor of the definitive nasal fossæ is formed by the fusion of the palatine shelves of the maxillary processes. During this change the primitive choanæ are merged in the nasal fossæ and the definitive choanæ are formed, eventually assuming their final position between the posterior ends of the nasal fossæ and the nasopharynx. At the same time the lower parts of the nasal fossæ are completely separated by the union of the lower margin of the nasal septum with the upper surface of the fused palatine shelves (fig. 38).

The agger nasi and inferior concha arise as processes from the lateral walls of the nasal fossa and the conchæ above them from both the medial and lateral walls of the upper parts of the fossæ. The conchæ are developed in part by the actual outgrowth of shelves from the wall and in part by the formation of grooves which limit these processes. The formation of the conchæ begins in the seventh week. For further details on the development of the nose, see p. 1238.

When the definitive nasal fossæ are first established they are quite short anteroposteriorly but their height and breadth are relatively great. During fetal life the length of the chambers grows more rapidly than the height and at birth the fossæ are relatively long, broad and low. The height of the fossæ increases nearly one-half in infancy but grows much more slowly thereafter. At 7 years it is about twice and in the adult 2.5 to 3 times as great as in the newborn. Apparently the length of the nasal fossæ is about doubled in the first decade and increases little thereafter. The breadth of the nasal cavity, on the other hand, increases very slowly in early childhood.

The *paranasal sinuses* arise as evaginations of the nasal mucous membrane in the latter part of the third and in the fourth fetal months. Their subsequent history is considered in connection with their adult anatomy (p. 1238).

THE UROGENITAL SYSTEM

All three germ-layers are involved in the formation of the urogenital system. The mesodermic contribution is derived from the intermediate mesoderm, the entodermal from the caudal ends of the cloaca and allantois, and the ectodermal mainly from the cloacal membrane.

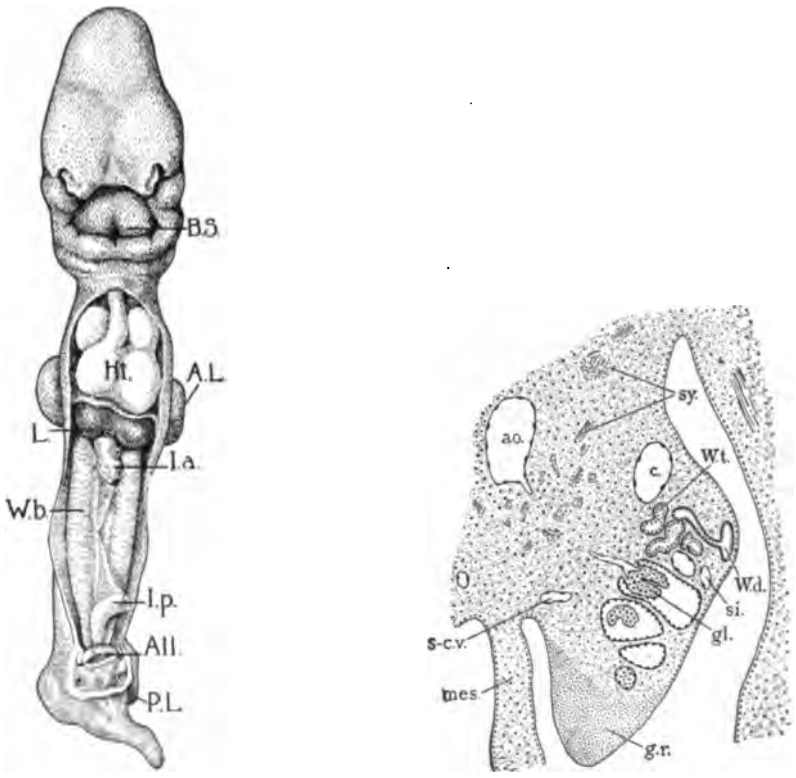
The excretory portion of the urogenital system is derived entirely from the intermediate mesoderm. In man, as well as in other mammals, and in reptiles and birds, there are formed successively in the embryo three sets of excretory organs or kidneys. The first of these, the pronephros or head-kidney, is a rudimentary structure even in the embryo and disappears

FIG. 57.—A, DISSECTION OF AN EMBRYO OF THE FIFTH WEEK, SHOWING THE WOLFFIAN BODY. (After Coste.)

A.L., anterior limb-bud. All., allantois. B.S., buccal sinus. Ht., heart. I.a., cranial limb of umbilical loop of the intestine. I.p., caudal limb of umbilical loop of the intestine. P.L., posterior limb-bud. W.B., Wolffian body.

B, TRANSVERSE SECTION OF THE WOLFFIAN BODY OF A HUMAN EMBRYO 10 MM. LONG. (After Lewis.)

ao., aorta. c., posterior cardinal vein. gl., glomerulus of Wolffian tubule. g.r., genital ridge. mes., mesentery. s.c.v., subcardinal vein. si., sinusoid. sy., sympathetic nerves. W.d., Wolffian duct. W.t., Wolffian tubule.



A B

completely except for its duct. The second, the mesonephros or Wolffian body, becomes a functional excretory organ in the embryo, but later degenerates with the exception of certain portions which are retained as parts of the male genital system and others which remain as vestigial structures. The third, the metanephros, remains as the permanent kidney.

The pronephros.—The pronephros arises as a series of outgrowths from the intermediate cell-mass of the cervical region. These sprouts develop into tubules which connect medially with the body-cavity and end blindly laterally. The blind ends of the tubules are directed caudally and growing backward fuse with one another forming a solid cord. The pronephros is a transitory structure and by the fifth week all of its tubules have degenerated; but the longitudinal cord formed from them persists, acquires a lumen, and, growing backward, connects with the lateral wall of the cloaca. It is now called the Wolffian duct.

The mesonephros and the Müllerian ducts.—The mesonephros arises as a series of tubules from the intermediate mesoderm of the lower cervical, thoracic, and the greater part of the lumbar region. These tubules become disconnected from the intermediate cell-mass, their lateral ends joining the Wolffian duct while their medial extremities are expanded into cup-shaped vesicles which enclose a capillary tuft derived from arterial sprigs which pass to them from the

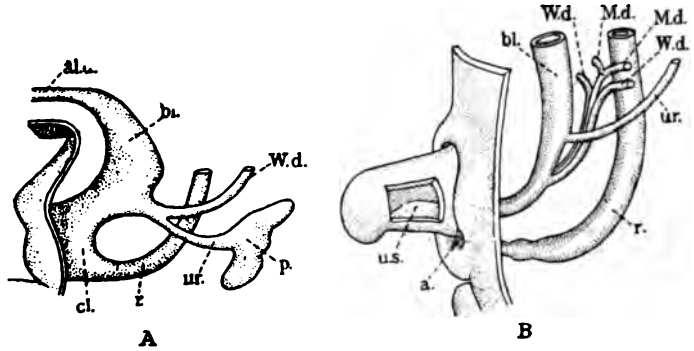
aorta. When fully developed the Wolffian or mesonephric tubules form a pair of large masses projecting from the dorsal wall of the abdominal cavity on either side of the mesentery (figs. 43–45, 57A). These masses, the Wolffian bodies, reach their greatest development in the sixth or seventh week and thereafter undergo a rapid involution, except for certain parts which are retained in connection with the genital glands.

At the time when the Wolffian body has almost reached its highest development the peritoneum near its cranial end on the medial surface is invaginated forming a second longitudinal duct, the Müllerian duct, which lies parallel with the Wolffian duct. The Müllerian ducts grow posteriorly and join the urogenital sinus. In the lower part of their course the Müllerian ducts lie side by side. They subsequently fuse into a single tube in this region and open into the urogenital sinus through a single ostium. Their upper parts, which are associated with the Wolffian bodies, remain paired and separate.

The metanephros.—The metanephros or permanent kidney is formed from the metanephric bud (primitive ureter), which is an outgrowth from the Wolffian duct, and from a thickened mass of mesenchyma, the metanephric blastema, derived from the lower part of the intermediate mesoderm. The metanephric bud arises from the lower part of the Wolffian duct in the fourth week. It grows backward and upward behind the Wolffian body where its distal end encounters and becomes imbedded in the metanephric blastema. The distal end forms the renal pelvis while the proximal portion remains as the ureter. The renal tubules are formed in part from the renal pelvis and in part from the metanephric blastema, the former giving rise to the straight and arched collecting segments and the latter to the remainder of the tubule. The metanephric blastema also forms the stroma of the kidney. The renal tubules are formed in a series of 14 to 18 generations, the last formed tubules occupying the periphery of the kidney. All of the renal tubules have been formed at birth and the subsequent increase in the renal parenchyma (about 90 per cent. of the total growth) takes place entirely through tubule hypertrophy.

FIG. 58.—DEVELOPMENT OF THE UROGENITAL SINUS. (From Lewis after Keibel.)

A, embryo 11.5 mm. long (4½ weeks). B, embryo 25 mm. long (8½ to 9 weeks). a, anus. al.d., allantoic duct. bl., bladder. cl., cloaca. M.d., Müllerian duct. p., pelvis of kidney. r., rectum. ur., ureter. u.s., urogenital sinus. W.d., Wolffian duct.



The position of the kidneys changes greatly during development. Starting in the sacral region they gradually pass into the abdominal region in the second month. In later fetal life they are shifted downward so that their lower poles are usually in the pelvis at the time of birth, but in infancy there is commonly a second upward shifting of the kidneys. The later changes in the position of the kidneys are probably passive, dependent on the growth of the posterior wall of the trunk.

The kidneys form about 0.7 per cent. of the weight of the body at birth. They decrease to about 0.46 per cent. in maturity, their total postnatal increase being about 14-fold. Their growth in absolute weight follows the general course of the splanchnic group of organs.

The urogenital sinus.—In young embryos the hindgut and the allantois unite in a common cloaca. This chamber is joined on either side by the Wolffian ducts and its ventral wall is formed, in part, by the cloacal membrane. The cloaca becomes divided, in the frontal plane, by the rectourethral septum into a dorsal (posterior) rectum and a ventral (anterior) urogenital sinus. This partition extends to the cloacal membrane which is differentiated into a ventral portion, associated with the later development of the urogenital sinus and a dorsal (posterior) part which forms the anal canal (see p. 38). The Wolffian ducts remain connected with the urogenital sinus when the cloaca is divided, and the ureters which spring from the Wolffian ducts separate from them and acquire independent openings in the urogenital sinus cranial to the ostia of the Wolffian ducts. At this time also the Müllerian ducts form a connection with the sinus medial to the openings of the Wolffian ducts.

The urogenital sinus is later differentiated into three segments. The upper portion (pars vesicalis) is an expanded chamber receiving the ureters and continuous with the allantois cranially. The middle portion (pars urethralis) is a short tube into which the Müllerian and Wolffian ducts open. The lower segment (pars phallica) is widely expanded and is floored by the ventral portion of the cloacal membrane.

The *pars vesicalis* forms the bladder. Its lining epithelium is of entodermal origin except in the region of the future trigone which is derived from the mesoderm of the proximal ends of the ureters. The connection of the allantois with the bladder is lost in the second fetal month and the cranial third of the bladder is obliterated in fetal life, remaining as a fibrous band, the

urachus. At birth the bladder is mainly an abdominal organ, its base lying behind the symphysis pubis and its apex extending halfway to the umbilicus, the long axis of the contracted organ being almost vertical at this time. During postnatal life the bladder shifts backward and downward in the pelvis. Three stages can be recognized in this process; a period of rapid descent in infancy and early childhood, a stationary phase in middle and later childhood, and a final period of slow descent in adolescence.

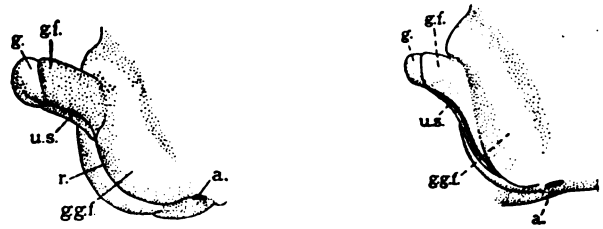
The *pars urethralis* forms the entire urethra in the female and the proximal portion of the urethra in the male. In the third fetal month the pars urethralis gives rise to a series of longitudinal folds from which are formed the prostatic tubules of the male and the corresponding but rudimentary paraurethral (Skene's) glands of the female. All of the prostatic glands are formed by the middle of fetal life.

The *pars phallica* enlarges in the second fetal month, encroaching on the pars urethralis and forming a shallow vestibule into which the urethra and the Müllerian ducts open independently. In its further development (which is considered in connection with external genitalia) the pars phallica is converted into the distal part of the urethra in the male and the vestibule in the female. A pair of evaginations from the lower part of the pars phallica in the fourth fetal month gives rise to the bulbovestibular glands in the female and to the bulbourethral glands in the male.

The external genitalia.—The formation of the external genitalia takes place through the development and transformation of a series of external elevations at the margins of the cloacal membrane. Each of these structures consists of a central core of mesenchyma covered by an outer layer of the ectoderm of the perineal region. A median elevation, the cloacal tubercle, is formed at the anterior end of the cloacal membrane in the fifth or sixth week. This is differentiated into an apical phallus, the genital eminence, and a basal portion, the genital tubercle, which surrounds the root of the phallus and extends caudally on either side of the cloacal membrane as the paired genital swellings. At the same time, the cloacal membrane forms a deep urethral groove the lips of which are converted into a second pair of longitudinal ridges termed the genital folds, which lie medial to the genital swellings. The urethral groove between them is converted into a longitudinal slit which connects the vestibule of the urogenital sinus with the exterior.

FIG. 59.—DIAGRAMS OF THE EXTERNAL GENITAL ORGANS. (A) of a male embryo. (B) of a female embryo. (After Lewis.)

a., anus. g., glans clitoridis and glans penis. g.f., genital folds. g.g.f., genital swellings. r., raphe. u.s., urogenital sinus.



In the female the phallic part of the cloacal tubercle forms the clitoris while the basal portion forms the mons veneris cranially and the labia majora caudally. The median slit becomes the rima pudendi and the genital folds at its margins the labia minora.

In the male the phallic portion of the cloacal tubercle forms the greater part of the penis. The genital folds are not so fully developed in the male but the margins of the urethral groove bend medially over this depression and fuse along the median line converting it into the proximal urethra. The anterior extremity remains open as the external urethral orifice. The genital swellings disappear in the male, being replaced by an unpaired scrotal swelling.

Origin of the testis and ovary.—In their earlier stages no differences can be recognized between the ovary and testis. The undifferentiated sex-gland appears as a ridge on the medial side of the Wolffian body extending from the middle thoracic through the abdominal region. This ridge consists of a covering epithelium and an inner solid core formed by the ingrowth of this covering. Two types of cells may be recognized in the gland, those having their origin from the epithelium of the body cavity, and larger and less numerous germ-cells whose origin in man is uncertain.

Development of the testis and its ducts.—In the transformation of the indifferent genital gland into the testis the inner part of its epithelial core is converted into a network of solid cords, and the outer part forms a layer of dense mesenchyma which underlies the covering epithelium and represents the tunica albuginea testis. The network of solid cords is converted into the tubuli contorti (seminiferous tubules), the tubuli recti, and probably a portion of the rete testis.

With this differentiation of the genital gland the Wolffian body is also greatly modified. A number of the upper mesonephric tubules become connected with the rete testis and form the efferent ducts of the testis. The tubules above and below this group lose their connection with the Wolffian duct and remain as vestigial structures, certain of the upper ones forming the appendix testis and possibly the appendix epididymidis, and the lower ones the paradidymis. The Wolffian duct remains in its entirety as the ductus epididymidis, the ductus deferens, and the ejaculatory duct. The seminal vesicles arise as outgrowths of the ejaculatory duct. The Müllerian duct degenerates in the male, except for its lower extremity which remains as the ostatic utricle (the homolog of the vagina) and for its upper or cranial end which may give e to the appendix epididymidis (fig. 1051).

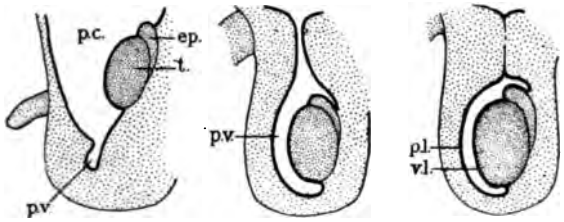
Development of the female genital tract.—In the female the core of the genital ridge forms the stroma of the ovary, the cells of the general covering epithelium give rise to the follicular cells, and the germ-cells which lie in the epithelium develop into the primitive ova (see fig. 1040).

The early changes in the Wolffian body resemble those of the male. The upper tubules degenerate with the exception of one or two which remain as the cystic *appendices vesiculosi* of the adult. The middle group of tubules form the *epoöphoron* (fig. 1042), a structure homologous with the efferent ducts of the testis but without function, which persists and increases in size until maturity. The lower group of tubules undergo a more complete involution although remnants of them persist in postnatal life as the *paroöphoron* (the homolog of the paradidymis). The Wolffian duct in the female loses its connection with the urogenital sinus but portions of it may be retained as the longitudinal duct of the epoöphoron or the duct of Gartner (homolog of the ductus deferens and ductus epididymidis).

The Müllerian duct is retained in its entirety in the female, the unpaired portion forming the uterovaginal canal and the paired portions the uterine tubes (fig. 1051). For the development of the broad ligament, see fig. 1040, p. 1297.

Descent of the testis and ovary.—In the latter part of the second fetal month the testes extend along the posterior wall of the trunk from the thoracic to the sacral region. In the third month they are found in the iliac fossæ, from the fourth to the seventh month at the level of the future internal abdominal ring, and in the eighth month they usually pass into the scrotum (fig. 60). The causes of the descent of the testes are obscure. Much of the early change in position is due not to the actual shifting of the organs but to the involution of their cranial parts. The later changes may be due in part to the contraction of the gubernaculum testis, an associated ligament of the fetal testis which contains smooth muscle.

FIG. 60.—DIAGRAMS OF THE DESCENT OF THE TESTIS. (From Lewis after Eberth.)
ep., epididymis. p.c., peritoneal cavity. p.v. processus vaginalis. t., testis. p.l., parietal layer of the tunica vaginalis. v.l., visceral layer of the tunica vaginalis.



The passage of the testes through the inguinal canal is preceded by the invasion of the solid strotum by a pocket of peritoneum, the saccus vaginalis, which later partially surrounds the cestis as the tunica vaginalis. The connection between the saccus vaginalis and the abdominal peritoneal cavity is usually patent in the newborn, being commonly closed in the first 6 months after birth. For further details, see p. 1287.

The ovaries, like the testes, shift from an abdominal to a pelvic position in the early part of fetal life (fig. 49), although their final position is usually acquired in childhood. In their passage the axes of the ovaries are shifted first from the longitudinal to the transverse plane of the body and finally into the sagittal plane. The canal of Nuck, the homolog of the saccus vaginalis, is found in the labia majora in the female fetus. It is generally open at birth but is obliterated in early infancy.

The growth of the male genital organs.—The male organs of generation follow without exception the scheme of growth of the genital group of organs. They are characterized by rather rapid increase in the later fetal months and this phase may extend into the first months of postnatal life. Thereafter there is little change in their absolute weights until the prepuberal period, when a stage of rapid growth begins which may extend through adolescence into early maturity. Most of the male generative organs increase over thirty-fold in absolute weight in the postnatal period, being relatively heavier in the adult than in the newborn. However, the relative size of the testes is probably greater at the close of the embryonic period than at any subsequent time.

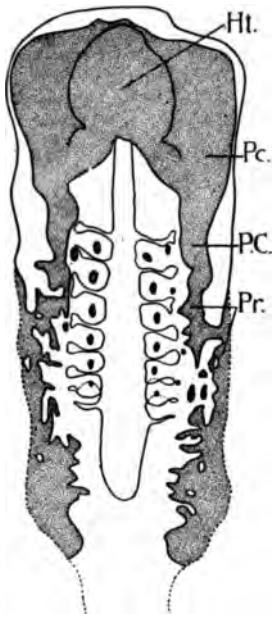
The growth of the female genital organs.—All of the female genital organs grow rapidly in fetal life and are relatively large at birth. In postnatal life the growth of the vagina, uterine tubes, and epoöphoron seem to follow the usual course of the genital organs. The postnatal growth of the ovaries is extremely irregular, the weight being influenced by the development of the ovarian follicles, a process which is active in childhood as well as in maturity. The uterus in the neonatal period undergoes a marked reduction in weight—a change which has been attributed to the withdrawal of a placental hormone at the time of birth. After this initial decrease there is little change in the size of the organ until the prepuberal period when it again enters on a phase of active growth. The adult dimensions are probably attained by puberty in the majority of cases. The paroöphoron does not increase in size after birth.

THE CELOMIC CAVITY

The general plan of the development of the celom as a cavity formed between the splanchnic and somatic layers of the lateral mesoderm has been outlined in connection with the development of the mesoderm (p. 12). In the higher mammals, including man, the celom first makes its appearance in the region of the heart as irregular clefts in the mesoderm on either side of

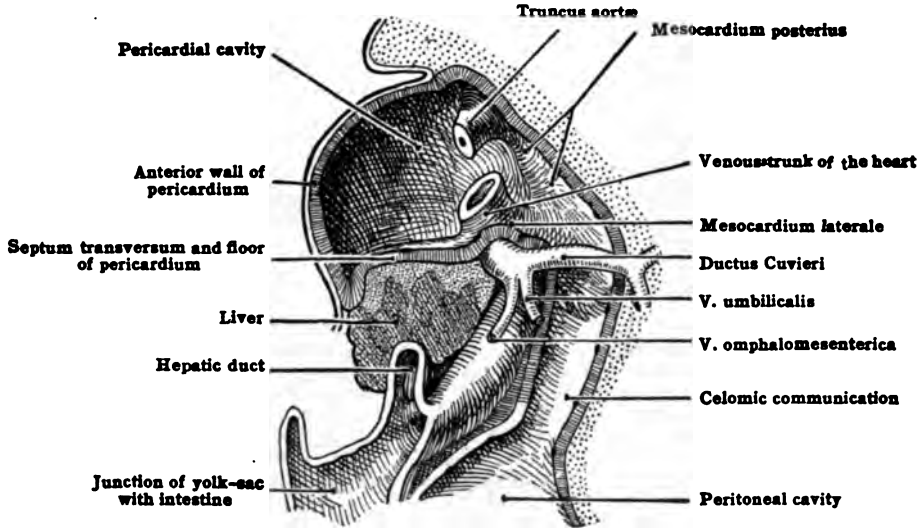
the body. These spaces unite with one another by the formation of a communication which crosses the midline of the body below the heart. The common cavity formed by this fusion is known as the pericardial celom (fig. 61). The pleuroperitoneal portion of the celom is

FIG. 61.—DORSAL VIEW OF A RECONSTRUCTION OF AN EMBRYO ABOUT 2 MM. LONG, SHOWING THE EXTENT AND DIVISIONS OF THE EMBRYONIC CELOM. (After Dandy.)
Ht., heart. P.c., pericardium. P.C., parietal (pleural) canal. Pr., peritoneal cavity.



formed by the caudal extension of the celom in the lateral plates of the mesoderm on either side of the body. The peritoneal celom communicates freely with the extraembryonic celom at the margins of the embryonic disk.

FIG. 62.—SAGITTAL SECTION SHOWING THE PRIMITIVE PERICARDIAL AND CELOMIC COMMUNICATION, SEPTUM TRANSVERSUM, LIVER, ETC., IN A HUMAN EMBRYO of 3 MM. (After Kollmann, from a model by His.)



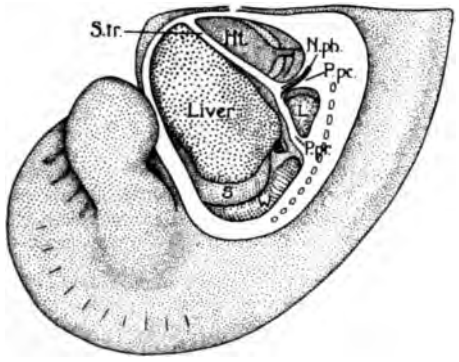
A single peritoneal cavity is formed from the two lateral ones as the embryo separates from the embryonic disk, and the ventral abdominal wall is formed. During this process the abdominal portion of the archenteron is enclosed between the right and left layers of splanchnic mesoderm which are reflected upon it from the dorsal and ventral abdominal walls. These layers remain dorsal to the archenteron as the dorsal mesentery. They also remain ventral to the archenteron from the end of the cavity to the umbilical region as the ventral

mesentery. Caudal to the umbilicus, however, the ventral mesentery disappears and the right and left peritoneal cavities become confluent. The formation of the ventral body-walls also separates the peritoneal cavity from the extraembryonic celom, although an extraembryonic extension of the peritoneal cavity, the *umbilical celom*, remains in the root of the umbilical cord through the embryonic period.

The separation of the peritoneal, pericardial and pleural cavities.—The final divisions of the celom are separated by the formation of the diaphragm and the lateral walls of the middle mediastinum. As will be seen from figs. 61 and 62, the pericardial celom communicates with the peritoneal portion of the celom only by a pair of lateral passages, the *parietal canals*. These channels are separated in the midline by the anterior part of the yolk-stalk and by the vitelline-umbilical trunks which pass along this structure to reach the heart. The media partition formed by these structures with their covering of splanchnic mesoderm is called the septum transversum and is the fundament of the greater part of the diaphragm. In the later shifting of the septum transversum the cranial parts of the parietal canals become funnel-shaped spaces which are invaded by the lung-buds and which form the fundaments of the *pleural cavities*. The pleural cavities become separated from the pericardial cavity by the *pleuropericardial membranes* which arise from the dorsal and lateral walls of the parietal cavity enclosing the phrenic nerve. The caudal openings of the pleural cavities into the peritoneal cavity become closed by the *pleuroperitoneal membranes* which arise from the dorsal margin of the septum transversum and extend dorsolaterally to unite with the dorsal abdominal wall (fig. 63).

FIG. 63.—LATERAL VIEW OF AN EMBRYO 11 MM. LONG, SHOWING THE PLEUROPERITONEAL (P. pr.) AND THE PLEUROPERICARDIAL MEMBRANES. (P. pc.). (After Mall.)

Ht., heart. L., lung. N.ph., phrenic nerve. S., stomach. S.tr., septum transversum. W, Wolffian body.



The fundament of the diaphragm is formed in the upper cervical region and rapidly shifts caudally in the embryonic period. The musculature of the diaphragm is derived from premuscle masses which are formed in the cervical region.

The further history of the peritoneum is considered with its adult anatomy (p. 1172). The development of the tunica vaginalis is outlined in connection with the descent of the testes (p. 53). For relations to hernia, see p. 1397.

THE DUCTLESS GLANDS

The several varieties of ductless glands have little in common in their germ-layer origin, in the method of their early development, or in the course of their subsequent growth.

The thyroid gland.—The thyroid gland appears in embryos of the third week as a shallow median depression of the floor of the pharynx at the level of the first and second branchial pouches (fig. 37*A*). This outgrowth is converted into a solid mass which for a variable period remains connected with the pharynx by a solid stalk, but which eventually becomes detached and migrates into the region of the neck occupied by the definitive thyroid gland (cf. p. 1316). The solid mass is broken into a number of fenestrated epithelial plates from which the thyroid follicles are developed. Colloid appears in the thyroid follicles about the third fetal month. The disappearance of the colloid at birth and also the desquamation and partial destruction of the follicular epithelium have been described, but are of doubtful significance.

The thyroid assumes its bilobed form at an early stage (fig. 41). Its stalk may persist in part as the pyramidal lobe of the gland and portions of it occasionally remain as isolated thyroid masses in the upper cervical region or in the base of the tongue. The foramen cecum of the tongue presumably marks the point of its pharyngeal attachment.

At birth the thyroid weighs from 2 to 3 grams and its weight increases 10 to 15-fold in postnatal life. The postnatal changes in weight follow the course of the visceral group of organs.

The parathyoid glands.—The parenchyma of the parathyroid glands is formed from the thickened lateral walls of the dorsal extremities of the third and fourth pharyngeal pouches (fig. 41, Ep. III and Ep. IV). These masses become detached from the pouches in the second month and then migrate to their adult position. For further details, see p. 41.

The pineal body.—The pineal body (epiphysis cerebri) arises in the fifth week as a diverticulum from the caudal extremity of the roof of the diencephalon (fig. 641). The distal

portion of this pouch becomes the body of the epiphysis. The proximal portion remains as the stalk. Ingrowths of connective tissue from the pia mater later divide the body of the organ into lobules. At birth the structure is relatively large and by 12 years it has obtained its full size. Structural involution of the pineal body begins about the sixth or seventh year and is practically complete by puberty.

The hypophysis cerebri.—The anterior or glandular lobe of the hypophysis cerebri (pituitary body) is formed from the extremity of Rathke's pouch from the oral sinus, while the posterior or neural lobe is formed from a part of the infundibular depression in the floor of the forebrain. These two structures come in contact in the fourth week. The extremity of Rathke's pouch soon becomes detached and partially incloses the neural portion. In the second month the walls of Rathke's pouch are differentiated into cords and tubules which form the trabeculæ and acini of the hypophyseal parenchyma and obliterate the greater part of its central cavity. The infundibular portion undergoes less extensive changes. The greater part of the stalk of Rathke's pouch usually disappears but a portion of its lower part probably forms the *pharyngeal hypophysis*, a constant glandular mass resembling the anterior lobe of the hypophysis and located in the region of the pharyngeal tonsil (see fig. 1069).

The hypophysis weighs about 0.12 grams in the newborn and its mass increases 5 or 6 times between birth and maturity. The curve of the postnatal increase in the absolute weight of the hypophysis is shown in fig. 24. It is characterized by a rapid rise in infancy and early childhood and a slow but steady growth thereafter to maturity.

The thymus.—While a part of the thymus is of branchial origin and the organ is commonly classed with the ductless glands, both its finer structure and the course of its growth indicate a close relationship with the lymphoid organs. In man the thymus first appears as outgrowths of the walls of the third and (inconstantly) of the fourth pair of branchial pouches (fig. 41). Usually the lower portion of the third pouch is converted into a long epithelial tube the lumen of which is soon obliterated. Its walls are reduced to a reticular network whose meshes are invaded by numerous lymphocytes. The thymic (Hassal's) corpuscles are formed by the secondary aggregation of reticular cells of entodermal origin. For further details, see p. 1321.

In its growth the thymus follows the typical course of a lymphoid organ (fig. 24). At birth it forms about 0.42 per cent. of the body. This relative weight drops to 0.12 per cent. in later childhood, 0.09 per cent. in adolescence and 0.05 to 0.02 per cent. in early maturity. The absolute weight rises from about 13 grams at birth to about 38 grams at puberty and then declines. The weight of the thymus is at all periods subject to great individual variation. After birth the parenchyma forms a constantly decreasing proportion of the thymus.

In the fetus the thymus occupies the anterior part of the superior mediastinum and often a little of the lower cervical region. Its thoracic portion is usually widely expanded coming in contact with the anterior chest wall over a considerable area. With the establishment of respiration at birth the gland is pressed between the expanding medial borders of the lungs and moulded into the more elongate form which is characteristic of infancy and childhood (figs. 1058, 1059).

The chromaffin bodies.—The cells of the various masses of chromaffin tissue (aortic bodies, carotid bodies, cardiac bodies, etc.) have their primary origin in the neural crest (see p. 1321) and form a part of the stream of cells which migrate to the ventral side of the vertebral column. These walls give rise both to cells of the sympathetic ganglia and to the chromaffin cells, the distinction between the two becoming evident in the latter part of the second month. The chromaffin bodies form prominent structures in the fetus and newborn, the largest being the aortic bodies which are located on either side of the abdominal aorta (fig. 1066). After infancy they undergo partial involution.

The suprarenal glands.—The suprarenal glands have a dual origin, the medulla being formed of chromaffin tissue (vide supra) and the cortex from the lining of the celom. The cortex appears in the fourth week as buds of celomic epithelium which project from the root of the mesentery into the loose mesenchyma. These form a compact isolated mass of epithelial cords lying on either side of the aorta. The medulla is formed by the migration of chromaffin cells into the center of the mass of cortex. This process begins in the second month and continues through the greater part of the fetal period. For further details, see p. 1324.

The suprarenals follow a peculiar growth-cycle (fig. 24). Growing rapidly in fetal life they acquire an average weight of about 7 grams at birth. During the period of the newborn they undergo a rapid decrease to about one-third of their natal weight. There is little increase in weight in infancy or early childhood but apparently a rapid phase of growth in middle or later childhood and a slower gain thereafter. The relative weight of the suprarenals is approximately 0.46 per cent. of the body-weight from the fourth fetal month until birth. Following the postnatal decrease it drops to about 0.15 per cent., rising again to about 0.2 per cent. in the adult. The neonatal decrease of the suprarenals is caused by the involution of the middle and inner cortical zones, which are not regenerated from the outer zone until after the middle of the first period of childhood.

THE SKIN AND APPENDAGES

The skin.—The epidermal portion of the skin is formed from the surface ectoderm of the embryo while the dermis is derived from the underlying mesenchyma. In an early stage the epidermis consists of two layers, a surface layer of flattened cells, the periderm, and a basal layer of columnar germinative cells. The layers of the epidermis recognizable in the adult skin do not appear until about the middle of the of fetal life. The dermis becomes distinguishable from the underlying tela subcutanea in the third month but its division into reticular and papillary layers does not occur until late in fetal life. The hair-follicles are formed from solid downgrowths of the germinal layer of the epidermis. The first appear at the close of the second month but the general hair-coat does not form before the fourth month. New hair-

follicles are formed until birth and probably for some time thereafter. The first hairs or fetal lanugo are soon shed, the process beginning before birth, and a second shedding of the infantile hair, including the hair of the eyelashes and crown, takes place about the end of the first year. After this time there is a constant hair-change but no definite periods of shedding can be recognized. The sebaceous glands arise as lateral outgrowths of the developing hair-follicles. The sudoriferous glands (sweat glands) are formed as solid downgrowth of the epithelium in the fourth or fifth months. All of the sudoriferous glands are formed in fetal life. For further details on the development of the skin, see pp. 66, 69.

The areas occupied by the nails are marked out on the dorsal surface of the digits in the early part of the third month. The epithelium at the proximal margin of the nail-area is invaginated forming the proximal or posterior nail-fold which projects into dermal mesenchyma, and smaller folds are formed at the lateral margins of the nails. The middle cells of the invagination form the horny layer of the nail and the lower cells form the germinative layer. The upper cells or periderm form a superficial covering, the *eponychium*, which is later thrown off except for a narrow proximal margin which persists through life. The dermal mesenchyma underlying the epithelial nail forms the nail-bed. For the growth of the nails, see p. 70.

The mammary glands.—In the fourth week a thickening of the surface ectoderm, the mammary line, is formed on either side of the trunk extending from the anterior to the posterior limb-bud. The portion of the mammary line in the region of the future mammary gland forms a solid mass of epithelium, the mammary hillock. The lactiferous ducts develop as outgrowths from the basal portion of the mammary hillock and the minor ducts and alveoli of the gland are formed through the further growth and subdivision of the lactiferous ducts. For further details, see p. 79.

Soon after birth a slight secretion (witch's milk) is formed in the lactiferous ducts of the mammary glands of both male and female infants. Ordinarily this secretion ceases by the close of the third postnatal week. There is little change in the structure of the mammary gland in childhood but in the latter part of the prepubertal period in the female there is a rapid growth of the gland parenchyma together with an increase in the adipose and elastic tissue.

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SECTION II

THE SKIN AND MAMMARY GLANDS

LARGELY REWRITTEN FOR THE SIXTH EDITION

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THE SKIN

THE bodies of all animals present a modified surface layer inclosing and protecting their more delicate inner parts. The existence of the individual largely depends upon the integrity of this limiting envelope and through it exchanges between the environment and the individual must take place. In the lowest animals such a modified surface layer is known as the ectoplasm, perisarc, theca, coat, etc. while in man and higher animals it is the skin. When an area of skin is destroyed the fluids of the body flow out freely and the elements of the environment invade the exposed parts. If the destruction of skin be too extensive, the individual is unable to maintain itself and actually disintegrates into the environment. On the basis of such a conception, the skin becomes one of the most important and complicated organs of the body, both as to structure and functions.

The human skin, or **common integument** [integumentum commune], covering the entire surface of the body and blending with the epithelial lining of the inner tubes at their orifices is so constructed as to maintain wide physical and chemical differences between the internal structures on the one side and the external environment on the other. At the same time the skin permits exchanges of fluids and, through special modifications, supplies all sensory communication and appreciation of the surrounding world.

The *primary function of the skin* is protective, but in addition and in connection with this function it supplies the mechanism for regulating or maintaining the body-temperature, the sensory apparatus for receiving impressions, widely distributed glands for the secretion of sweat and sebum, local glands secreting waxes and the milk-glands on which the existence of the race has depended. The skin also possesses slight powers of excretion, respiration and absorption. Its outer layer further gives rise to the hair and nails which are protective in nature.

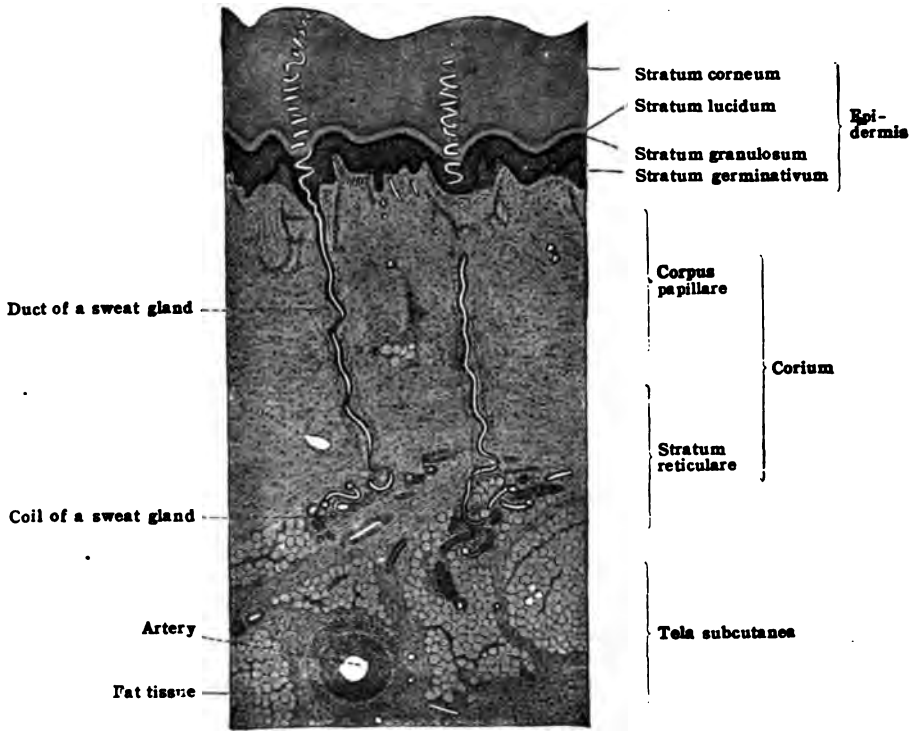
The receptor portions of the organs of special sense are developmental modifications of the embryonic skin. Thus all means of acquaintance with the world about must depend primarily upon skin-organs. And finally the stimuli received by the organs of special sense are conveyed to the central nervous system, the brain and spinal cord, which in evolution and embryonic development represent a modified portion of the embryonic skin or ectoderm. The skin of animals, broadly speaking, is the protective and sensory sheath enclosing the body.

Layers.—The skin consists of two principal layers. The outer layer, **epidermis** or scarf-skin, contains no vessels and is derived from the ectoderm. This is truly the protecting layer and from modifications of it the hair, nails and skin-glands as protective organs are derived, although these may later extend deep into the underlying tissues (fig. 64). Immediately below this outer epithelial epidermis lies the **corium** (cutis, derma) or connective tissue skin. This is richly supplied with blood and lymph-vessels and from these the epidermis is nourished. Sensory

end-organs and nerves are also very abundant in the corium. Further details of structure of the corium and its relation to the surface patterns of the epidermis are described later. The corium passes imperceptibly into a deeper, looser connective tissue layer, the **tela subcutanea** or superficial fascia, which serves to connect more or less loosely the corium or skin proper to the deep fascia or underlying tissues.

Thickness.—In general the skin on the more exposed or extensor surfaces of the body and extremities is thicker and less sensitive than on the ventral surfaces yet on the palms and soles it is thicker than in any dorsal region except the neck and interscapular back region. At the same time the palm and sole skin is highly sensitive. The average thickness is from 1 to 2 mm.; but over the tympanic membrane and eyelids it may be less than 0.5 mm., while on the back it may reach almost 5 mm. in thickness.

FIG. 64.—VERTICAL SECTION OF THE SOLE OF THE FOOT OF AN ADULT. ×25. (Lewis and Stöhr.)



The **color** of the dorsal skin and also of the dorsal hair, which includes the head-hair, is darker than the ventral skin and ventral hair, such as the beard. An individual may have black crown hair and a lighter or red beard but rarely, if ever, the reverse arrangement.

The color of the skin has considerable general significance and the races of mankind are roughly separated on such a basis into Caucasian or white, Mongolian or yellow, Malay or brown, Indian or red, Ethiopian or black. The hair and eye-color are very dark brown or black in all races except the white. This race of mankind alone shows golden or flaxen hair and blue eyes. The color of the skin varies with the amount of melanin pigment present in the deepest layers of the epidermis, being black in the negro where it is most abundant and decreasing in the different races to the scantest amount in the blonde Caucasian. The blood in the cutaneous vessels also affects the color of the skin, giving the pinkish complexion to the albino and blonde; in the brunette often producing a dark color below the eyes and about the lips. The influence of the blood on skin-color is readily appreciated by noting the blueness of the lips and fingers when very cold, the scarlet flush of anger, and the pallidness of fear.

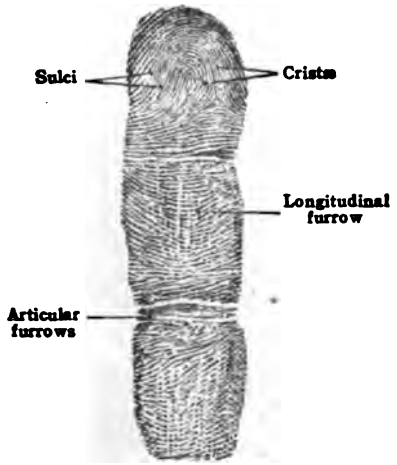
The skin of blondes on exposure to strong sunlight or cutting winds becomes red, and usually shows later irregular pigmented spots or *freckles*. Darker individuals become uniformly pigmented or *tanned* on exposure. Both tan and freckles are more or less transient and generally disappear when the body is no longer exposed.

Complete absence of pigment from the skin gives the condition known as albinism. Partial

absence of pigment or white spots at times occur; if congenital the condition is known as leukoderma, if acquired it is called vitiligo.

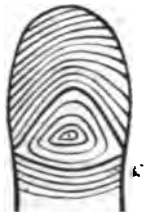
Young children of darker races, e. g., Japanese and Chinese, occasionally present a bluish pigmentation known as 'blue Mongolian spots' of the skin over the sacral, coccygeal and ischial regions. This also occurs rarely in white children. The appearance is due to the presence in the corium of spindle-shaped or stellate pigment cells, chromatophores, resembling the pigment cells of the choroid layer of the eyeball. Similar cells are found distributed generally in the corium of monkeys' skin and their occurrence in man has been thought to be of possible phylogenetic significance.

FIG. 65.—FINGER PRINT (NATURAL SIZE) SHOWING CRISTÆ AND SULCI.



The **elasticity and strength** of the skin are due to the corium, and this layer when tanned or cured gives leather. The skin is more elastic or stretchable over certain regions than others and this property varies in different individuals. The skin is more lightly attached to underlying parts in certain regions, and is here very movable. Its elasticity is well shown under these conditions. If an arm be firmly grasped with the hand it will be found that the skin may move up and down over the underlying muscles as if it were a sleeve. The degree of motility of the skin is appreciated in surgical operations.

FIG. 66.—DIAGRAM SHOWING THE ARRANGEMENT OF THE PRINCIPAL CRISTÆ OF THE THUMB.

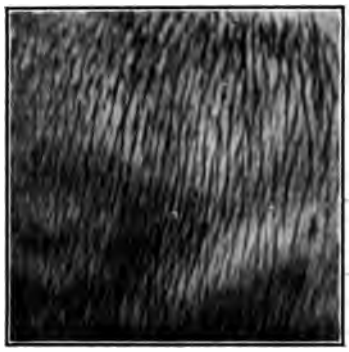


The infinite folds and irregularities on the surface of the skin along with its loose under attachment and elastic nature render it *distensible* to a considerable extent. Roughly speaking, the skin of an individual is sufficiently extensive to cover a body of much larger size. Under certain conditions a leg, for example, may swell to double the usual size but the skin stretches to cover it. The skin over such a swollen part is smoother and more glistening than usual, since the minute folds and patterns are obliterated or smoothed out by the expansion. When increase in size is gradual such as normally occurs during pregnancy the skin area may be stretched to four or five times its previous extent. In these cases the skin is often injured and short parallel, slightly reddish streaks occur which after reduction in size become the silvery white lines, or striæ seen in the abdominal skin of a woman who has borne children.

The surface-area of the skin corresponds approximately to the surface of the body and naturally varies with the size of the individual. It has been variously estimated at from 10,500 to 18,700 sq. cm. for a medium-sized adult male. For the area in children, see p. 23.

Folds and furrows.—The skin presents elevations and depressions due to the fact that it follows more or less closely the contour of the underlying structures, but in addition to this it possesses certain elevations and depressions peculiarly its own. They are found on the skin in various parts of the body. Some are permanent, others only temporary. Large permanent **folds** which include all the layers of the skin are seen, as the prepuce of the penis and the pudendal labia. The most marked depression is the **umbilical fovea.** Other conspicuous folds and furrows are seen in the neighborhood of the lips and eyelids. Certain other less permanent folds and furrows are produced by the action of the joints, **joint-furrows,** and of the muscles of expression of the skin, **'wrinkles.'**

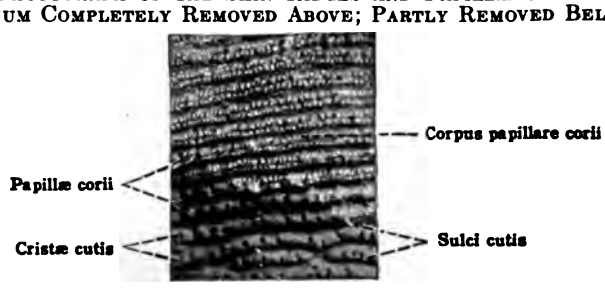
FIG. 67.—FROM A PHOTOGRAPH OF THE SUPERFICIAL FURROWS ON THE BACK OF THE HAND. (× 1.)



Other minute folds and furrows which affect only the epidermis and the superficial layer of the corium are seen in various places. These are represented by the numerous fine superficial creases, unassociated with elevations, forming rhomboidal and triangular figures over almost the whole of the surface of the skin (figs. 65, 66). They are especially numerous on the dorsal surface of the hands (fig. 67). The fine curvilinear ridges [cristæ cutis] with intervening furrows [sulci cutis] arranged in parallel lines in groups on the flexor surface of the hands and feet are also of this type. They form patterns characteristic for each individual and permanent throughout life.

Among the projections are the large permanent folds of skin such as the **labia pudendi,** the **preputium penis,** the **frenula preputii, clitoridis,** and **labiorum pudendi,** and less marked ridges as the median **raphe** of the perineum, scrotum and penis, and the **tuberculum labii superioris.** Of a somewhat different sort are the **touch pads** [toruli tactiles] of the hands and feet. Among

FIG. 68.—FROM A PHOTOGRAPH OF THE SKIN RIDGES AND PAPILLÆ OF THE PALM OF THE HAND. EPITHELIUM COMPLETELY REMOVED ABOVE; PARTLY REMOVED BELOW. (× 5.)



the larger depressions in addition to the **umbilical fovea,** is the **coccygeal foveola,** and a considerable number of well-marked permanent furrows found in various places, such as the **nasolabial** and **mentolabial sulci,** the **philtrum labii superioris,** the **infraorbital sulcus,** and the **infra-** and **supraorbital palpebral sulci.** There are numerous **articular furrows** on both the flexor and extensor surfaces produced by the action of the joints, and associated with intervening folds of skin, particularly on the dorsal surface. They are especially noticeable on the hands. Variations of the palmar joint-sulci are due to variations in opposition of the thumb and the use of the fingers and the relative arrangement of the thumb and fingers and joints. They are of importance as indicating topographically the position of the joints, their relation to which has been made clearer by means of the X-ray.

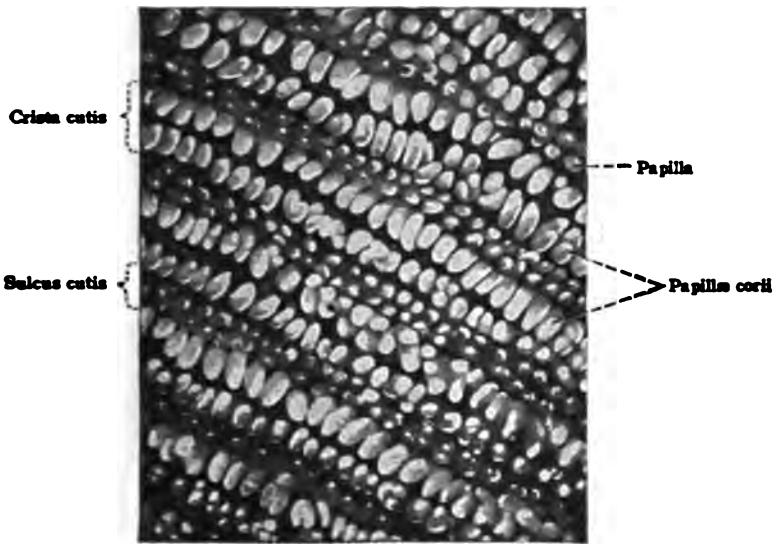
The folds and furrows brought about through the action of the skin muscles run at right angles to the muscle fibers and are more or less transitory at first but become more permanent through repeated or long-continued action. They are represented by the **wrinkles** of the forehead, the lines of expression of the face, the transverse wrinkles of the scrotum and the **radiating** folds around the anus. The more superficial **cristæ cutis** and **sulci cutis** are arranged in groups

within and around the touch pads, on the volar surface of the hands and the plantar surface of the feet (figs. 65, 66). The cristæ of each group are parallel. They correspond to the rows of papillæ of the corium. Since the patterns of the cristæ and sulci are characteristic for the individual, and permanent from youth to old age, they have been classified in a number of types and are important as a means of identification.

There are also a great number of minute depressions which mark the points where the hairs pierce the surface and where the glands open. These are popularly known as **pores.** Under the influence of cold and emotion the hair muscles contract and cause a slight elevation of the skin at the point where the hair emerges. This roughened appearance of the skin is generally known as 'goose-flesh.'

A complex wrinkling of the skin appears in old age, or in the course of exhausting diseases, as a result of loss of elasticity and from absorption of the cutaneous and subcutaneous fat. Rounded depressions called **dimples** are produced by the attachment of muscle-fibers to the deep surface of the skin, as on the chin and cheek, and are made more evident by the contraction of these fibers. Others are produced by the attachment of the skin by fibrous bands to bony eminences, as the elbow, shoulder, vertebræ, and posterior iliac spines. They are best seen when the subcutaneous adipose tissue is well developed.

FIG. 69.—PAPILLÆ OF THE CORIUM AFTER MACERATION. FROM RETOUCHED PHOTOGRAPH EPITHELIUM REMOVED BY MACERATION. (× 25.)



Structure of the corium.—The superficial layer of the corium is of fine, close texture, free from fat, and forms a multitude of eminences called **papillæ corii** (figs. 68, 69) which project into corresponding depressions on the deep surface of the epidermis. For this reason this part of the corium although but indistinctly separated from the deeper layer is called the **corpus papillare.**

Some of the papillæ contain vessels, other nerves, hence they are known as vascular or tactile papillæ. They are very closely set, varying considerably in number in different parts of the body from 36 to 136 to a square millimeter and it has been estimated that there are about 150 million papillæ on the whole surface.

The deeper layer of the corium, the **tunica propria** (stratum reticulare), is composed of coarse loose bands of fibrous tissue intermingled with small fat lobules. The fibrous and elastic tissue is arranged for the most part in intercrossing bundles nearly parallel to the surface of the skin.

The bundles running in some directions are usually more strongly developed and more numerous than those in others, but the direction of the strongly developed bundles varies in different parts of the body. In general those are best developed which have a direction parallel with the usual lines of tension of the skin, hence it results that wounds of the skin tend to gape most at right angles to these lines. The bundles take a direction nearly at right angles to the long axis of the limbs, and on the trunk run obliquely, caudally, and laterally from the spine (figs. 70, 71). On the scalp, forehead, chin, and epigastrium, equally strong bundles cross in all directions, and a round wound, instead of being linear as elsewhere, appears as a ragged or triangular hole. The arrangement of the connective tissue bundles influences the arrangement of the blood-vessels of the skin.

The quantity of *subcutaneous fat* varies considerably in different parts of the body. It is, for instance, entirely absent in the penis, scrotum, and eyelids. When it is abundant, the subcutaneous layer is known as the *panniculus adiposus*.

In some situations, as in the caudal portion of the abdomen and in the perineum, the connective tissue is so arranged that the panniculus may be divided into layers, so that a superficial and a deep layer of the superficial fascia may be recognized. The fat is well developed over the nates, volar surface of the hands and plantar surface of the feet, where it serves as pads or cushions; in the scalp it appears as a single uniform lobulated layer between the corium and the aponeurosis of the epicranial muscle; and on other parts of the surface it is somewhat unequally distributed and shows a tendency to accumulate in apparent disproportion in some localities, as on the abdomen, over the symphysis pubis, about the mammæ in females, etc. Everywhere except on the scalp it may undergo rapid and visible increase or decrease under the influence of change of nutrition.

FIGS. 70 AND 71.—DIAGRAMS SHOWING THE ARRANGEMENT OF THE CONNECTIVE TISSUE BUNDLES OF THE SKIN ON THE ANTERIOR AND POSTERIOR SURFACES OF THE BODY. (After Langer.)

Skin-muscles.—In the subcutaneous tela and the corium muscle fibers are found in larger or smaller groups. These are of two kinds, striated and unstriated (smooth) fibers.

Subcutaneous planes of *striated muscle* are relatively scanty in man when compared with the great panniculus carnosus of the lower mammalia. This is mainly represented by the platysma in the neck which has both its origin and part of its insertion in the skin. Closely associated with this are the muscles of expression of the face and the palmaris brevis muscle which have one end terminating in the deep surface of the skin. The epicranial muscle is also considered by some to belong to this group.

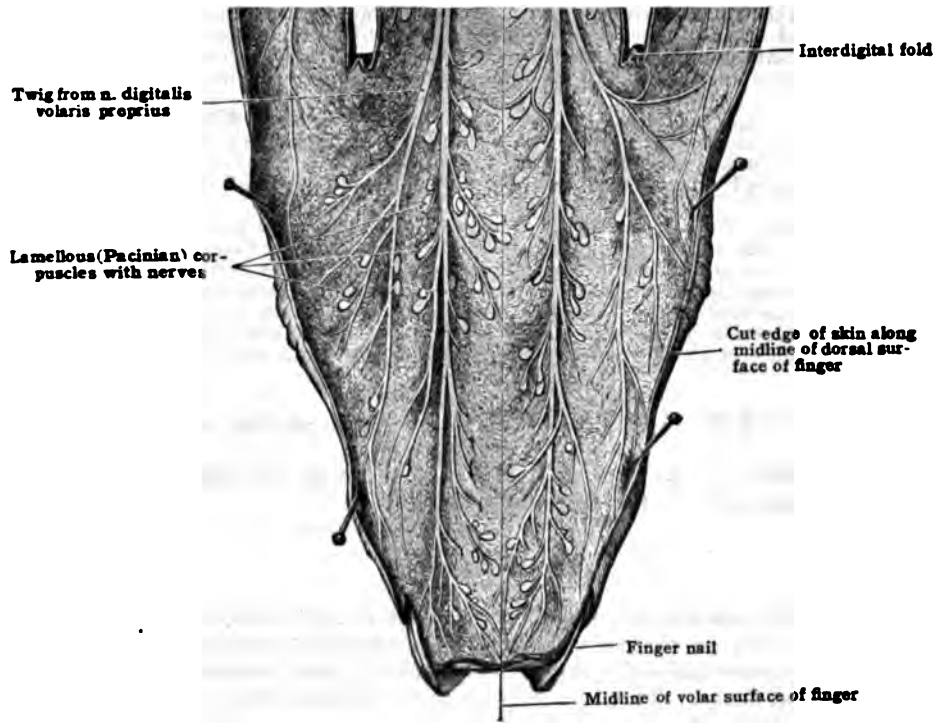
Smooth muscle fibers are scattered through the corium collected into bundles in the neighborhood of the sebaceous glands and the hairs. They are described in connection with these latter (p. 68). In addition to these muscles are found in the scrotum as the dartos, in the perineum, around the anus, and beneath the papilla and areola of the mammary gland.

Bursæ mucosæ subcutaneæ.—In some situations where the integument is exposed to repeated friction over subjacent bones or other hard structures its movements are facilitated by the development of sac-like interspaces in the subcutaneous tissue, the **subcutaneous mucous bursæ.** They are similar to the more deeply placed bursæ which are found in relation with muscle tendons. Their occurrence is quite variable. In some individuals they are numerous, in others very few. They have a considerable practical importance from the fact that they may become greatly swollen.

The most constant subcutaneous mucous bursæ are the following:

Bursa anguli mandibulæ; B. subcutanea prementalis, between the periosteum and soft parts over the tip of the chin; **B. subcutanea prominentiæ laryngeæ** over the ventral prominence of the thyroid cartilage of the larynx (often found in the male); **B. subcutanea acromialis,** between the acromion and the skin; **B. subcutanea olecrani,** beneath the skin on the dorsal surface of the olecranon; **B. subcutanea epicondyli humeri lateralis,** found beneath the skin over the lateral epicondyle of the humerus (occasional); **B. subcutanea epicondyli humeri medialis,** between the skin and the medial epicondyle of the humerus (more frequent); **B. subcutanea metacarpophalangea dorsalis,** between the skin and the dorsal side of the metacarpophalangeal joints (occasional especially the fifth); **B. subcutanea digitorum dorsalis,** beneath the skin over the proximal finger-joints; and rarely over the distal finger-joints; **B. subcutanea trochanterica,** between the skin and the great trochanter of the femur; **B. subcutanea præpatellaris,** beneath the skin covering the caudal half of the patella; **B. subcutanea infrapatellaris,** between the skin and the cephalic end of the ligamentum patellæ; **B. subcutanea tuberositatis tibiæ** ventral to the tibial tuberosity, covered by skin or by skin and crural fascia; **B. subcutanea malleoli lateralis,** between the skin and the point of the lateral malleolus; **B. subcutanea malleoli medialis,** between the skin and medial malleolus; **B. subcutanea calcanea,** in the sole of the foot between the skin and the plantar surface of the calcaneum; **B. subcutanea sacralis,** beneath the skin which covers the lumbodorsal fascia and the region between the sacrum and coccyx.

FIG. 72.—CUTANEOUS NERVES OF THE MIDDLE FINGER AND LAMELLOUS (PACINIAN) CORPUSCLES. (From Toldt's Atlas.)


Interdigital fold
Twig from n. digitalis volaris proprius
Lamellous (Pacinian) corpuscles with nerves
Cut edge of skin along midline of dorsal surface of finger
Finger nail
Midline of volar surface of finger

Blood-vessels of the skin.—The corium and subcutaneous tela are richly supplied with blood-vessels. The cutaneous arteries are as a rule perforating branches from the deeper arteries supplying the muscles and underlying tissue of the region. There are, however, a number of arteries directly supplying the skin, though all of these are small except some of the arteries of the scalp. The skin of the trunk is supplied by branches from the intercostal arteries in a metameric fashion. The areas supplied by certain groups of vessels and the directions which the arteries follow in the skin show much regularity.

The arteries enter the corium from the underlying fascia and there break up into a network of minute vessels supplying the hair-follicles, glands and all cutaneous tissues. The veins of the skin usually accompany the arteries and lead back to the larger underlying vessels. Other veins of considerable size, particularly noticeable on the extremities run in the fascia immediately beneath the skin and independent of the arteries. These large vessels are described in the general section on the veins (p. 701).

Lymphatics of the skin.—The cutaneous lymphatic vessels are found in the skin of all parts of the body but are more abundant in certain places. The lymph-vessels of the skin are developmentally among the first lymph-vessels to appear. The larger vessels and glands of the subcutaneous tela will be found described in connection with the general lymphatic system Section VII. In the corium the lymphatics from the papillæ form a **subpapillary network** which opens into a **subcutaneous plexus** connected with the larger lymph-vessels of the subcutaneous tela. There are no lymph-vessels in the epidermis, but this is supposed to be nourished

by the lymph in the tissue spaces between the cells and these spaces connect indirectly with the lymph-vessels.

The nerves.—The skin has one of the richest nerve supplies of the body. The nerves are in greater proportion in those parts which are most sensitive. The various skin-areas are supplied by specific (segmental) nerves with much greater regularity than in the case of the arteries. The nerves supplying adjoining areas overlap so that there is an intermediate space supplied by both. The variations consist in an extension of one area and a corresponding contraction of an adjoining area. The distribution of the nerves in the skin shows, especially on the trunk and neck, a marked metameric arrangement (see fig. 805).

With the exception of the nerves to the sudoriferous and sebaceous glands, the skin-muscles and blood-vessels, all the cutaneous nerves are sensory. They have diverse modes of termination. Some end in the subcutaneous tela; others, the greater number, terminate in the corium; still others extend to the epidermis. Some of the sensory organs of the skin are shown in fig. 648.

Development of the skin.—The ectoderm of the embryo is at first a single layer of cells but it soon becomes two-layered, the outer layer being very different in form from the uniformly regular underlying cells. This outer layer, *epitrichium or periderm*, is present only in the embryo and fetus and is cast off. The cells of the deeper layer of ectoderm multiply and form a many-celled stratified epithelium. The ectodermal cells also give rise to the hairs, nails, various types of skin-glands, and enamel-organs of the teeth.

The stratified epithelium becomes differentiated into several more or less clearly marked layers due to changes taking place in the cells as they near its outer surface. The lower cells continue to multiply throughout life as the *stratum germinativum*. Cells above this stratum deposit granules in their protoplasm and form the *stratum granulosum*. These cells on reaching a more superficial position become cornified and constitute the *stratum corneum*. This cornified layer is continuously desquamated or thrown off and replaced from the deeper cells. Such is the continuous wear and tear of the outer surface of the body and its means of regeneration.

The *corium* or connective tissue skin is mesodermal in origin and differentiates from the cells of the dermo-muscular plate of mesoderm immediately underlying the embryonic ectoderm. It forms the matrix which received the down-growths from the epidermis, hair-follicles, glands, etc. and serves by means of its rich vascular supply to nourish all the skin organs and parts.

Old age changes.—With advanced age the skin becomes thinner, less elastic and in certain regions the papillæ of the corium almost completely disappear. The cutaneous and subcutaneous fat becomes absorbed and the thin inelastic skin wrinkles over the wasted parts. The epidermis becomes smoother, with finer markings less pronounced, and takes on a sleek, shiny, often scar-like appearance. The hair becomes rough and fails to maintain its general directions. The function of the skin-glands is impaired and scaling often occurs. These changes give to the skin of the aged an entirely different feel and texture from that of the vigorous adult.

THE APPENDAGES OF THE SKIN

The appendages of the skin include: (A) the hairs; (B) the nails; (C) the cutaneous glands; and (D) the mammary glands.

A. THE HAIRS

The **hairs** [pili] are less developed in man than in any other primate. Where well developed they in themselves serve as a protective organ and moreover through their connection with the nervous system they become in a measure organs of special sense. They are strong, flexible, somewhat elastic, and poor conductors of heat. They cover the entire surface of the body with the following exceptions: The flexor surfaces of the hands and feet; the dorsal bends and sides of the fingers and toes; the dorsal surfaces of the distal phalanges of the fingers and toes; the red borders of the lips; the glands and inner surface of the prepuce of the penis and clitoris; the inner surface of the labia majora; the labia minora and the papilla mammæ.

The **size** and **length** of hairs varies greatly not only in different parts of the body but also in different individuals and races. In certain situations the hairs are especially long and large and are designated by special names (such as the capilli, barba, hirci, and pubes).

Strong, well-developed short hairs are found in connection with the organs of sense forming the eyebrows, **supercilia,** the eyelashes, **cilia,** at the entrance to the external acoustic meatus, **tragi,** and at the nares, **vibrissæ.** Upon the extensor surfaces of the extermities, upon the chest, and in other situations in some individuals, especially in adult males, the hairs are also longer and stronger than upon the rest of the body, where they are, as a rule, short, fine and downy. The first hairs appearing in the fetus are very fine, and are called **lanugo.**

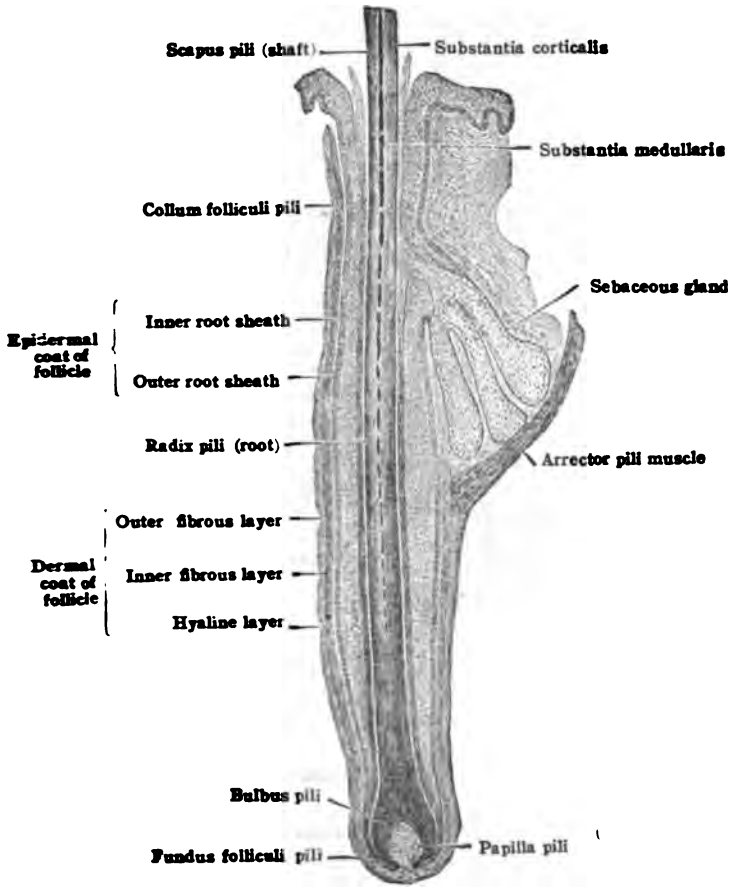
Excess of long hairs, **hypertrichosis,** may involve the whole hairy surface of the body as seen in the exagerated cases of hairy men and bearded women exhibited as freaks. This condi-

tion may be inherited and affect several individuals in the same family. Local areas of long hairs also occur as over nævi and upon the sacrum. Local congestion due to inflammation, irritation, or pressure may cause hypertrichosis. In women, hair upon the upper lip or other parts of the face may be an inherited peculiarity and due to some abnormality of the ovaries. It is also not uncommon after the menopause.

In color the hairs may be either blonde, brown, black, red, or some gradation of these colors. The color varies with the race, and also with the individual, and according to age. It is due to pigment in the cells of the hair but is also influenced by the amount of air between the cells.

Greying and whitening of the hair is due not only to a decrease of pigment but also to an increase in the amount of air between the cells. Sudden blanching of the hair is thought to be due almost entirely to an increase in the quantity of this contained air. Whitening of the hair is

FIG. 73.—LONGITUDINAL SECTION OF A GROWING HAIR OF THE HEAD. (×30.) (From Toldt's Atlas.)



physiological in old age and not infrequent in younger persons. This may be an inherited peculiarity or may follow mental overwork, nervous shock, or prolonged disease. Local blanching is also seen as the result of disease.

The hair may be straight, waved, curled, or frizzled in varying degree. Here also there is not only an individual but also a racial variation, as instanced in the curled or crinkled hair of the African negro and the straight hair of the American Indian. The curliness is caused by the form and manner of implantation in the skin. Straight hairs are round or oval in transection and curled hairs are more flattened. The root of curled hair has been observed in certain instances, as in the negro, to have a curved course in the skin which may account in a measure for its curliness.

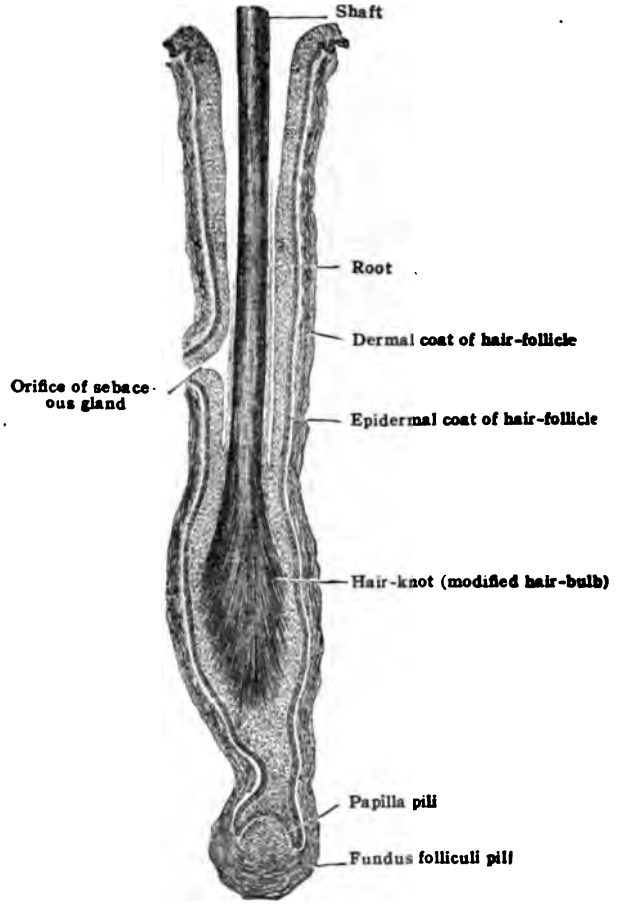
The hairs are *arranged* singly or in groups of from two to five and, except those of the eyelashes, are implanted at oblique angles to the surface of the skin. The directions in which the hairs point are constant throughout life for the same individual. They are arranged in tracts in which the hairs diverge from a center in whorls, the **vortices pilorum.**

These vortices are found constantly in certain definite regions and apportion the whole hairy surface. The centers of vortices are found at the vertex (sometimes double) upon the face, around the external auditory meatus, in the axilla, in the inguinal region, and sometimes on the

lateral surface of the body. These are all paired except as a rule the first. Where adjoining vortices come together the hairs are arranged in lines along which they all point in nearly the same direction, only slightly diverging, forming the **hair streams, flumina pilorum.** In other lines and places the hairs point in coverging directions such as at the umbilicus and over the tip of the coccyx.

The structure of the hair.—Each hair consists of a **shaft** [scapus pili] (fig. 73) projecting from the free surface of the skin to end (unless broken or cut) in a conical tip [apex pili], and of a **root** [radix pili], imbedded in the case of the lanugo hair in the corium and of the larger hairs at various depths in the subcutaneous tela. Surrounding the root is a downgrowth of the skin known as the **follicle** [folliculus pili].

FIG. 74.—LONGITUDINAL SECTION OF A HAIR READY TO FALL OUT, WITH FOLLICLE FOR NEW HAIR. (×30.) (From Toldt's Atlas.)



The root of the hair at its deepest parts swells to from one and one-half to three times the diameter of the shaft forming thus the **bulb** [bulbus pili] (fig. 73). The bulb is hollow and a vascular connective tissue process, the hair **papilla** [papilla pili] (figs. 73, 74) extends from the deepest part of the follicle into the cavity in its base. The follicle consists of an external connective tissue portion, the **theca folliculi,** formed by the corium, and an internal epithelial portion belonging to the epidermis and divided into two portions, the **inner** and **outer root-sheaths** (fig. 73).

At the junction of the outer and middle thirds of the follicle of most of the hairs, the ducts of usually two or more sebaceous glands connect with the space between the hair and its follicle (figs. 73, 75). Immediately beneath this is the narrowest part of the follicle, the **neck** [collum folliculi pili], especially important as the position of the nerve ending of the hair.

Many of the hairs have in connection with their follicle round or flat bundles of unstriped muscle fibers, the **arrectores pilorum** (figs. 73, 75). These are situ-

ated on the side toward which the hairs point, their deep ends being attached to the hair-follicle beneath the sebaceous glands, which they more or less embrace; and their superficial ends connect with the papillary layer of the skin. Contraction of the arrectores not only causes the hairs to become more erect and the skin around them to project somewhat causing 'goose flesh,' but also compresses the sebaceous glands which are situated between the follicle and muscle and helps to empty the glands of their secretion.

The blood supply of the hairs.—The hair-follicles are surrounded by a capillary network of arteries connected with those of the corium and the papillæ are also supplied with loops of arteries.

The **nerves** of the corium supply branches to the hairs. Some of these branches enter the papillæ, others surround the follicle at its neck and are distributed among the cells of the outer root sheath.

Development.—The hairs are developed from the epidermis by thickenings and downgrowths into the corium of plugs of epithelium. The deepest parts of these plugs become swollen to form bulbs and from these the hairs are produced. The central cells of the epithelial downgrowths disintegrate producing the lumen of the follicle. The hairs continue to grow from the deeper cells and protrude from their follicles between the fifth and seventh fetal months. Abnormally they may be scanty at birth and rarely entirely absent, **alopecia.** The lanugo hairs which cover all the hairy parts of the body at birth are soon shed and replaced by new hairs in the old follicles. Throughout life also the hairs are being constantly shed and replaced by

FIG. 75.—VERTICAL SECTION OF THE SKIN FROM SCALP. (×20.)

new ones. This is accompanied by cornification of the bulb and fibrillation of the deep end of the hair (fig. 74). Thinning of the hair and baldness occur when the shed hairs cease to be replaced. This is common in old age and a premature baldness appears to run in certain families. The rate of growth is normally from 1 to 1.5 cm. per month, but is subject to variation.

B. THE NAILS

The **nails** [ungues] are thin, translucent, horny epidermic plates upon the dorsal surfaces of the distal phalanges of the fingers and toes. Through their hardness they serve as protective organs not only by covering the nerve-endings and other delicate structures of the skin; but also by acting as natural weapons. On the fingers they form useful tools. They are four-sided plates presenting a distal free border [margo liber], which overhangs the tips of the fingers, an irregular, sharp proximal edge [margo occultus], and on each side a somewhat thinned border [margo lateralis] (fig. 76).

Each nail is composed of an exposed distal part, the **body** [corpus unguis], and a proximal covered part, the **root** [radix ungius], (figs. 76–78), which ends in the margo occultus. The nail is at a slightly deeper level than the surrounding skin which overhangs the root and the lateral margins in a fold, the **nail-wall** [vallum unguis] (figs. 77, 78). The epidermis of the free edge of the nail-wall, especially proximally, is thickened and often appears as a ragged edge. At a deeper level than the above and extending somewhat more distally is a variably developed thin parchment-like membrane, the **eponychium,** closely attached to the superficial surface of the nail. The groove which is formed between the

vallum and the underlying nail bed is known as the **sulcus matricis unguis.** This lodges the root and lateral margins of the nail and is deepest in the center of the root, becomes shallower toward the lateral margins, and finally disappears entirely toward the free border of the nail (fig. 78).

The **stratum corneum unguis** (fig. 78) which forms the principal thickness of the nail, presents fine longitudinal lines on the free dorsal surface The deeper surface of the nail, the **stratum germinativum unguis,** is a soft epithelial layer. Both these layers are transparent,

FIG. 76.—DORSAL SURFACE OF ISOLATED FINGER-NAIL. (×1.) (From Toldt's Atlas.)

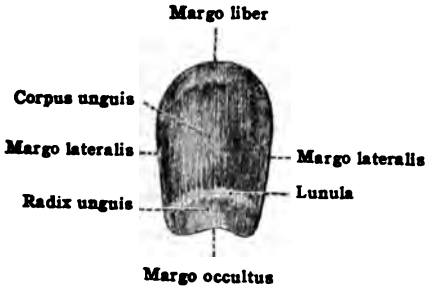


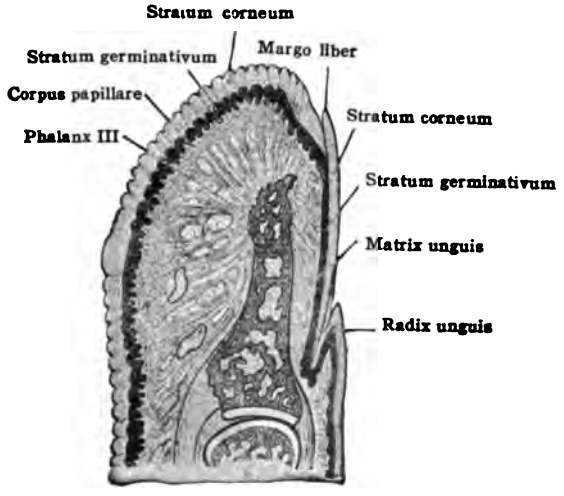
FIG. 77.—FINGER-NAIL AND NAIL BED.

excepting a semilunar area near the root, the **lunula** (figs. 76, 77), which is opaque whitish in color. Beneath the stratum germinativum is the fibrous **nail bed** [matrix unguis], corresponding to the corium and presenting well-marked longitudinal ridges, the **cristæ matricis unguis** (fig. 77).

Blood-supply of the nails.—The **arteries** are numerous in the matrix beneath the body of the nail but fewer beneath the root. They pass from the deep parts of the nail bed toward the surface, running in the main longitudinally and sending anastomosing branches to the papillæ.

The **nerves** beneath the nail are abundant and terminate in free sensory endings and in special end organs of several sorts.

FIG. 78.—LONGITUDINAL SECTION THROUGH THE TIP OF THE MIDDLE FINGER. (×2.) (From Toldt's Atlas.)



Development of the nails.—For an account of the development of the nails, see pp. 57, 70.

Growth of the nails.—The nail grows in length and thickness by multiplication of those cells of the stratum germinativum which are situated between the margo occultus of the root and the distal border of the lunula. The older cells are pushed distally and toward the surface by the deeper cells. As a result the nail becomes gradually thicker from the occult border as far as the distal margin of the lunula. Over the rest of the nail bed no thickening appears to take place. The rate of growth is faster on the fingers than on the toes and varies with age, season, and the individual. When the nail is torn off, or detached through inflammation, it may be regenerated if the cells of the stratum germinativum have not been destroyed.

Congenital hypertrophy of the nails sometimes occurs, but absence or imperfect development is rarely seen. The white spots so frequently seen in the nail are caused by air between the cell layers due usually to injury or impaired development.

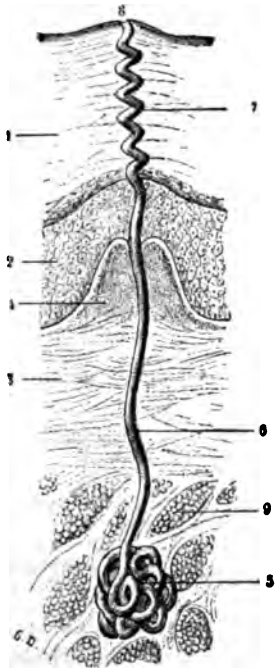
C. THE CUTANEOUS GLANDS

The **glands of the skin** [glandulæ cutis] are of two kinds: **glomiform glands** and **sebaceous glands.** The *glomiform* ('skein-like') glands [glandulæ glomiformes] are of four types: sudoriferous, ciliary, ceruminous and circumanal glands.

The **sudoriferous glands** [glandulæ sudoriferæ] or sweat-glands are modified simple tubular glands which secrete the *sweat* [sudor]. They are found in the skin of all parts of the body except that part of the terminal phalanges covered by the nails, the concave surface of the concha of the ear, the labia minora, and the inferior part of the labia majora in the female and the surface of the prepuce and the glans penis in the male.

FIG. 79.—VERTICAL SECTION OF THE PALMAR SKIN SHOWING AN ISOLATED SUDORIFEROUS GLAND. (Testut.)

1, Stratum corneum; 2, Malpighian layer; 3, corium; 4, papilla; 5, body of sudoriferous gland; and 6, 7, its excretory duct; 8, orifice of duct on surface; 9, subcutaneous fat.



The *number* of sweat glands found in different parts of the body varies greatly. There are very few on the convex surface of the concha and on the eyelid. They are also rather scanty on the dorsal surface of the trunk and neck, more numerous on the ventral surface of these parts and on the extensor surfaces of the extremities, still more numerous on the flexor surfaces and most numerous on the volar surface of the hands and plantar surface of the feet. They vary from less than 57 to more than 370 to the square centimeter.

Each gland (figs. 64, 79) consists of a secretory portion or **body** [corpus gl. sudoriferæ], and an excretory **duct** [ductus sudoriferus], which opens on the surface of the skin by a mouth visible to the unaided eye, the so-called 'pore' [porus sudoriferus]. Occasionally the duct opens into a hair-follicle.

The **bodies** of the glands are irregular or flattened spherical masses, yellowish or yellowish red in color and somewhat transparent. They vary in size from .06 to 4 mm. or more with a mean diameter of .2 to .4 mm., the largest being found in the axilla. They are formed of the irregularly many times coiled terminal part of the gland tube. The bodies of the glands are situated in the deeper part of the corium or in the subcutaneous tela.

The **ducts,** beginning as several coils bound up with those of the bodies, extend often in a straight or slightly wavy course nearly at right angles to the surface as far as the epidermis. This they pierce as spiral canals of from two to sixteen turns, more marked where the epidermis is thickest (fig. 64), and opened on the surface by somewhat widened funnel-shaped mouths. The ducts pass between the papillæ of the corium and open on the summits of the cutaneous cristæ where these are present. The diameter of the ducts is distinctly smaller than that of the secreting part of the glands, and this is true of the lumen also.

The degree of development of the sweat-glands varies with the situation, the individual, and also racially, as instanced by their great development in the negro. In rare cases sweat glands are completely absent from the human skin. The general body-skin of a number of mammals contains no sweat-glands. The glands are smaller in the aged than in the young.

The sudoriferous glands in the axillary region seem to be in some way connected with the sexual function for although a large number persist as small glands, others undergo further development beginning about the ninth year in the female and at puberty in the male. These glands in places form almost a continuous layer and are formed of large partly branched tubules with high secreting cells. The reddish color of the sweat in the axillary and some other regions, especially in certain individuals, is probably derived from the pigment-granules which are found in the glands here. The oil in the secretion lubricates the skin and keeps it soft and supple.

Vessels and nerves.—The sudoriferous glands are supplied from the deep cutaneous plexus by an abundant network of arteries which surround and penetrate between the coils of the gland-tubules. There is an enclosing network of nerve-fibers some of which have been traced to the gland cells.

Development.—The sudoriferous glands are seen first in the fourth or fifth fetal month. The anlages resemble closely those of the hair, but the cells are not so loosely packed. They project down as solid plugs which become long, slender, and tortuous rods. In the seventh fetal month the rods begin to develop a lumen in the deeper parts, which also now begin to coil. A lumen soon develops also in the superficial parts and joins that in the deeper part of the gland. The outer of the two layers of epithelium in the ducts becomes transformed at its transition into the gland proper into the myoepithelial layer.

The **ciliary glands** [gl. ciliares; Molli] are modified sudoriferous glands of the branched tuboalveolar type. They have simpler coils but are larger than ordinary sweat glands. They are situated in the eyelids near their free borders and open into the follicles of the cilia or close to them (see Section IX).

The **circumanal glands** [gl. circumanales] are found in a circular area about 1.5 cm. wide which surrounds the anus, a short distance from it.

These glands are several times the size of the ordinary sweat glands and resemble the glands found in the axilla, their secretion likewise having a strong odor. They are branching tubular glands. The other kinds of glands which are found in this same area are ordinary sweat glands, glands with straight ducts, with saccules and secondary alveoli, and tuboalevolar glands.

Ceruminous gland [gl. ceruminosæ] are glomiform glands somewhat modified from the sudoriferous type. They are branched tuboalveolar glands with relatively large lumina in the coils and narrow short ducts, and occur only in the external acoustic (auditory) meatus.

They are very abundant on the dorsal and superior part of the acoustic meatus in the region of the cartilaginous part, where in the adult most of them open on the surface of the skin close to hairs. Others open into the hair-follicles as they all do in the fetus and child. Their secretion, the **cerumen,** is, when freshly secreted, a fluid or semifluid oily material of a yellowish-brown color, which on exposure to the air becomes solid like wax.

The **sebaceous glands** [gl. sebaceæ] are simple branched or unbranched alveolar glands distributed over nearly the whole surface of the body. Nine-tenths of them are closely associated with the hairs, into the follicles of which they empty (figs. 73, 74), and are therefore absent from certain of the non-hairy parts of the body, as the flexor surfaces of the hands and feet, the dorsal surfaces of the distal phalanges of the fingers and toes. On the other hand, a few are found, usually much modified, opening independent of the hair-follicles, as at the angles of the red margins of the lips, around the nares, around the anus, and the *tarsal* (Meibomian) glands in the eyelids. Modified sebaceous glands are also found upon the mammary papilla and areola in the female, and in some cases upon the superficial surface of the glans and the surface of the prepuce of the penis, here known as **preputial glands;** also a few very small ones may be found upon the labia minora, the glans and prepuce of the clitoris.

The sebaceous glands vary in size in different situations and also in individuals and races. They range from .2 to 2.2 mm. long and nearly as broad. Among the smallest are those of the scalp. The largest are found on the alæ of the nose and on the cheeks where their ducts are visible to the unaided eye. They are also large on the mons pubis, labia majora, scrotum, about the anus and on the mammary areola. Smaller glands are also found associated with these large ones. The size of the glands is independent of the size of the hairs with which they are associated but the number of glands depends upon the size of the hair. On small hairs one or more glands are always found and on large hairs there may be a whole wreath of from four to six separate glands opening into the hair follicle.

The **number** of sebaceous glands has never been exactly estimated, although, it is known that they are less numerous than the su oriferous glands. This is very evident on the extrem-

ities, trunk, and neck, where they bear a relation of 1 to 6 or 8. On the scalp, concha of the ear, and skin of the face they are about equal in number while on the forehead, alæ of the nose, free borders of the eyelids and external genital organs in the female the number of sebaceous glands is greater than the number of sudoriferous glands.

Each sebaceous gland consists of a secretory portion, the **body**, connected with the hair-follicle or the surface of the skin by a wide short **duct**. In the small glands, the body of the gland may consist of a single alveolus but in the larger glands there are from four to twenty of these connected by irregular ducts to a single excretory duct.

The **ducts** open into the hair-follicles near their necks between the inner root-sheath and the hair or upon the surface of the skin. They are always very short, cylindrical, or infundibuliform, and their epithelium is directly connected with that of the outer root-sheath of the hair-follicle or with the epidermis where the hair is wanting.

The glands lie in the superficial layers of the corium and where one or a few are connected to a single hair, they usually open into the hair-follicles on the side toward which the hairs point. Where there are several glands for one hair they may completely surround the hairs like a rosette. The active secretion of the sebaceous glands does not begin before the fifth or sixth year of life. It attains its maximum in the adult and decreases in the aged.

The relation of the arrectores pilorum to the sebaceous glands has been described in connection with the relation of these muscles to the hairs.

Vessels and nerves.—The sebaceous glands are surrounded by a fine capillary plexus of **blood-vessels** closely associated with those of the hairs and skin. Concerning their **lymph-vessels** little is known. The **nerves** of the sebaceous glands are connected with those of the skin and hair but the exact manner of distribution is uncertain.

Development.—The sebaceous glands appear first in the fifth fetal month as single, rarely double, buds on the anlages of the hair-follicles. The distal ends of these enlarged buds become lobulated. In these solid masses of cells lumina for the alveoli and the ducts later are formed, through the fatty degeneration of the central cells. The oily contents of these cells together with the débris and the cast-off surface cells of the epidermis form the **vernix caseosa** on the surface of the fetus.

D. THE MAMMARY GLANDS

The **mammary glands** [mammæ] or breasts are modified cutaneous glands. In the male they remain rudimentary and functionless throughout life, but in the female they are functionally closely associated with the reproductive organs since they secrete the milk for the nourishment of the newborn and are subjected to marked changes at puberty, throughout pregnancy, during and after lactation, and after the menopause.

The two mammæ (fig. 80) are situated on the ventral surface of the thorax one on each side of the sternum. As examined from the surface in a well-developed nulliparous female they appear to extend from the second or third rib to the sixth or seventh costal cartilage and from the lateral border of the sternum to beyond the ventral folds of the axillæ. (For further details on topography and clinical relations, see p. 1366.) Separating the two mammæ there is a median area of variable size, the **sinus mammarum**.

In **shape** they are conical or hemispherical, and in consistency somewhat firm and elastic. The two breasts are seldom equal in size, the left, as a rule being slightly the larger. Each measures from 10 to 13 cm. in diameter being slightly longer in the direction parallel to the lateral border of the pectoralis major muscle. The **weight** of each gland varies from 140 to 200 grams, or more.

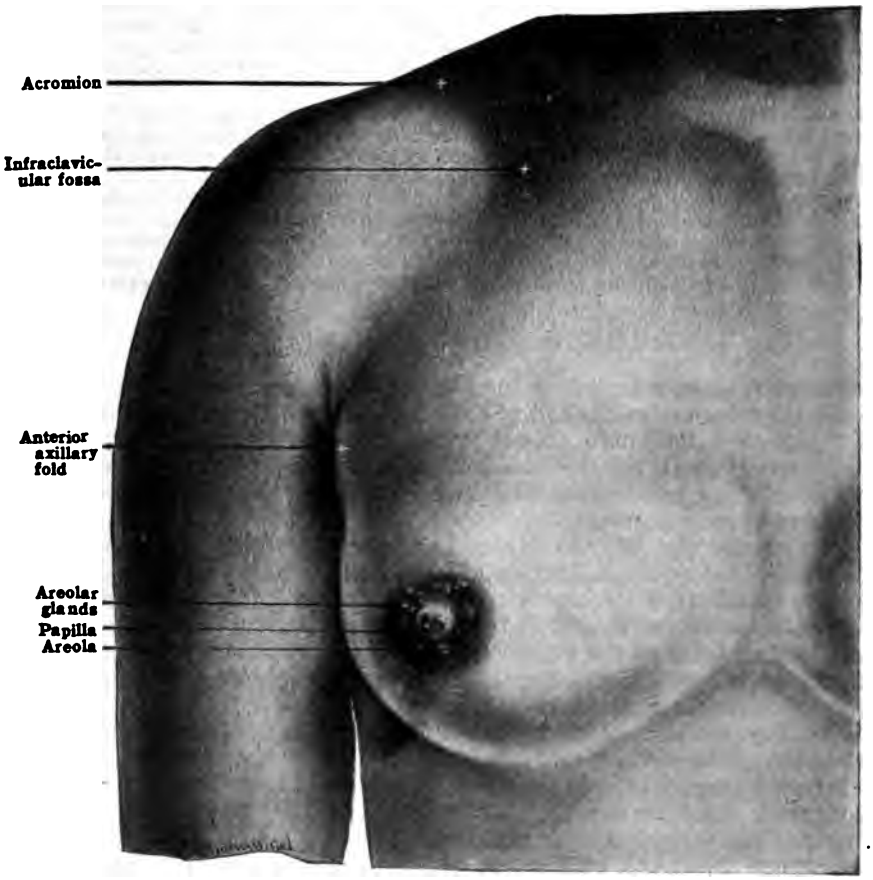
Each mamma presents a ventral surface and a dorsal surface. The **ventral surface** is free, covered by skin, smooth and convex. It is continuous cephalically, without sharp demarcation, with the ventral surface of the thorax but laterally and caudally it is usually sharply defined (figs. 80, 82). It is most prominent slightly mesocaudal to the center and at this point there is a marked pigmented projection, the **nipple** [papilla mammæ] surrounded by a slightly raised area, also pigmented, the **areola mammæ**. These two structures will be described separately later.

The **dorsal surface** of the mammary gland (figs. 82, 83) is attached and concave. It is in relation in its cephalomedial two-thirds with the fascia over the pectoralis major muscle. In its caudolateral third it extends over the base of the axillary fossa, where it is in relation with lymphatic glands and with the serratus anterior muscle, and at its most caudal part, sometimes with the external abdominal oblique muscle.

The usual **number** of breasts in the human species is two; rarely is the number reduced, much more often do we find an increase in this number. Each of these conditions is found in both sexes and may be complete or partial. Complete suppression of both breasts, **amastia**, is

one of the rarest anomalies and is usually associated with other defects. Complete absence of one is less rare. A more frequent condition is arrest of development, **micromastia,** leading to rudimentary but functionless organs. Absence of the nipple, **athelia,** is much commoner and generally affects both breasts. All grades of the imperfection from complete absence to slightly imperfect nipple may be found. When there is an increase this may include the whole breast, **polymastia,** or just the nipple, **polythelia.** The supernumerary structures [mammæ accessoriæ] may be represented only by a pigmented area indicating an areola; or by a nipple with or without an areola: by a gland with a more or less perfect nipple and areola; or with ducts opening without a nipple; or there may be no opening on the surface. The extra mamma is very rarely perfectly developed and functional. Various observers have found the supernumerary breasts or nipples occurring in from 1 to 7 per cent. of the cases examined and somewhat oftener in males than in females. The extra organs are found more frequently on the left side, usually along a line extending from the axilla toward the genitalia. This corresponds to the position in which the mammæ occur in some other mammals and also to the milk-line of the embryo. Although they are occasionally found in other situations, over 90 per cent. of them

FIG. 80.—THE RIGHT MAMMA OF A GIRL 18 YEARS OLD. (Modified from Spalteholz.)



are encountered upon the ventral surface of the thorax along the above-mentioned line caudal and medial to the normal pair of breasts. They are frequently hereditary. It is doubtful whether their possessors are either more fertile or more liable to bear twins.

The **shape** of the breasts varies with the development and functional activity and with the amount of fat. The smooth, somewhat conical breast of the nullipara becomes hemispherical with increase in the amount of fat, while in emaciation it may be reduced to a flattened disk with an irregular surface. After lactation the breasts tend to become more pendulous with marked sulci between them and the thoracic walls, and after repeated pregnancies they may become elongated so as to be almost conical or even have pedunculated bases.

The **size** of the mammary gland in girls remains relatively the same as in the infant up to puberty, when it suddenly increases considerably and continues for a time to enlarge slightly at each menstrual period. There is also a temporary enlargement and soreness at each menstrual period, due perhaps to the increased blood supply. Until the age of puberty the glands measure 8 to 10 mm. in diameter but when they have attained their complete adult development they have in-

creased to 100 to 110 mm. in the cephalomedial, 120 to 130 mm. in the cephalolateral (obliquely from above downward) direction, and 50 to 60 mm. in thickness.

FIG. 81.—THE FEMALE MAMMA DURING LACTATION. (After Luschka.)

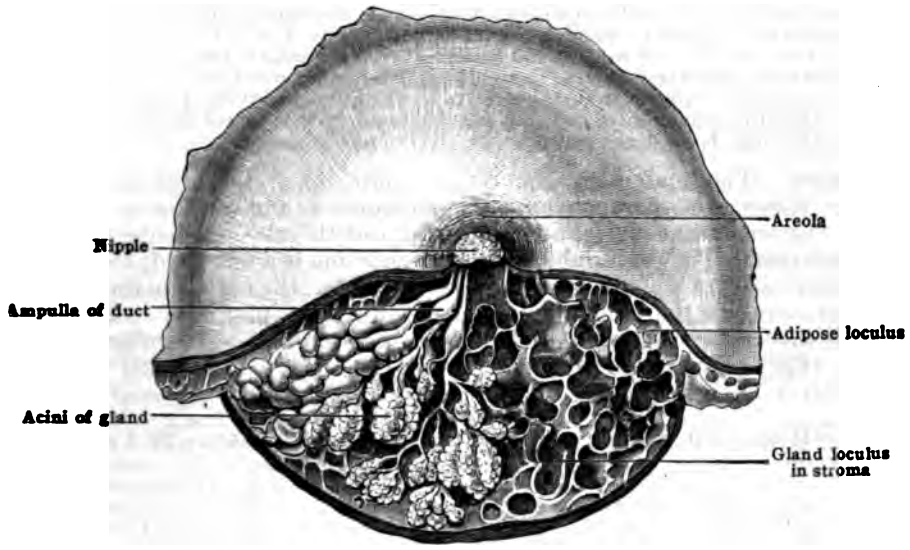
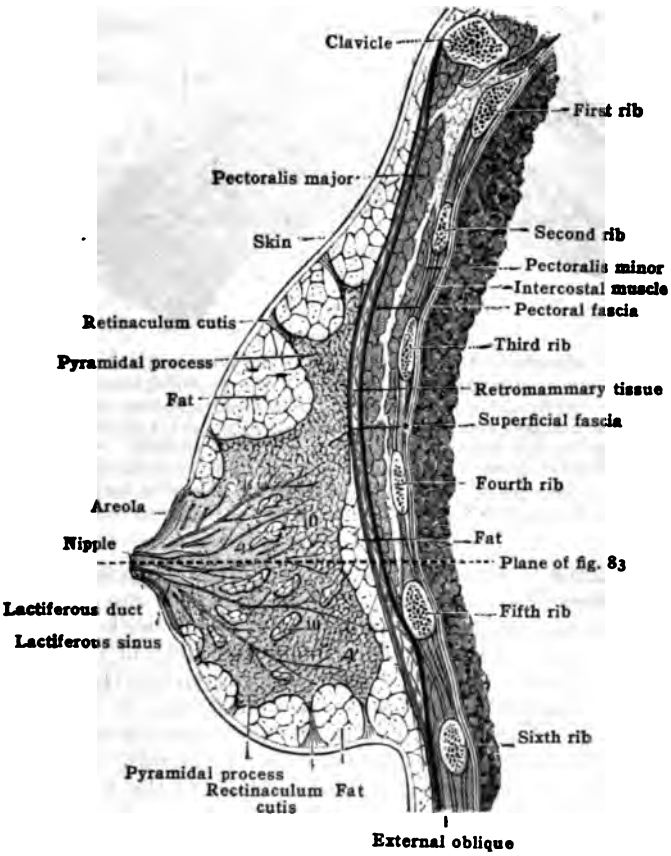


FIG. 82.—SAGITTAL SECTION OF THE RIGHT MAMMA OF A WOMAN TWENTY-TWO YEARS OLD. (Testut.)



During pregnancy the breasts again increase in size, more especially after the birth of the child. When their full functional activity is established, their volume may be two or three times as great as before pregnancy. After lactation they return again nearly to their former

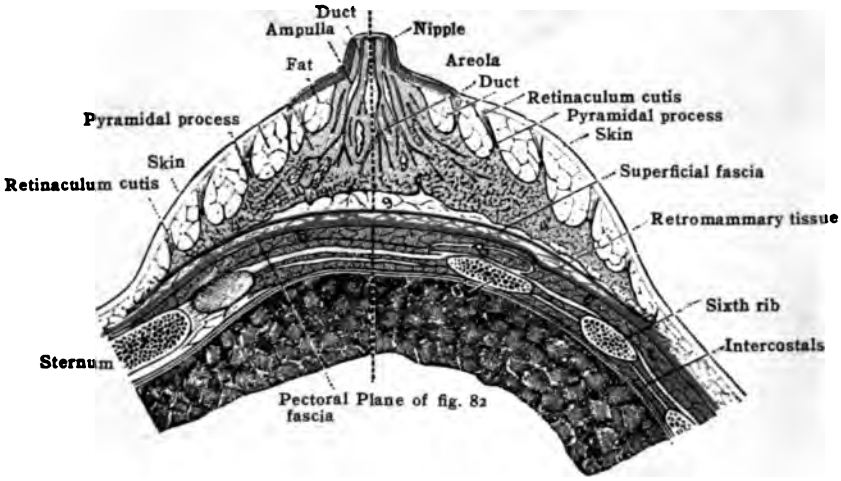
size, which they retain until another pregnancy. After the menopause the useless glands in some cases atrophy and are reduced to small discoidal masses. In others, especially in fat individuals, although the secreting tissue disappears, it is replaced by fat so that there is little or no reduction in size. In addition to the above-mentioned variations in size, the breasts are subject to great individual differences, the cause of which is little understood. Large robust women are sometimes seen with small mammary glands, and small women with large glands.

The *position* of the gland is considered more fully in Section XIV. The level of the mammæ varies with the stature; as a rule, in tall women it is more caudal and in short and broad-chested women it is more cephalic. The tightness of the attachment to the sheath of the pectoralis major muscle is quite variable, but even when quite loose there is some movement of the breast when the arm is raised. The glandular tissue of that part of the breast which overhangs the axilla may be in direct contact with the lymphatic glands.

Structure.—The mammary glands are composed of the essential epithelial glandular tissue, the **parenchyma,** the supporting and enclosing connective tissue of the subcutaneous tela, the **stroma,** and the covering cutaneous layer.

Parenchyma.—The essential part of each mamma is a flattened, circular mass of glandular tissue of a whitish or reddish-white color, the **corpus mammæ.** This is thickest opposite the nipple and thinner toward the periphery. The ventral surface of this mass is convex and made uneven by numerous irregular pyramidal processes (figs. 82, 83) which project toward the skin. The dorsal sufrace, or base, is flat or slightly concave and much less irregular than the ventral surface.

FIG. 83.—HORIZONTAL SECTION OF THE RIGHT MAMMA OF A WOMAN 22 YEARS OLD. (Testut.)



Minute processes of glandular tissue extend from the corpus mammæ into the retromammary tissue, some of them accompanying the septa of the pectoral fascia between the bundles of muscle fibers of the pectoralis major muscle. The circumference of the mamma is thick and well defined, more marked caudally than cephalically, but it presents numerous irregular processes which extend beyond the limits apparent from the surface. One of these especially large and well marked extends cephalolaterally into the axillary fossa, and there are frequently other large but less-marked projections. The glandular tissue in section appears grayish or pinkish in color, and is firm and resistant in consistency. It is thus readily distinguished from the adipose tissue.

The **corpus mammæ** is not a single structure but is composed of from fifteen to twenty separate **lobes** [lobi mammæ] (fig. 81). These are larger and smaller irregular flattened pyramidal groups of glandular tissue, with their apices toward the nipple and their bases radiating toward the periphery of the gland.

Each lobe has a single excretory **duct** [ductus lactiferus] (figs. 81, 82, 83), which opens by a contracted *orifice* (porus lactiferus) in a depression upon the tip of the nipple. When traced from the pore toward the circumference of the gland, the ducts are seen to run first directly dorsally through the nipple, parallel and close to one another. From the base of the nipple they diverge. Each duct is here visible to the unaided eye and measures from 1.5 to 2.5 mm. in diameter. Beneath the areola its diameter increases for a short distance to from 4 to 9 mm., forming thus a reservoir, the ampulla or **sinus lactiferus,** in which the secretion may accumulate for a time. Beyond this dilation the duct continues, gradually decreasing in size as it breaks up into smaller and smaller branches.

There is no anastomosis between the ducts during their course, although at or beneath the pore two or more ducts may join to have a common opening. They possess no valves but when empty their inner surface is thrown into longitudinal plicæ. The ducts have an external coat of white fibrous connective tissue mixed with circular and longitudinal elastic fibers, and an epithelial lining.

Each of the terminal branches of a duct ends in a tubulosaccular, spherical or pyriform **alveolus**. A number of these alveoli which open into a common branch of the duct, when grouped together and bound up with connective tissue, constitute a **lobule** of the gland (lobulus mammæ). A lobe is made up of all the lobules whose ducts join one common excretory duct.

Stroma.—The lobes, lobules, and alveoli are completely covered by a connective tissue sheath too delicate to constitute a distinct capsule. Outside of this the whole gland is embedded in the subcutaneous tela which forms for it a sheath, **capsula adiposa mammæ**. This is particularly well developed on the ventral surface where the fat fills in between the irregularities caused by the lobes and lobules and gives to the surface of the gland its smooth appearance. Within the corpus mammæ there is little fat between the lobules in nulliparæ but much more fat is found here in the stroma in multiparæ. When the fat is absorbed, as it is during lactation and in emaciation, the lobules stand out much more distinctly. There is however, no fat immediately beneath the areola and nipple. The connective tissue is here loosely arranged and allows free motility of the nipple and also permits the more easy distention of the ducts and sinuses during lactation. The connective tissue strands, **retinacula mammæ**, which extend from the apices of the glandular processes on the ventral surface of the mamma are connected to the corium and correspond to the retinacula cutis found in other situations. These are sometimes particularly well developed over the cephalic part of the mamma and have been called the *suspensory ligament of Cooper*.

The dorsal surface of the mamma is bound to the pectoral fascia by loose connective tissue containing, as a rule, only a small amount of retromammary fat (figs. 82, 83). The attachment to the sheath of the pectoralis major muscle is at times so loose that the spaces between the connective tissue appear to form serous sinuses, the **retromammary bursæ**.

In addition to the axillary process or 'tail' of the gland, a projection is sometimes seen extending toward the sternum and another caudolaterally; also processes extending toward the clavicle and caudomedially have been described. Besides these large projections there are numerous branched interlacing processes which combine into larger and smaller masses on the ventral surface and exist as minute extensions on the dorsal surface. In thin women, the parenchyma at the apex of these triangular processes reaches nearly to the surface.

A mammary gland may be made up of a larger amount of stroma and a smaller amount of glandular tissue, or the reverse, and therefore a small breast may furnish more milk than a large one. There is also a variation in different parts of the same breast, one lobe or section may have well-developed lobules while in another they remain almost as at puberty, merely branching ducts.

The **skin** covering the ventral surface of the mamma is covered with lanugo hairs associated with sebaceous glands, and contains many sweat glands of the ordinary type. It is so thin that the subjacent veins are readily seen through it. It is closely adherent to the subjacent fatty layer but its flexibility, elasticity, and motility over the deeper glandular tissue permit much stretching during the enlargement which occurs at the time of lactation. In spite of this, **lineæ albicantes** are often produced especially when the breasts have been unusually large. Aside from the above-mentioned particulars it does not differ from the skin of the adjacent part of the thorax, except over the center of the breast where it forms the areola and nipple.

The **areola mammæ** (figs. 80 to 83) is covered by a thin, delicate, pigmented skin. The *color* in young nulliparæ is reddish, the shade varying with the complexion. During pregnancy the color darkens, slightly in blondes, but so as to become almost black in marked brunettes.

This pigmentation serves as one of the signs of gestation. After lactation the color fades, but little pigmentation remaining in blondes, considerable in brunettes. During pregnancy there is sometimes seen extending more or less beyond the areola a less deeply and less uniformly pigmented ring, the **secondary areola**. In size, the areola is subject to considerable individual variation and is increased in pregnancy.

The **surface** of the areola is roughened by a number of slight elevations irregularly arranged. These are due to underlying large sebaceous and rudimentary milk-glands [gl. areolares: Montgomerii], tubercles or *glands of Montgomery*. Projections caused by sebaceous glands are also found in the secondary areola. All of these tubercles enlarge greatly during pregnancy and the glands produce a slight secretion which is discharged through ducts that open on their summits. The sweat glands are few but large, and in addition to the lanugo hairs there are usually several well-developed hairs.

The *corium* of the areola is devoid of fat but contains a well-developed layer of smooth muscle-fibers, the fascicles of which intercross in various directions but may be seen to be mainly of two orders, circular and radial. They are continuous with those of the nipple. The circular fibers are most numerous adjacent to the nipple, where they may form a layer nearly 2 mm. in thickness.

The areola varies greatly in size, measuring from 15 to 60 mm. in diameter. There is some confusion in regard to the areolar glands and the tubercles of Montgomery. Some consider

the tubercles to be caused by the areolar glands, others consider them caused by the sebaceous glands. Sebaceous glands undoubtedly cause the projections in the secondary areola. The sudoriferous glands of the areola are large and compound tubular glands with a complicated glomerulus and are considered as transitions between sweat and mammary glands. The sebaceous glands are even more numerous than the sudoriferous and are composed of several lobes. They also have been considered by some as intermediate stages in the formation of mammary glands, but this is improbable. There are ten to fifteen very small areolar glands (though Pinard found an average of but four to each breast), whose structure is essentially identical with that of the principal mammary glands. They have dilations on their ducts and they open on the areola at times in common with a sebaceous gland.

The **nipple** [papilla mammæ] (figs. 80 to 83) in well-developed nulliparæ is situated slightly mesocaudal to the center of the breast and on a level with the fourth rib or fourth intercostal space about 12 cm. from the median line. But its position in reference to the thoracic wall varies greatly with age, individual, and the present and past activity of the gland. The nipple is usually somewhat conical or cylindrical with a rounded fissured tip marked by fifteen to twenty minute depressions into which the lactiferous ducts empty. The average length of the nipple is 10 mm. to 12 mm. The skin is thin, wrinkled, and pigmented like the areola, except over the tip of the nipple where there is no pigment.

The **corium** of the nipple has many large vascular and nervous papillæ and there is no fat in it. Hairs and sudoriferous glands are absent, but sebaceous glands are present in great numbers. Their secretion here and over the areola serves to keep the skin soft and to protect it from the saliva of the nursing infant. In the deeper layers of the corium smooth muscle-fibers form a loose stratum continuous with that of the areola. This is made up principally of an external circular layer and to a slight extent by an internal layer whose bundles of fibers are parallel with the milk-ducts. Numerous interlacing muscle-fibers connected with these layers and mixed with loose connective tissue, and elastic fibers, but no fat, surround the lactiferous ducts as they pass through the axis of the nipple.

The nipple usually does not project from the surface until the third year. It soon becomes conical but does not attain its full size until shortly after puberty. The size of the nipple is variable, ordinarily in proportion to the size of the gland, but large nipples are sometimes found on small breasts and small nipples on large breasts. During pregnancy the nipple increases in size and becomes more sensitive and more easily erectile. The shape of the nipple in addition to conical or cylindrical may be hemispherical, flattened, discoidal, or slightly pedunculated. Its end may be invaginated or the entire nipple retracted beneath the surface of the gland and projecting only in response to stimuli.

The circular muscle-fibers of the nipple act like those at its base in the areola. By intermittent, rhythmic contractions they tend to empty the lactiferous ducts; by continuous and tight contraction they act as a sphincter. When contracted they also narrow the nipple, make it harder, erect, and more projecting. When the vertical fibers contract they depress the tip of the nipple or they may retract the whole nipple beneath the surface. The muscle of the areola when stimulated puckers the skin toward the nipple causing circular, concentric folds in the skin of the areola.

The **male mammary gland** [mamma virilis]. This develops exactly as in the female. From birth to puberty the glands in the two sexes have a parallel growth and development, but from this time on the glands in the male grow but slightly and reach their full development about the twentieth year.

The corpus mammæ in the adult male measures from 1.5 to 2.5 cm. in diameter and .3 to .5 cm. in thickness. It is whitish in color, tough, and stringy. It is composed of the same number of lobes as in the female but these consist of little more than short ducts with no true acini and may be reduced to mere epithelial or connective tissue strands. The areola and nipple are present and pigmented, but the nipple averages only 2 to 5 mm. in height. The areola has a diameter of 2 to 3 cm. and is covered with hairs. The areolar tubercles may be recognized and the areolar muscle is present. The position of the nipple in relation to the chest-wall is more constant than in the female as the breast is less movable. It is seldom beyond the limits of the fourth intercostal space or the two adjacent ribs, and averages 12 cm. from the median line. Occasionally the male breast may hypertrophy on one or both sides (**gynecomastia**).

Blood-supply.—The main arterial supply to the mammary gland is from mammary rami of perforating branches of the internal mammary artery (p. 607). Usually that from the second or third intercostal space is especially large. Small branches, external mammary rami, are also supplied to the caudal and lateral segments of the breast by the lateral thoracic artery (p. 611). Some rami from the thoracoacromial or supreme thoracic arteries may reach the cephalo-lateral segment of the breast and small twigs, lateral mammary rami, from the anterior branches of the lateral cutaneous rami of the aortic intercostal arteries (p. 627) supply its deep surface. The veins from a superficial plexus communicating with deeper veins corresponding to the arteries.

The lymphatics.—The lymphatics of the mammæ are extremely numerous, forming rich plexuses and free anastomoses. There is a rich plexus in the skin of the areola and nipple which empties mainly into a subareolar plexus. Deep lymphatics arise in the spaces around the alveoli in all parts of the gland, and most of these converge toward the nipple where they join the subareolar plexuses. They anastomose freely with the cutaneous lymphatics and many of

them empty into the subareolar plexus through large lymph-vessel swhich run parallel with the lacteal ducts. From the subareolar plexus usually two large lymph-vessels arise and pass toward the axilla to empty into the axillary lymph-glands. Other lymphatic vessels of the mammary gland follow the course of the various blood-vessels. For further details on the lymphatics, see p. 756.

The nerves.—The gland proper receives its nerves laterally from the lateral mammary rami of the anterior rami of the lateral cutaneous branches of the fourth to sixth intercostal nerves and medially from the medial mammary rami of the anterior cutaneous branches of the second to the fourth intercostal nerves. The skin over the breast receives in addition to branches from the above nerves, branches from the supraclavicular nerves of the cervical plexus. Sympathetic fibers reach the gland but by what course is not yet clear. The nerves are distributed in part to the skin, in part to the plain muscle of the areola and nipple, some to the blood-vessels, and others to the glandular tissue. The secretion is, however, not entirely controlled by nerves as it is influenced also by hormones from other organs brought to it by the blood.

Development.—In very early embryos the epithelium over an area on the side of the body extending from the forelimb to the hindlimb (or beyond these limits) is seen to be deeper and more cubical, the mammary streak. In this area there is produced by multiplication of cells a ridge, the *mammary line or ridge*. In spots along this line, corresponding to the relative position of the mammary glands in some mammals and the supernumerary mammæ in man, the epithelium thickens. The intervening parts of the line disappear as the spots enlarge to form transient *mammary hillocks*. In man development ordinarily proceeds in but one of these hillocks on each side. The deep surface of the hillock projects into the corium as the superficial surface flattens out and the mesodermic cells of the corium condense around the ingrowth producing the *nipple zone*. Rapid proliferation of the deeper cells produces a *club-shaped stage* from the deeper surface of which small bud-like masses of epithelial cells sprout and extend as solid plugs into the corium. These are the anlages of the true secreting part of the gland and the number of buds corresponds to the number of lobes of the future gland. The sprouts extend beyond and beneath the nipple zone and are supported by closely packed connective tissue cells forming the *stroma zone*. The epithelial buds continue to grow and branch and a lumen is finally produced in the originally solid plugs. The primary epithelial ingrowth degenerates and ultimately disappears. A cavity is produced in it which later connects with the lumina of the gland ducts. The depressed nipple zone becomes elevated above the surface soon after birth.

References for the skin and mammary gland.—*General and topographic:* Quain's Anatomy, 11th ed., vol. ii, pt. 1: Testut, Traité d'Anatomie Humaine, 4th ed.; Poirier-Charpy, Traité d'Anatomie, vol. v; Rauber-Kopsch, Lehrbuch der Anatomie, 9th ed.; Bardeleben, Handbuch der Anatomie, vol. v, pt. 1; Merkel, Topographische Anatomie; Corning, Lehrbuch der topographischen Anatomie. *Development:* Keibel and Mall, Human Embryology. *Skin:* Heidenhain, Anat. Hefte., vol. xxx; Kean (finger-prints), Jour. Amer. Med. Assoc., vol. xlvii; Unna (blood and lymph), Arch. f. mikr. Anat., vol. lxxii; Botezat (nerves) Anat. Anz., vol. xxxiii. *Nails:* Branca, Annales de Dermat. et Syphilis, 1910; *Mammary glands:* Kerr, Ref. Hand. Med. Sci. (Breast).

SECTION III

OSTEOLOGY

REVISED FOR THE SIXTH EDITION

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THE SKELETON

THE skeleton forms the solid framework of the body, and is composed of bones, and in certain parts, of pieces of cartilage. The various bones and cartilages are united by means of ligaments, and are so arranged as to give the body definite shape, protect from injury the more important delicate organs, and afford attachment to the muscles by which the various movements are accomplished.

In its widest acceptance, the term **skeleton** includes all parts of the framework, whether internal or external, and as in many of the lower animals there are, in addition to the deeper osseous parts, hardened structures associated with the integument, it is convenient to refer to the two groups as **endoskeleton** and **exoskeleton** or **dermal skeleton,** respectively. All vertebrate animals possess an endoskeleton, and many of them a well-developed exoskeleton also; but in mammals, the external skeleton, when it exists, plays a relatively subordinate part. In most of the invertebrates the endoskeleton is absent and the dermal skeleton alone is found. The exoskeleton is phylogenetically the older and the endoskeleton the more recent form; transition between the two is presented by the ganoid fishes.

Bones are divisible in regard to form into four classes:—**long, short, flat, and irregular.** The **long bones,** found in the limbs, sustain the weight of the trunk and form a system of levers which, with the muscles attached to them, provide the means of prehension and locomotion. The **short bones,** illustrated by those of the carpus and tarsus, are found mainly where compactness, elasticity, and limited motion are the principal requirements. **Flat bones** confer protection or provide broad surfaces for muscular attachment, as in the case of the cranial bones and the shoulder-blade. Lastly, the **irregular** or **mixed bones** constitute a group of peculiar form, often very complex, which cannot be included under either of the preceding heads. These are the vertebræ, sacrum, coccyx, and many of the bones of the skull.

The **surface contour** of a bone presents inequalities in the shape of eminences and depressions. Ridges, spines, tubercles and grooves are directly related to the origin and insertion of muscles; other grooves of crooked and branched form, canals and foramina are adapted to blood-vessels; smooth surfaces, cartilage-covered and of various forms (heads, condyles, trochlear surfaces) enter into the formation of joints. The surfaces of a bone with the exception of cartilage-covered articular surfaces are closely invested with a tough, fibrous vascular **periosteum** intimately connected with the tendons and ligaments which find attachment on the bone. All bones present a superficial layer of **compact osseous substance** which varies in thickness. Within the denser covering there exists a sponge-structure of bony plates and tubes known as **cancellous bone** which is most abundant in the short and irregular forms: in long bones it is limited almost entirely to the enlarged extremities. The cancellous bone contains the **red marrow.** The plates of cancellous bone correspond to the lines of pressure and tension to which most bones are subjected. The shaft of a long bone contains a spacious **medullary cavity** occupied by the fatty marrow; into this space a constant artery (the medullary or nutrient) enters by the so-called **nutrient foramen** of the shaft. The flat bones of the cranial vault have very dense outer and inner tables of compact substance; the intermediate layer of cancellous bone, channeled for large veins, is known as the **diploë.** In certain parts of the skull the spongy substance is replaced by the air-filled **paranasal sinuses.**

Vessels and nerves.—It is a characteristic of the vascular system of the skeleton that the bones are poor in capillary nets but are furnished with an abundance of fine arterioles. Arteries enter the flat bones at various points. Veins run at first with the arteries, then enter separate bony-walled canals. In the long bones, arteries supply (1) the spongy structure of the extremities, by twigs coming from the articular arteries which branch in the periosteum; (2) the compact bone of the shaft, by vessels of the periosteum; (3) the walls of the medullary cavity and the medulla by the **nutrient artery.** The latter divides on entering the medullary cavity into proximal and distal branches which at the extremities anastomose with the articular arteries supplying the red marrow and cancellous bone. The nutrient artery is accompanied

by two **veins**; most of the venous blood of the medulla and spongy bone is returned by large and numerous veins which leave the bone by foramina at the extremities. **Lymph vessels** are abundant in the periosteum and perivascular lymphatics are present in the Haversian canals. Very little is known concerning the **nerves** which accompany the arteries into bone.

Among the **physical properties** of bone of special interest is that of *elasticity*, which declines in old age, the bones becoming brittle and liable to fracture.

The *strength* of bone has been determined in various ways with pressure in the direction of its long axis. The femur broke at 263–400 kg.; the humerus at 174–276 kg., (Messerer.)

In regard to *hardness*, there is not a great deal of variation generally throughout the skeleton; the petrous portion of the temporal bone is exceptionally hard. The *specific gravity* of bone ranges from 1.87 to 1.97.

The *color* of bones in the living is white tinged very slightly with pink and yellow.

Burning a bone in the air reduces its weight one-third and the residue consists of earthy salts chiefly phosphate of lime. The mineral matter may be removed from a bone by treating it with an acid; there remains a tough, elastic substance, retaining the form of the original bone and which on boiling yields gelatine.

Like other systems, the osseous framework is subject to **variation.** The bones are among the last organs to assume their definitive shapes and are directly or indirectly under the environmental influences of all the soft structures. Skeletal variations may or may not represent heritable characters. In the following discussion of the bones, only a few of the more typical and important variations are noted.

The number of bones in the skeleton varies at different ages (see p. 26), some, which are originally quite independent, becoming united as age advances. They are arranged in an **axial set,** which includes the vertebral column, the skull, the ribs, and the sternum, and an **appendicular set,** belonging to the limbs. The following table shows the number of bones usually distinct in middle life, excluding the auditory ossicles:—

		Bones
Axial Skeleton	The vertebral column	26
	The skull	23
	The ribs and sternum	25
Appendicular Skeleton	The upper limbs	64
	The lower limbs	62
	Total	200

Several of the skull-bones are **compound,** i. e., in the immature skeleton they consist of separate elements which ultimately unite to form a single bone. In order to comprehend the nature of such bones it is advantageous to study them in the various stages through which they pass in the process of development in the fetus and the child.

It follows, therefore, that to appreciate the **morphology** of the skeleton the **osteogenesis** or mode of development of the bones must be studied, as well as their topography or position.

Some bones arise by **ossification** in **membrane,** others in **cartilage.** In the embryo, many portions of the skeleton are represented by cartilage which may become infiltrated by lime-salts—**calcification.** This earthy material is taken up and redeposited in a regular manner—**ossification.** Portions of the original cartilage persist at the articular ends of bones, and, in young bones, at the **epiphysial** lines, i. e., the lines of junction of the main part of a bone with the extremities or epiphyses. Long bones increase in length at the **epiphysial cartilages,** and increase in thickness by ossification of the deeper layers of the investing membrane or **periosteum.** These processes—intracartilaginous and intramembranous ossification—proceed concurrently in the limb-bones of a young and growing mammal.

There is no bone in the human skeleton which, though preformed in cartilage, is perfected in this tissue. The ossification is completed in membrane. On the other hand, there are numerous instances in the skull, of bones the ossification of which begins in, and is perfected by, the intramembranous method. Ossification in a few instances commences in membrane, but later invades tracts of cartilage; occasionally the process begins in the **perichondrium** and remains restricted to it, never invading the underlying cartilage, which gradually disappears (vomer and nasal bones are examples). Further details of development and ossification are included in the description of each bone. (For early development, see p. 25.)

The **limb-bones** differ in several important particulars from those of the skull. Some of the long bones have many centers of ossification, but these have not the same significance as those of the skull. It is convenient to group the centers into two sets, **primary** and **secondary.** The **primary** nucleus of a long bone appears quite early in fetal life, and the main part (shaft) thus formed is called the **diaphysis.** In only three instances does a **secondary** center appear before birth, e. g., the lower end of the femur, the head of the tibia, and occasionally the head of the humerus. Many **primary** ossific nuclei appear after birth. When a bone possesses one or more secondary centers, the primary nucleus, as a rule, appears early.

Secondary centers which remain for a time distinct from the main portion of a bone are termed **epiphyses** (fig. 84). An epiphysis may arise from a single nucleus, as is the case at the lower end of the femur, or from several, as at the upper end of the humerus. Prominences about the ends of long bones may be capped by separate epiphyses.

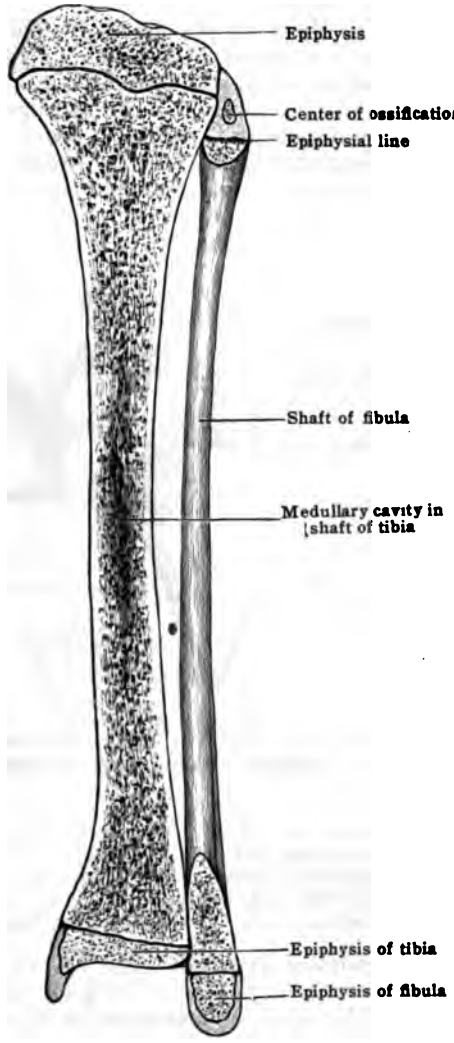
According to Parsons, there are at least three kinds of epiphyses:—(1) Those which appear at the articular ends of long bones, which, since they transmit the weight of the body from bone

to bone, may be termed *pressure* epiphyses. (2) Those which appear as knob-like processes, where important muscles are attached to bones; and as these are concerned with the pull of muscles, they may be described as *traction* epiphyses. (3) The third kind includes those epiphyses which represent parts of the skeleton at one time of functional importance but which, having lost their function, have now become fused with neighboring bones and only appear as separate ossifications in early life. These may be termed *atavistic* epiphyses and include such epiphyses as the tuberosity of the ischium, the representative of the hypoischium of reptiles.

The epiphyses of bones seem to follow certain rules, thus:—

1. Those epiphyses whose centers of ossification appear last are the first to unite with the shaft. There is one exception, however, to this statement, viz., the upper end of the fibula, which is the last to unite with the shaft, although its center appears two years after that for the lower end. This may perhaps be accounted for by the rudimentary nature of the proximal end of the fibula in man and many other mammals.

FIG. 84.—THE TIBIA AND FIBULA IN SECTION TO SHOW THE EPIPHYSES.



2. The epiphysis toward which the nutrient artery is directed is the first to be united with the shaft. It is also found that while the increase in length of the long bones takes place at the epiphysial cartilages, the growth takes place more rapidly and is continued for a longer period at the end where the epiphysis is the last to unite. The shifting of the investing periosteum, which apparently results from these two factors, leads to obliquity of the vascular canal by drawing the proximal portion of the nutrient artery toward the more rapidly growing end. Moreover, when a bone has only one epiphysis, the nutrient artery will be directed toward the extremity which has no epiphysis.

3. The centers of ossification appear earliest in those epiphyses which bear the largest relative proportion to the shafts of the bones to which they belong.

4. When an epiphysis ossifies from more than one center, the various nuclei coalesce before the shaft and epiphysis consolidate, e. g., the upper end of the humerus.

I. THE AXIAL SKELETON

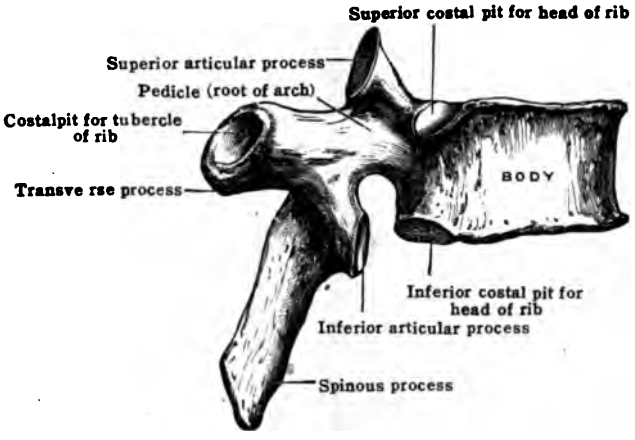
A. THE VERTEBRAL COLUMN

The **vertebral column** [columna vertebralis] (fig. 100) functions as a pillar for the support of the trunk and a case for the protection of the spinal cord and nerve roots. It consists of a series of bones called **vertebræ,** closely connected by means of fibrous and elastic structures, which allow of a small amount of motion between any two adjacent members of the series, but which give to the column as a whole a high degree of flexibility.

Stability of the vertebral column is secured partly through the form of the individual vertebræ and the form of the entire pillar, but also to a large extent by means of muscular control.

In the young subject the vertebræ are thirty-three in number. Of these, the upper twenty-four remain separate throughout life, and are distinguished as **movable** or **true vertebræ.** The succeeding five vertebræ become consolidated in the adult to form one mass, called the **sacrum,** and at the terminal part of the column are four rudimentary vertebræ, which also tend to become united as age advances, to form the **coccyx.** The lower nine vertebræ thus lose their mobility as individual bones, and are accordingly known as the **fixed** or **false**

FIG. 85.—A THORACIC VERTEBRA. (Side View.)



vertebræ. Of the true vertebræ, the first seven are called **cervical** [cervicales], the succeeding twelve **thoracic** [thoracales] or **dorsal,** and the remaining five **lumbar** [lumbales].

Although the vertebræ of the different regions of the column differ markedly in many respects, each vertebra is constructed on a common plan, which is more or less modified in different regions to meet special requirements. The essential characters are well seen in the vertebræ near the middle of the thoracic region, and it will be advantageous to commence the study of the vertebral structures with one selected from this region.

Description of a thoracic vertebra (figs. 85, 86).—The vertebra consists of two essential parts—a body in front and an arch behind.

The **body** [corpus vertebræ] or **centrum** functions in supporting the weight of the trunk. It is a solid disk of bone, somewhat heart-shaped, deeper behind than in front, slightly concave on its superior and inferior surfaces, and wider transversely than anteroposteriorly. The upper and lower surfaces are rough for the intervertebral disks which are interposed between the bodies of the vertebræ, and the margins are slightly lipped. The circumference of the body is concave from above downward in front, convex from side to side, and perforated by numerous vascular foramina. Posteriorly it is concave from side to side and presents one or two large foramina for the exit of veins from the cancellous tissue. On each side of the body, at the place where it joins the arch, are two **costal pits** (superior and inferior) [fovea costalis superior; inferior] placed at the upper and lower borders, and when two vertebræ are superimposed, the adjacent

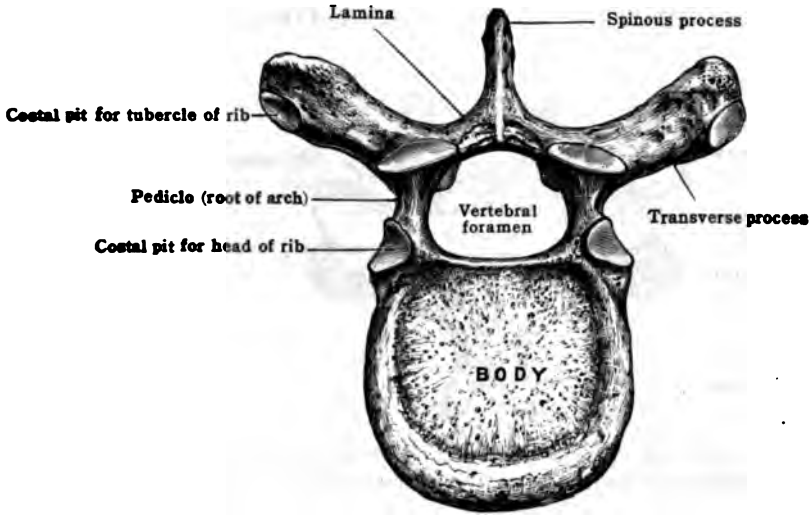
costal pits form a complete articular pit for the head of a rib. The superior and inferior costal pits were formerly designated as 'demifacets.'

The **arch** [arcus vertebræ] serves to protect the spinal cord and the roots of the spinal nerves. It is formed by two pedicles and two laminæ, and supports seven processes—one spinous, two transverse, and four articular. The pedicles or **roots** of the vertebral arch [radices arcus vertebræ] are two short, constricted columns of bone, projecting horizontally backward from the posterior surface of the body. The concavities on the upper and lower borders of each pedicle, of which the lower is much the deeper, are named **vertebral notches** [incisuræ], and when two vertbræ are in position, the notches are converted into **intervertebral foramina** for the transmission of the spinal nerves and blood-vessels. The **laminæ** are two broad plates of bone which connect the spinous process with the roots (pedicles) and complete the arch posteriorly.

The superior border and the lower part of the anterior surface of each lamina are rough for the attachment of the ligamenta flava which bind together the adjacent vertebræ. The upper part of the anterior surface is smooth, where it forms the posterior boundary of the vertebral canal. When articulated, the laminæ in the thoracic region are imbricated or sloped, one pair over the other, somewhat like tiles on a roof.

The **spinous process** [processus spinosus], serves mainly for muscular attachment. It is long and three-sided, projects backward and downward from the

FIG. 86.—A THORACIC VERTEBRA. (From Above.)



center of the arch and terminates in a slight tubercle. It gives attachment by its prominent borders to the interspinous ligaments and by its free extremity to the supraspinous ligament.

The **transverse processes** [processus transversus] are two in number and extend laterally from the arch at the junction of the pedicles and laminæ. They are long, thick, backwardly directed columns of bone terminating in clubbed extremities, on each of which is a costal pit [fovea costalis transversalis] for articulation with the tubercle of a rib. The transverse processes, in addition to supporting the ribs, afford attachment to and powerful leverage for muscles.

The **articular processes,** two superior and two inferior, project upward and downward opposite the attachments of the transverse processes and form joints between successive vertebræ. The superior are flat and bear facets or surfaces [facies articulares superiores] which are directed upward, backward, and laterally, and are situated a little in advance of the inferior, the facets of which [facies articulares inferiores] are oval, concave, and directed downward, forward, and medially.

The **vertebral foramen** is bounded anteriorly by the body, posteriorly and on each side by the arch. It is nearly circular, and is smaller than in the cervical or the lumbar region. When the vertebræ are articulated, the series of rings constitute the **spinal** or **vertebral canal** [canalis vertebralis], in which is lodged the spinal cord and its membranes.

THE CERVICAL VERTEBRÆ

The segment of the vertebral column which forms the axial skeleton of the neck is posessed of a high degree of flexibility, resulting from the peculiar conformation of its constituent vertebræ and from the special characteristics of the articulations between the individual bones. For **muscular attachments,** see figs. 90 and 91; also section on MUSCULATURE.

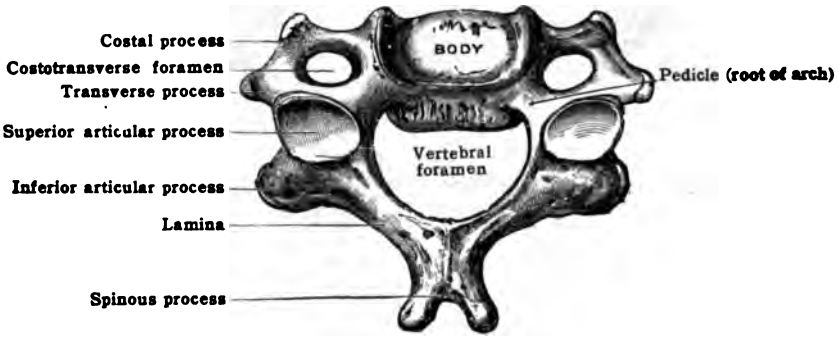
A typical cervical vertebra (from the third to the sixth inclusive) presents the following characteristics (fig. 87):—The **body** is smaller than in other regions of the column and is of oval shape with the long axis transverse.

The lateral margins of the upper surface are raised into prominent lips, so that the surface is concave from side to side; it is also sloped downward in front. The inferior surface, on the contrary, projects downward in front and is rounded off at the sides to receive the corresponding lips of the adjacent vertebra. It is concave antero-posteriorly and convex in an opposite direction. The partial interlocking of the adjacent bodies increases the stability of the intervertebral articulations.

The **roots** (pedicles) are directed laterally and backward and spring from the body about midway between the upper and lower borders. The superior and inferior notches are nearly equal in depth, but the inferior are usually somewhat deeper. The **laminæ** are long, narrow, and slender. The **spinous process** is short and bifid at the free extremity.

Articular processes.—Both the superior and inferior articular processes are situated at the junction of the root with the lamina and they form the upper and

FIG. 87.—A CERVICAL VERTEBRA.



lower extremities of a small column of bone. The articular surfaces are oblique and nearly flat, the superior looking backward and upward, and the inferior forward and downward.

The **transverse process** presents near its base a round **costotransverse foramen** [foramen transversarium] for the transmission of the vertebral artery, vein, and a plexus of sympathetic nerves. Moreover, each process is deeply grooved above for a spinal nerve, and is bifid at its free extremity, terminating in two tubercles—anterior and posterior.

The **costotransverse foramen** is very characteristic of a cervical vertebra. It is bounded medially by the pedicle, posteriorly by the transverse process (which corresponds to the transverse process of a thoracic vertebra), anteriorly by the **costal process** (which corresponds to the rib in the thoracic region), and laterally by the costotransverse lamella. The latter is a bar of bone joining the two processes and directed obliquely upward and forward in the upper vertebræ and horizontally in the lower.

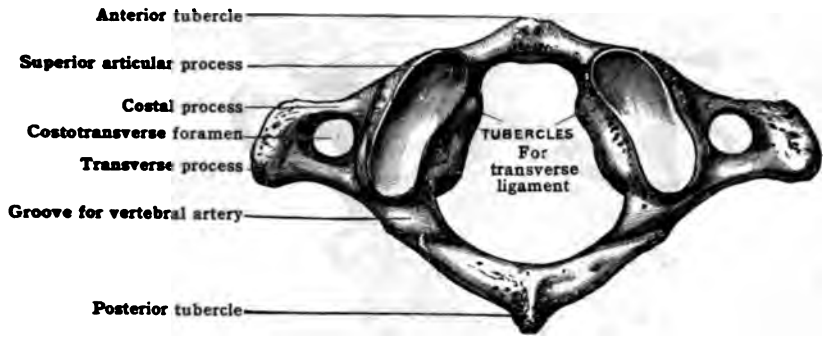
The **vertebral foramen** is triangular with rounded angles; it is larger than in the thoracic or lumbar vertebræ, in adaption to the cervical enlargement of the spinal cord and the greater mobility of the cervical region of the column.

Peculiar cervical vertebræ.—The various cervical vertebræ possess distinguishing features, though, with the exception of the first, second, and seventh, which are so different as to necessitate separate descriptions, these are largely confined to the direction of the costotransverse lamella, and the size and level of the anterior and posterior tubercles. In the third the anterior tubercle is higher than the posterior and the costotransverse lamella is oblique; in the fourth the anterior tubercle is elongated vertically, so that its lower end is nearly on a level with the posterior, though the lamella still remains oblique. In the fifth and sixth they are nearly on the same level, but in the latter the anterior tubercle is markedly developed to form the **carotid tubercle.**

The Atlas or First Cervical Vertebra

The atlas (fig. 88) is remarkable in that it has neither body nor spinous process. It has the form of an irregular ring, and consists of two thick portions, the **lateral masses,** united in front and behind by bony arches. The **anterior arch** joins the lateral masses in front and constitutes about one-fifth of the entire circumference of the ring. On its anterior surface it presents a **tubercle** for the attachment of the *longus colli* muscle and the anterior longitudinal ligament, and its posterior surface a circular facet [fovea dentis] for articulation with the odontoid process [dens] of the epistropheus. The upper and lower borders serve for the attachment of ligaments uniting the atlas to the occipital bone and epistropheus respectively.

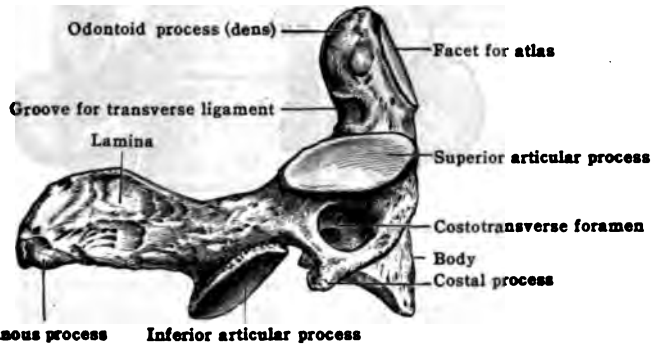
Fig. 88.—The First Cervical Vertebra or Atlas.



The **lateral masses** are thick and strong, supporting the articular processes above and below and extending laterally into the transverse processes. The superior articular surfaces are elongated, deeply concave, and converge in front. Directed upward and medially they receive the condyles of the occipital bone, and occasionally each presents two oval facets united by an isthmus. The inferior articular surfaces are circular and almost flat; they are directed downward and medially and articulate with the epistropheus. The articular processes, like the superior articular processes of the epistropheus, differ from those of other vertebræ in being situated in front of the places of exit of the spinal nerves.

Between the upper and lower articular surfaces on the inside of the ring are two smooth rounded **tubercles,** one on each side, to which the transverse ligament is attached. This liga-

Fig. 89.—The Epistropheus or Axis.



ment divides the interior of the ring into a smaller anterior part for the dens of the epistropheus, and a larger posterior part, corresponding to the foramina of other vertebræ, for the spinal cord and its membranes.

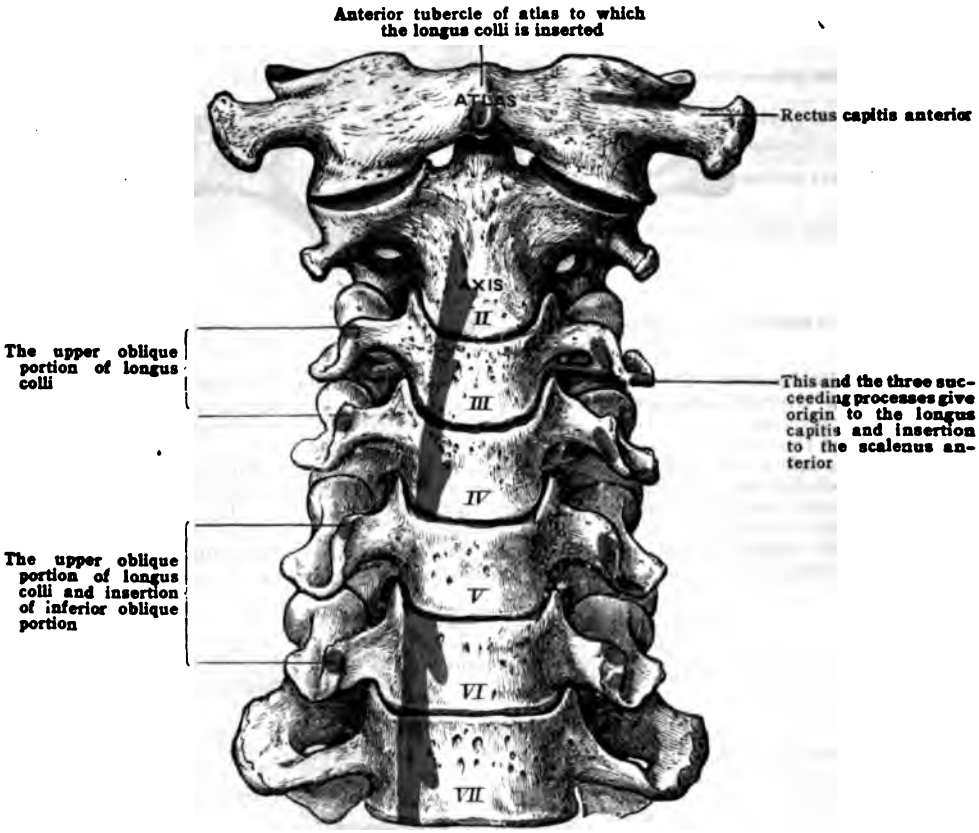
The **transverse processes** are large and extend farther outward than those of the vertebræ immediately below. They are flattened from above downward and each is perforated by a large **costotransverse** foramen; the extremity is not bifid, but, on the contrary, is broad and rough for the attachment of numerous muscles. The **posterior arch** unites the lateral masses behind and forms about two-fifths of the entire circumference. It presents in the middle line a rough elevation or tubercle representing a rudimentary spinous process. At its junction with the lateral mass on the superior surface is a deep **groove,** the **sulcus arteriæ vertebralis,** which lodges the vertebral artery and the suboccipital (first spinal) nerve. The groove corresponds to the superior notches of other vertebræ and occasionally it is converted into a foramen by a bony arch—the ossified oblique ligament of the atlas. A similar but much shallower notch is present on the inferior surface of the posterior arch, and, with a corresponding notch on the

axis, forms an intervertebral foramen for the exit of the second spinal nerve. The upper and lower surfaces of the arch afford attachment to ligaments uniting the atlas to the occipital bone and the axis. For **muscular attachments,** see figs. 90 and 91.

THE EPISTROPHEUS (AXIS)

The **epistropheus** (axis)(fig. 89) is the thickest and strongest of the cervical vertebræ, and is so named from forming a pivot on which the atlas rotates, carrying the head. It is easily recognized by the rounded **dens** (odontoid process) which surmounts the upper surface of the **body.** This process, which represents the displaced body of the atlas, is large, blunt, and tooth-like, and bears on its anterior surface an oval facet for articulation with the anterior arch of the atlas;

FIG. 90.—THE CERVICAL VERTEBRÆ. (Anterior View.)


Anterior tubercle of atlas to which the longus colli is inserted
ATLAS
Rectus capitis anterior
AXIS
II
III
IV
V
VI
VII
The upper oblique portion of longus colli
This and the three succeeding processes give origin to the longus capitis and insertion to the scalenus anterior
The upper oblique portion of longus colli and insertion of inferior oblique portion
Origin of vertical portion of the longus colli; its insertion is into the second, third, and fourth vertebræ

posteriorly it presents a smooth groove which receives the transverse ligament. To the apex a thin narrow fibrous band (the apical dental ligament) is attached, and on each side of the apex is a rough surface for the attachment of the alar ligaments which connect it with the occipital bone. The enlarged part of the process is sometimes termed the **head,** and the constricted basal part the **neck.**

The inferior surface of the body resembles that of the succeeding vertebræ and is concave from front to back and slightly convex from side to side. Its anterior surface is marked by a median ridge separating two lateral depressions for the insertion of the *longus colli.*

The roots (pedicles), are stout and broad; the **laminæ** are thick and prismatic: the **spinous process** is large and strong, deeply concave on its under surface, and markedly bifid; the **transverse processes** are small, not bifurcated and not grooved. The costotransverse foramen is directed very obliquely upward and laterally and the costal process is larger than the transverse.

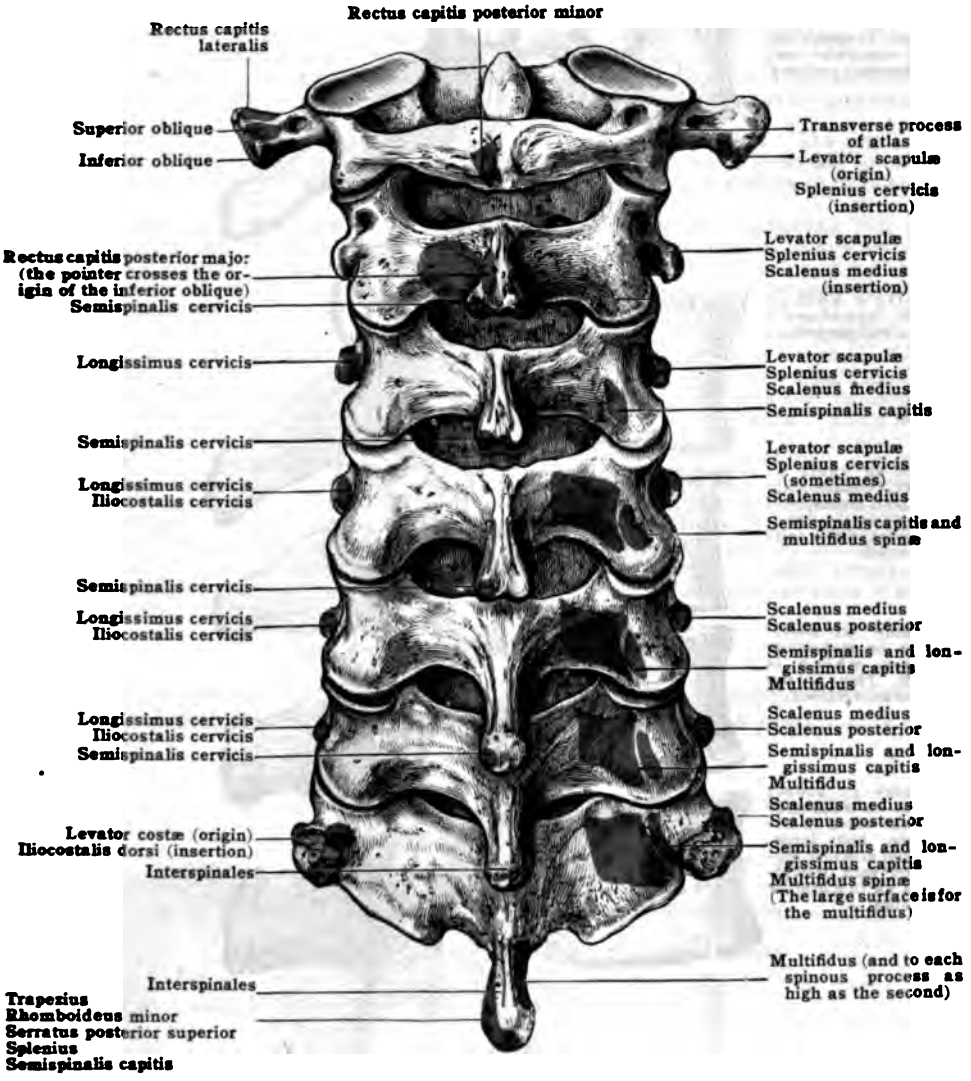
The **superior articular surfaces** are oval, and directed upward and laterally for articulation with the atlas. They are remarkable in being supported partly by the body, and partly by the pedicles, and in being situated in front of the superior notches. The **inferior articular surfaces** are similar in form and position to those of the succeeding vertebræ. For **muscular attachments** see figs. 90 and 91.

The Seventh Cervical Vertebra

Situated at the junction of the cervical and thoracic regions of the vertebral column, the seventh cervical vertebra (figs. 90, 91) may be described as a transitional vertebra—i. e., possessing certain features characteristic of both regions.

The **spinous process** is longer than that of any of the other cervical vertebræ. It is not bifurcated, but ends in a broad tubercle projecting beneath the skin, whence the name **vertebra prominens** has been applied to this bone. The **trans-**

Fig. 91.—The Cervical Vertebræ. (Posterior View.)



verse process is massive; the costal element of the process is very small, but, on the other hand, the posterior or vertebral part of the process is large and becoming more like the transverse process of a thoracic vertebra.

The costotransverse foramen is the smallest of the series and may be absent. It does not, as a rule, transmit the vertebral artery, but frequently gives passage to a vein. Occasionally the costal process is segmented off and constitutes a cervical rib. The body sometimes bears on each side near the lower border a costal pit for the head of the first rib. When this is present, there is usually a well-developed cervical rib. For **muscular attachments,** see figs. 90 and 91.

Variations.—The cervical vertebræ exhibit great variation in regard to the extremities of their spinous processes. As a rule among Europeans, the second, third, fourth, and fifth vertebræ possess bifid spines. The sixth and seventh exhibit a tendency to bifurcate, their tips presenting two small lateral tubercles; sometimes the sixth has a bifid spine, and more

rarely the seventh presents the same condition. Occasionally all the cervical spines, with the exception of the second, are non-bifid, and even in the axis the bifurcation is not extensive. In the lower races of men the cervical spines are relatively shorter and more stunted than in Europeans generally and, as a rule, are simple. The only cervical vertebra which presents a bifid spine in all races is the epistropheus; even this may be non-bifid in the Negro, and occasionally in the European. (Owen, Turner, Cunningham.) The laminæ of the lower cervical vertebræ frequently present posteriorly distinct tubercles from which fasciculi of the *multifidus* muscle

FIG. 92.—PECULIAR THORACIC VERTEBRÆ.

An entire costal pit above a half-pit below. In shape the body resembles that of a cervical vertebra
I
Usually a half-pit above (sometimes it has a half-pit below)
IX
Usually an entire pit above. Occasionally this pit is incomplete. The pit on the transverse process is usually small
X
An entire pit above. None on transverse process, which is small. This is the anticlinal vertebra
XI
An entire pit above; no pit on transverse process which is tripartite; body large. Inferior articular processes turn lateralward as in a lumbar vertebra
XII

arise. They are usually confined to the sixth and seventh vertebræ, but are fairly frequent on the fifth, and are occasionally seen on the fourth.

The occurrence of *cervical ribs* was mentioned above in connection with the seventh cervical vertebra. They occur normally in birds and reptiles. For their clinical significance in man, see p. 1365.

The dens epistrophei may form a separate *os odontoideum*, the apex of which may correspond to a vestigial body of the atlas. In the atlas, ossification of the anterior or posterior arch may be incomplete The groove for the vertebral artery is not rarely converted into a foramen (typical for mammals). Fusion, partial or complete, of the atlas with the occipital frequently occurs.

THE THORACIC VERTEBRÆ

The general characters of the thoracic (or dorsal) vertebræ have already been considered (p. 84). Their most distinguishing features are the pits on

the **transverse processes** and sides of the **bodies** articulating with the **tubercles** and **heads of the ribs** respectively.

Peculiar thoracic vertebræ.—Several vertebræ in this series differ from the typical example. The exceptional ones are—the **first, ninth, tenth, eleventh,** and **twelfth** (fig. 92).

The **first** thoracic vertebra is a transitional vertebra. The **body** in its general conformation approaches very closely the seventh cervical, in that the greatest diameter is transverse, and its upper surface is concave from side to side. On each side is an entire pit, close to the upper border, for the head of the first rib, and a very small pit (inferior costal pit) below for the head of the second rib. The **spinous process** is thick, strong, almost horizontal and usually more prominent than that of the seventh cervical, an important point to remember when counting the spines in the living subject.

The **ninth** has superior costal pits, and usually no inferior; when the inferior pits are present, this vertebra is not exceptional.

The **tenth** usually has an entire costal pit at its upper margin, on each side, but occasionally only a superior costal pit. It has no lower pits and the pits on the transverse processes are usually small.

The **eleventh** has a large body resembling that of a lumbar vertebra. The pits are on the pedicles and they are complete and of large size. The transverse processes are short, show evidence of subdivision into three parts, and have no pits for the tubercles of the eleventh pair of ribs.

In many mammals, the spines of the anterior vertebræ are directed backward, and those of the posterior directed forward, whilst in the center of the column there is usually one spine vertical. The latter is called the *anticlinal vertebra*, and indicates the point at which the thoracic begin to assume the characters of lumbar vertebræ. In man the eleventh thoracic is the anticlinal vertebra.

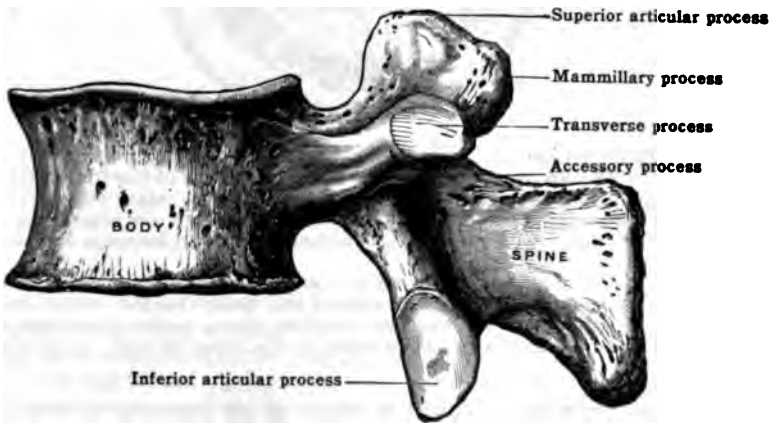
The **twelfth** resembles in general characters the eleventh, but may be distinguished from it by the articular surfaces on the inferior articular processes being convex and turned laterally as in the lumbar vertebræ. The transverse process is rudimentary and tripartite, presenting for examination three tubercles, *superior*, *inferior*, and *lateral*, which correspond respectively to the mammillary, accessory, and transverse processes of a lumbar vertebræ. There is one complete pit on the root (pedicle) for the head of the twelfth rib.

Variations.—The twelfth thoracic, in the absence of the twelfth pair of ribs, commonly conforms to the type of a lumbar vertebra. The transverse process of the tenth occasionally lacks the facet for costal articulation. The lumbar form of transverse process may be present in the eleventh thoracic vertebra. A peculiarity, more frequent in the thoracic and lumbar than in the cervical and sacral regions of the column, is the existence of a half-vertebra (fig. 101). Such specimens have a wedge-shaped half-centrum, to which are attached a lamina, a transverse, superior, and inferior articular, and half a spinous process. As a rule, a half-vertebra is ankylosed to the vertebræ above and below.

THE LUMBAR VERTEBRÆ

The lumbar segment of the vertebral column is massive to support the weight of the head, thorax and upper limbs, yet sufficiently flexible to permit of a con-

FIG. 93.—A LUMBAR VERTEBRA. (Side view.)



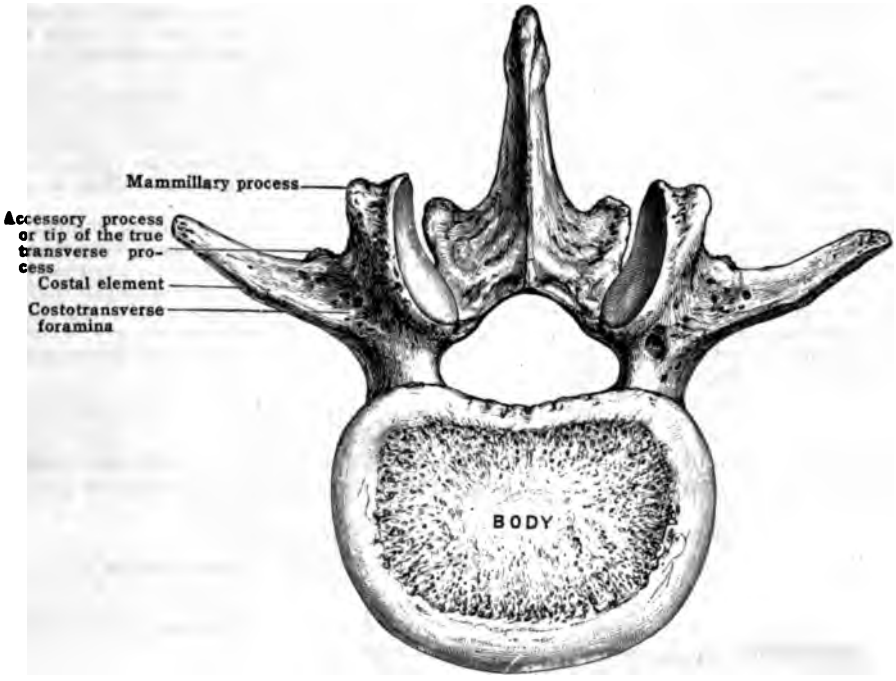
siderable range of movement. The **lumbar vertebræ** (figs. 93, 94) are distinguished from the cervical and thoracic vertebræ by their large size and by the absence of costal articular surfaces.

The **body** is somewhat reniform, with the greatest diameter transverse, flat above and below, and generally slightly deeper in front than behind. The **roots** (pedicles) are strong and directed straight backward, and the lower vertebral

notches are deep and large. The **laminæ** are shorter and thicker than those of the thoracic or cervical vertebræ, and the **vertebral foramen** is triangular, wider than in the thoracic, but smaller than in the cervical region. The vertebral canal of the lumbar region contains the termination of the spinal cord and its membranes, and the cauda equina. The **spinous process,** thick, broad, and somewhat quadrilateral, projects horizontally backward. The **articular processes** are thick and strong. The superior articular surface is concave and directed backward and medially; the inferior is convex and looks forward and laterally. The superior pair are more widely separated than the inferior pair and embrace the inferior articular processes of the vertebra above.

The posterior margin of each superior articular process is surmounted by the **mammillary process** or tubercle (metapophysis) which corresponds to the superior tubercle of the **transverse process** of the last thoracic vertebra. In man the mammillary tubercles are rudimentary, but in some animals they attain large proportions, as in the kangaroo and armadillo. The **transverse processes** are long, slender, somewhat spatula-shaped, compressed from before backward, and directed laterally and a little backward. They are longest in the third vertebra

FIG. 94.—A LUMBAR VERTEBRA.
(Showing the compound nature of the transverse process. Upper view.)



and diminish in the fourth, second, and fifth, in this order, to the first, in which they are shortest of all. Their extremities are in series with the lateral tubercles of the transverse processes of the twelfth thoracic vertebra and also with the ribs. With the latter the so-called transverse processes in the lumbar region are homologous, and hence they are sometimes called the **costal processes**. Occasionally the costal element differentiates and becomes a well-developed lumbar rib.

Behind the base of each transverse or costal process is a small eminence, directed downward, which corresponds with the inferior tubercle of the lower thoracic transverse process, and with the transverse processes of the thoracic vertebræ above, and is named the **accessory process** (anapophysis). It is well developed in some of the lower animals, as in the dog and cat.

The **fifth lumbar vertebra** deviates in some of its features widely from the other members of the series. It is massive, and the **body** is much thicker in front than behind; it forms with the sacrum the *sacrovertebral angle*. The **transverse processes** are short, thick, conical, and spring from the body as well as from the roots of the arch. They afford the attachment to the iliolumbar ligaments. The **spinous process** is smaller than that of any of the other lumbar vertebræ; the **laminæ** project into the vertebral foramen on each side; and the **roots** are stout and flattened from above downward. The **inferior articular**

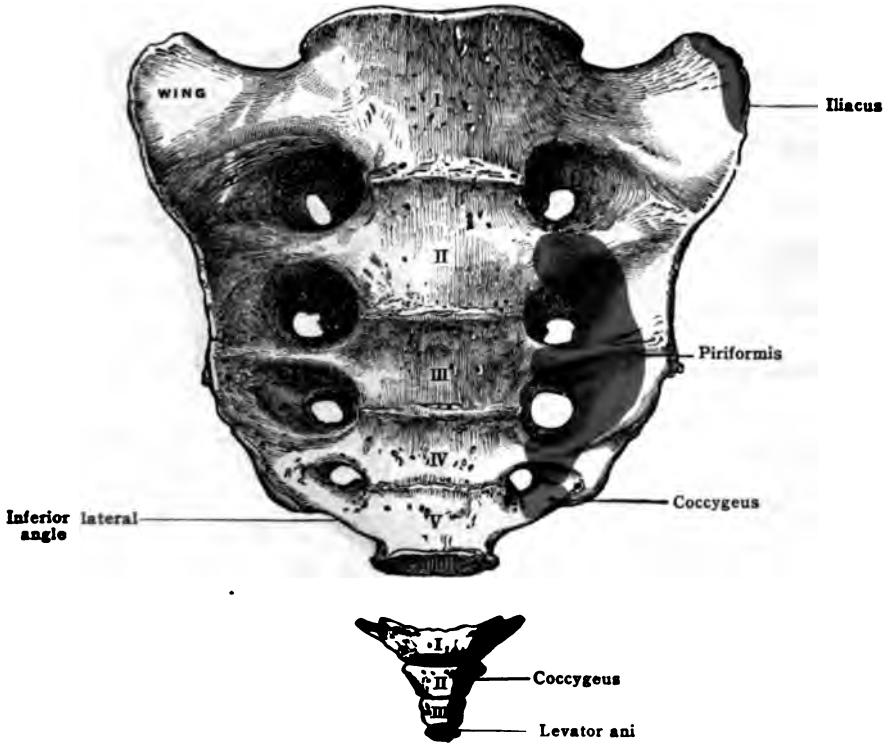
processes are separated to such a degree as to be wider apart than the superior, and they articulate with the first sacral vertebra.

Variations.—The roots of the arch in this vertebra are liable to a remarkable deviation from the conditions found in other parts of the spine. The peculiarity consists of a complete solution in the continuity of the arch immediately behind the superior articular processes. In such specimens the anterior part consists of the body carrying the roots, transverse and superior articular processes; while the posterior segment is composed of the laminæ, spine, and inferior articular processes. The posterior segment of the ring of this vertebra may even consist of two pieces. There is reason to believe that this abnormality of the fifth lumbar vertebra occurs in five per cent. of all subjects examined. Sir William Turner found seven examples among thirty skeletons examined. The skeletons in which this occured were;—a Malay, an Andamanese, a Chinese, two Bushmen, an Eskimo, and a Negro. A similar condition is occasionally met with either unilaterally or bilaterally in the thoracic vertebræ. The fifth lumbar may show a tendency to conform to the type of upper sacral vertebræ, with which it may even become fused.

THE SACRUM

The five sacral vertebræ (figs. 95, 96) are united in the adult to form the **os sacrum,** a large, curved, triangular bone, forming the base of the vertebral column and lying between and firmly connected with the hip bones. Together with the coccyx, it completes the posterior boundary of the minor pelvis. Of

FIG. 95.—THE SACRUM AND COCCYX. (Anterior view.)



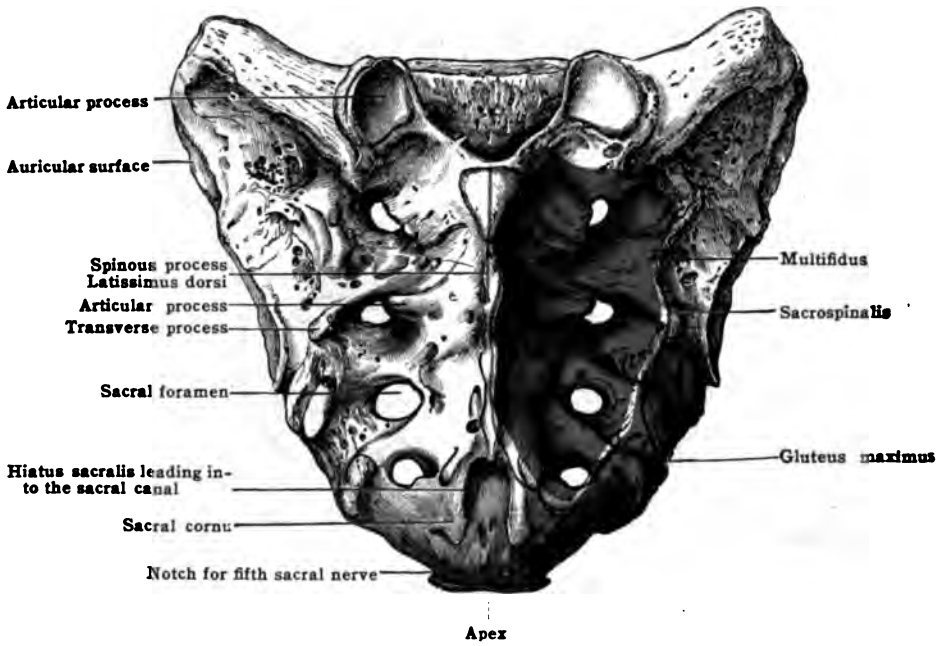
the five vertebræ which compose the sacrum the uppermost is the largest, the succeeding ones become rapidly smaller, and the fifth is quite rudimentary. In the erect posture the sacrum lies obliquely, being directed from above downward and backward, and forms with the last lumbar vertebra an anterior projection known as the sacrovertebral angle or **promontory**.

Surfaces.—The **pelvic surface,** [facies pelvina] directed downward and forward, is smooth, concave from above downward and slightly from side to side. It is crossed in the middle by four transverse ridges [lineæ transversæ] which mark the positions of the intervertebral disks and separate the bodies of the five sacral vertebræ. Of the bodies, the first and second are nearly equal in size and are larger than the third, fourth, and fifth, which, in vertical depth, are also nearly equal to each other. At the extremities of the transverse ridges on each side

are four openings, called the **anterior sacral foramina,** which transmit the anterior divisions of the first four sacral nerves; they are also traversed by branches of the lateral sacral arteries. The foramina are separated by wide processes, representing the costal processes of the vertebræ, which unite laterally to form the **lateral portion** (or mass) [pars lateralis]. The latter presents grooves occupied by the sacral nerves, and is rough opposite the second, third, and fourth sacral vertebræ, where the *piriformis* muscle takes origin. The lateral part of the fifth sacral vertebra gives insertion to the *coccygeus.*

The **dorsal surface** [facies dorsalis] is strongly convex and rough giving origin to the powerful sacrospinalis muscle. The midline is occupied by four eminences representing the somewhat suppressed **spinous processes.** Of these the first is the largest, the second and third may be confluent, and the fourth is often absent. The processes are united to form an irregular ridge or crest [crista sacralis media]. The bone on each side of the spines is slightly hollowed and is formed by the united **laminæ.** In the fourth sometimes, but always in the fifth, the laminæ fail to meet in the middle line, leaving a gap, the **hiatus sacralis,** at the termination of the spinal canal, the lateral margins of which are prolonged downward as the **sacral cornua.**

FIG. 96.—THE SACRUM. (Posterior View.)



The cornua represent the lower articular processes of the fifth sacral vertebra and give attachment to the posterior sacrococcygeal ligaments. Lateral to the laminæ is a second series of small eminences which represent the **articular** and **mammillary processes** of the vertebræ above. The first pair are large for the last lumbar vertebra, the second and third are small, and the fourth and fifth are inconspicuous. Together they form a pair of irregular ridges [cristæ sacrales articulares].

Immediately lateral to the articular processes are the **posterior sacral foramina,** four on each side; they are smaller than the anterior, and give exit to the posterior primary divisions of the first four sacral nerves. Lateral to the foramina on each side are five elevations representing the **transverse processes.** The first pair, situated at the junction of the posterior surface with the base, are large and conspicuous; all serve for the attachment of ligaments and muscles.

Together they form on each side of the sacrum an irregular ridge, **crista sacralis lateralis.** The space between the spinous and transverse processes presents a shallow concavity known as the **sacral groove,** continuous above with the vertebral groove of the upper part of the column, and, like it, lodging the *multifidus* muscle. Bridging across the groove and attached to the sacral spines medially, and to the lower and back part of the sacrum laterally, is the **flat tendon** of origin of the *sacrospinalis* (*erector spinæ*). The *gluteus maximus* takes origin from the back of the lower two pieces of the sacrum.

The base [basis ossis sacri] or upper surface of the sacrum (fig. 98) bears considerable resemblance to the upper surface of the fifth lumbar vertebra. It presents in the middle the body, of a reniform shape, posterior to which is the upper end of the sacral canal bounded by two laminæ. On each side of the canal are two articular processes bearing well-marked mammillary tubercles. The conjoined transverse and costal processes form on each side a broad surface, the wing or **ala** of the sacrum, continuous with the iliac fossa of the hip-bone, and giving attachment to a few fibers of the iliacus.

The lateral margins (fig. 97).—It has already been noted that the lateral portion of the sacrum is the part lateral to the foramina. It is broad and thick above, where it forms the ala, but narrowed below. The lateral aspect of the upper part presents in front a broad irregular surface, covered in the recent state with fibrocartilage, which articulates with the ilium and is known as the **auricular**

FIG. 97.—LEFT LATERAL VIEW OF SACRUM AND COCCYX.

surface [facies auricularis]. The position is somewhat variable, but in most instances corresponds to the sides of the first, second and third sacral bones. The general direction of the auricular surface approaches an anteroposterior plane. It is bounded posteriorly by some rough depressions for the attachment of the posterior sacroiliac ligaments.

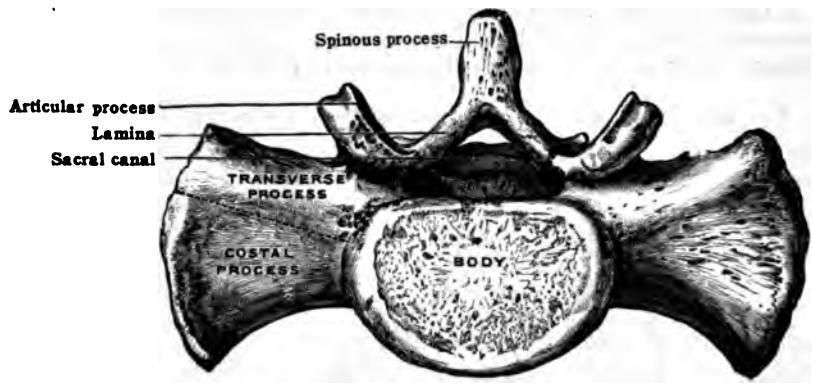
Below the auricular surface, the lateral margin is rough for the sacrotuberous and sacrospinous (greater and lesser sacrosciatic) ligaments, and terminates in the projection known as the **inferior lateral angle.** Immediately below the angle is a notch, converted into a foramen by the transverse process of the first coccygeal vertebra, and a ligament connecting this with the inferior lateral angle of the sacrum. Through this foramen passes the anterior branch of the fifth sacral nerve.

The apex [apex ossis sacri] is directed downward and forward and is formed by the inferior aspect of the body of the fifth sacral vertebra. It is transversely oval and articulates by means of an intervertebral disk with the coccyx. In advanced life the apex of the sacrum becomes united to the coccyx by bone.

The **sacral canal** is the continuation of the spinal canal through the sacrum. Like the bone, it is curved, triangular in section at the base and flattened toward the apex. It terminates at the hiatus sacralis between the sacral cornua, where the laminæ of the fourth and fifth sacral vertebræ are incomplete. The canal opens on the surface by the anterior and posterior sacral foramina and lodges the lower branches of the cauda equina, the filum terminale, and the lower portion of the dura and arachnoid. The subdural and subarachnoid spaces extend downward within the canal as far as the body of the second sacral vertebra.

Differences in the two sexes.—The sacrum of the female is usually broader in proportion to its length, much less curved, and directed more obliquely backward than that of the male. The curvature of the female sacrum belongs chiefly to the lower part of the bone, whereas in the

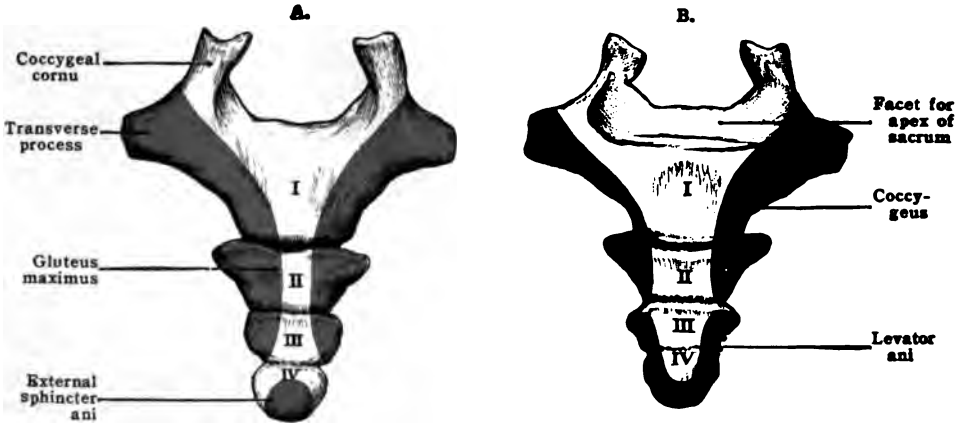
FIG. 98.—BASE OF SACRUM.



male it is equally distributed over its whole length; but the curvature is subject to considerable variation in different skeletons.

Racial differences.—The human sacrum is characterized by its great breadth in comparison with its length, though in the lower races it is relatively longer than in the higher. The proportion is expressed by the *sacral index* $= \frac{\text{breadth} \times 100}{\text{length}}$. The average sacral index in the British male is 112, in the female 116. Sacra in which the index is above 100 are *platyhieric*, as in Europeans; those under 100 are *dolichohieric*, as in most of the black races (Sir W. Turner).

FIG. 99.—THE COCCYX. A. Posterior view; B. Anterior view.



THE COCCYGEAL VERTEBRÆ

The four coccygeal vertebræ are united in the adult to form the **coccyx** [os coccygis] (fig. 99). While four is the usual number of these rudimentary vertebræ, occasionally there are five, and rarely three. In middle life the first piece is usually separate, and the original division of the remaining portion of the coccyx into three parts is indicated by transverse grooves. In advanced life the pieces of the coccyx, having previously united to form one bone, may also become joined to the sacrum.

The **first** piece of the coccyx is much broader than the others. It consists of a body, transverse processes, and rudiments of a neural arch. The body presents on its upper surface an oval facet for articulation with the apex of the sacrum. On each side of the body a **transverse**

process projects laterally and is joined either by ligament or bone to the inferior lateral angle of the sacrum, forming a foramen for the anterior division of the fifth sacral nerve. From the posterior surface of the body two long **coccygeal cornua** project upward and are connected to the sacral cornua by the posterior sacrococcygeal ligaments, enclosing on each side an aperture —the last intervertebral foramen—for the exit of the fifth sacral nerve. The coccygeal cornua represent the roots and superior articular processes of the first coccygeal vertebra. The **second** piece of the coccyx is much smaller than the first, and consists of a body, traces of transverse processes, and a neural arch, in the form of slight tubercles at the sides and on the posterior aspect of the body. The **third** and **fourth** pieces of the coccyx, smaller than the second piece, are mere nodules of bone, corresponding solely to vertebral bodies.

The **anterior surface** of the coccyx gives attachment to the anterior sacrococcygeal ligament and near the tip to the *levator ani;* it is in relation with the posterior surface of the rectum. The **posterior surface** of the coccyx is convex, and the upper three pieces afford attachment to the *gluteus maximus* on each side, and the last piece to the coccygeal portion of the *sphincter ani externus*. The **lateral margins** are thin, and receive parts of the sacrosciatic ligaments, of the *coccygei* muscles, and of the *levatores ani*.

Variations of the sacrum and coccyx.—The number of sacral vertebræ may be increased to six, resulting from the fusion of the first coccygeal or, less often, of the last lumbar. The number may be reduced to four. The junction between the lumbar and sacral parts of the column is occasionally made by an element presenting the characteristics of a lumbar vertebra on one side and of a sacral on the opposite. The auricular surface may extend beyond the general level of the base of the sacrum or be displaced downward to reach the fourth sacral vertebra. The sacral canal may be open posteriorly to a greater degree than is normally the case. Coalescence of the coccyx and sacrum takes place less often and later in life in the female than in the male.

THE VERTEBRAL COLUMN AS A WHOLE

The vertebral column (fig. 100) is the central axis of the skeleton and is situated in the median line at the posterior aspect of the trunk. Superiorly it supports the skull; laterally it gives attachment to the ribs, through which (in part) it receives the weight of the upper limbs, and inferiorly it is supported by the hip-bones, by which the weight of the trunk is transmitted to the lower limbs. Its length varies in different skeletons, but on an average it measures about 70 cm. (28 in.) in the male and about 2.5 cm. (1 in.) less in the female. To the entire length the cervical region contributes about one-sixth, the thoracic about one-third, the lumbar about one-fourth, and the sacrococcygeal portion the remaining about one-sixth. About one-fourth of the length of the presacral spine is made up of intervertebral disks.

Curvatures.—The vertebral column presents a series of curvatures, four when viewed in profile and one when viewed from the front or back. The former are directed alternately forward and backward, and are named, from the regions of the column in which they occur, **cervical, thoracic, lumbar,** and **sacral**. The fifth curve is **lateral,** being in most cases directed toward the right side. The cervical, thoracic and lumbar curvatures pass imperceptibly into one another, but at the junction of the last lumbar vertebra with the sacrum a well-marked angle occurs, known as the **sacrovertebral** or **lumbosacral** angle, with the result that the promontory of the sacrum overhangs the cavity of the minor pelvis and forms a portion of its superior aperture.

The thoracic and sacral curves have their concavities directed forward and are developed during intrauterine life (fig. 25). They are in obvious relation to two great cavities of the trunk, thoracic and pelvic, and may be regarded as **primary** or **accommodation** curves, for the thoracic and pelvic viscera. The thoracic curve extends from the second to the twelfth thoracic vertebra and the sacral curve coincides with the sacrum and coccyx.

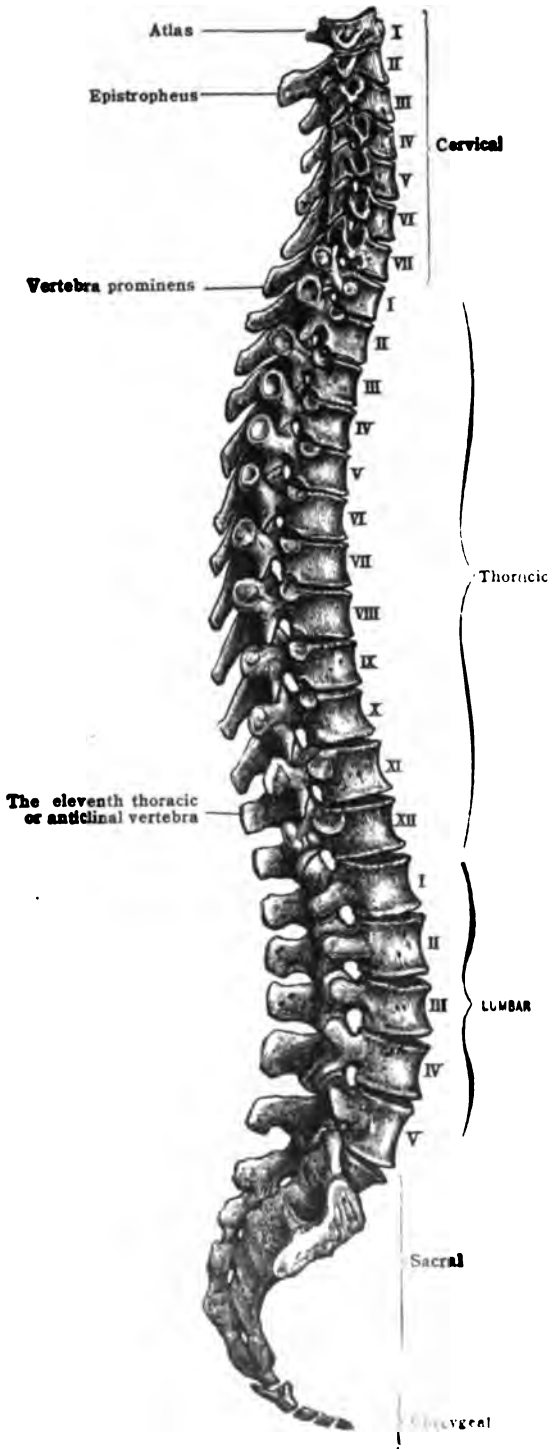
The cervical and lumbar curves have their convexities directed forward, and are developed during the first year after birth (see p. 27). They are essentially curves of **compensation,** necessary for the maintenance of the upright posture, and are brought about mainly by modifications in the shape of the intervertebral disks. The cervical curve is formed about the third month, or at the time when the infant can sit upright. The great peculiarity of the curve is that it is never consolidated, being present when the body is placed in the erect position and obliterated by bending the head down upon the chest. The lumbar curve is developed about the end of the first year or when the child begins to walk, but is not consolidated until adult life. (Symington.) The cervical curve extends from the atlas to the second thoracic vertebra, and the lumbar curve from the twelfth thoracic to the promontory of the sacrum.

The lateral curve is situated in the upper thoracic region, usually presenting the convexity to the right, is probably associated with the greater use made of the right hand. This curve, however, is particularly liable to modification in different occupations and in different races. The *aortic impression* normally present consists of a variable flattening of the left side of the thoracic vertebræ in the middle of the series.

Viewed from the front, the vertebral column presents a series of **pyramids** due to the successive increase and decrease in size of the bodies. These become broader from the axis to the first thoracic vertebra and then decrease to the fourth thoracic. The first pyramid therefore includes all the cervical vertebræ except the atlas, and has the apex directed upward and its base downward, whilst the second is inverted and formed by the first four thoracic vertebræ. The third pyramid, much the longest, is the result of the increase in size from the fourth thoracic to the fifth lumbar vertebra, and the fourth, which is inverted, is produced by the rapid contraction of the sacral and coccygeal vertebræ.

Viewed from behind, the spinous processes project in the midline, and the transverse processes as two lateral rows. Of the spines, those of the epistropheus, seventh cervical, first thoracic, and the lumbar vertebræ appear most prominent. On each side is the **vertebral groove,** the floor of which is formed in the cervical and lumbar regions by the laminæ and articu-

FIG. 100.—VERTEBRAL COLUMN. (Lateral view.)



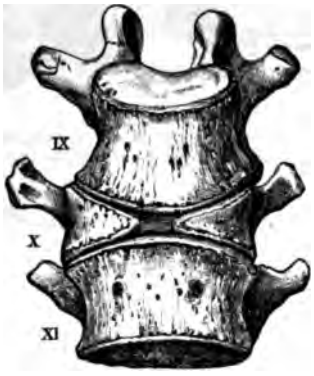
lar processes, and in the thoracic region, by the laminæ and transverse processes. The transverse processes project laterally for a considerable distance in the atlas, first thoracic, and the middle of the lumbar series; they are shortest in the third cervical and the twelfth thoracic.

In the lateral view, the intervertebral foramina appear oval in shape, and are small in the cervical, larger in the thoracic, and largest in the lumbar region.

Numerical variation.—Addition to the total number of vertebræ by intercalation of an element probably does not occur. Addition to a group is rather frequently observed and has been accounted for by reduction in number of the elements in an adjacent group, the total number of vertebræ in the column remaining unaltered. In this fluctuation, the vertebra added is intermediate in form between the types of the two groups concerned.

Structure of a vertebra.—The bodies of the vertebræ are largely composed of cancellous tissue, with a thin outer covering of compact tissue. In a vertical section through the centrum the fibers of the cancellous tissue are seen to be arranged vertically and horizontally, the vertical

FIG. 101.—A DIVIDED THORACIC VERTEBRA. (After Turner.)



fibers being curved with their concavities directed toward the center of the bone (fig. 102). The horizontal fibers are slightly curved parallel with the upper and lower surfaces, and have their convexities toward the center of the bone. They are not so well defined as the vertical set. (Wagstaffe.)

Ossification.—The vertebræ in general.—The ossification of each vertebra (see p. 27) takes place in cartilage from three primary and five secondary centers. The three primary centers appear, one in the body and two in the arch, about the seventh week of intrauterine life. In the thoracic region the nucleus for the body appears first, but in the cervical region it is preceded by the centers for the arch. The nucleus for the body soon becomes bilobed, and this condition is sometimes so pronounced as to give rise to the appearance of two distinct nuclei. Indeed, the nucleus is very rarely double and the two parts of the body may remain separate throughout life (fig. 101). The bilateral character of the nucleus is further emphasized by the occasional formation of half-vertebræ. The lateral centers are deposited near the bases of the superior articular processes and give rise to the roots, laminæ, articular, and the greater parts of the transverse and spinous processes.

FIG. 102.—A VERTEBRAL CENTRUM IN SECTION TO SHOW THE PRESSURE CURVES.

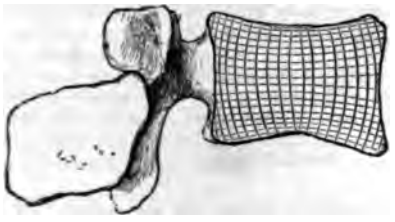
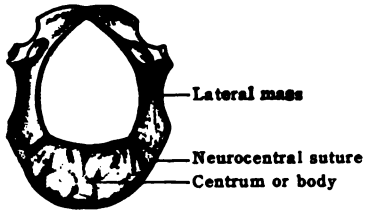


FIG. 103.—A VERTEBRA AT BIRTH.

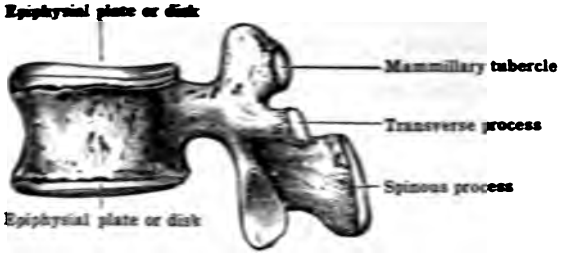


At birth a typical vertebra (fig. 103) consists of three osseous pieces—a body and two lateral masses, which constitute the arch, the parts being joined together by hyaline cartilage. The line of union of the lateral portion with the body is known as the *neurocentral suture*, and is not actually obliterated for several years after birth. In the thoracic region the central ossification does not pass beyond the point with which the head of the rib articulates, and leaves a portion of the body on each side formed from the lateral ossification. A thoracic vertebra at the fifth year shows that the pits for the heads of the ribs are situated behind the neurocentral suture, which is directed obliquely backward and medially. The laminæ unite during the first year after birth; and by the gradual extension of ossification into the various processes, the vertebræ have attained almost their full size by the time of puberty. Subsequently the secondary centers appear in the cartilaginous extremities of the spinous and transverse processes (fig. 104), and in the cartilage on the upper and lower surfaces of the bodies, forming in each vertebra two annular plates, thickest at the circumference and gradually thinning toward the central deficiency (figs. 104, 105). The epiphyses appear from the fifteenth to the twentieth year and join with the vertebra by the twenty-fifth year.

In several vertebræ the mode of ossification differs from the account given above—in some cases considerably—and necessitates separate consideration.

Atlas (fig. 104).—The lateral portions and posterior arch are formed from two centers of ossification, which correspond to the lateral centers of other vertebræ and appear about the seventh week. The anterior arch is ossified from one center, which, however, does not appear until a few months after birth. Union of the lateral parts occurs posteriorly in the third year,

FIG. 104.—LUMBAR VERTEBRA AT THE EIGHTEENTH YEAR WITH SECONDARY CENTERS.

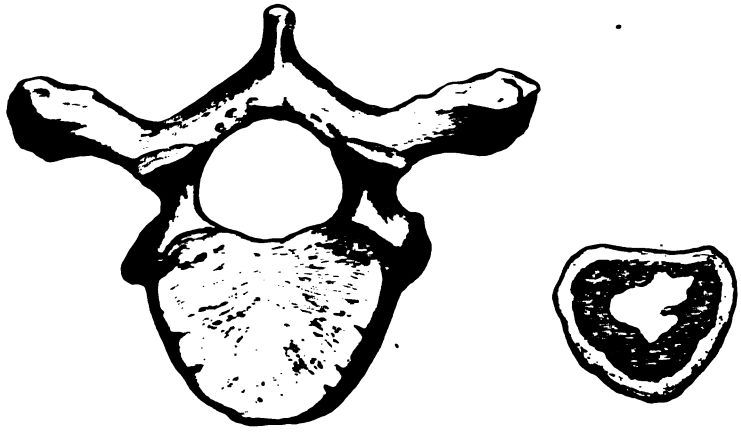


being sometimes preceded by the appearance of a secondary center of ossification in the intervening cartilage and the union of the lateral parts with the anterior arch occurs about the seventh year.

Epistropheus (figs. 105–107).—The arch, and the processes associated with it, are formed from two lateral centers which appear, like those in the other vertebræ, about the seventh

FIG. 105.—UPPER THORACIC VERTEBRA WITH AN EPIPHYSIAL PLATE REMOVED AND DRAWN AT THE SIDE.

The plate shows the characteristic deficiency in the center. ×1.



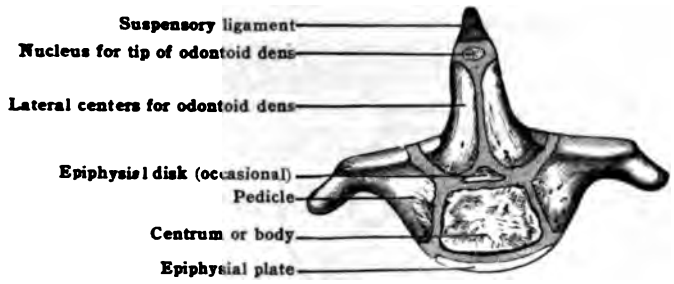
week. The common piece of cartilage which precedes the body and dens is ossified from four or five centers, one (or two) for the body of the epistropheus, in the fourth month, two, sometimes three, for the dens, a few weeks later, and one, for the apex of the dens, in the second year. The two collateral centers for the main part of the dens soon coalesce, so that at birth the epistropheus consists of four osseous pieces—two lateral portions which constitute the arch, the body, and the dens, surmounted by a piece of cartilage. During the third or

FIG. 106.—IMMATURE ATLAS. (Third Year.)

fourth year the dens joins with the body, the line of union being indicated even in advanced life by a small disk of cartilage, and the arch unites in front and behind about the same time or a little later. The apical nucleus of the dens, which represents an epiphysis, joins the main part about the twelfth year and in the seventeenth year an epiphysial plate appears for the lower surface of the body. There are also rudiments, adjoining the cartilaginous disk, of the upper plate of the body.

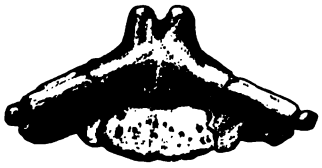
Cervical vertebræ (fig. 110).—In the cervical vertebræ the lateral centers form a larger share of the body than in the vertebræ of other regions, and the neurocentral suture runs almost in a sagittal direction. The sixth, seventh, and even the fifth have additional centers which ap-

FIG. 107.—DEVELOPMENT OF THE EPISTROPHEUS (AXIS).



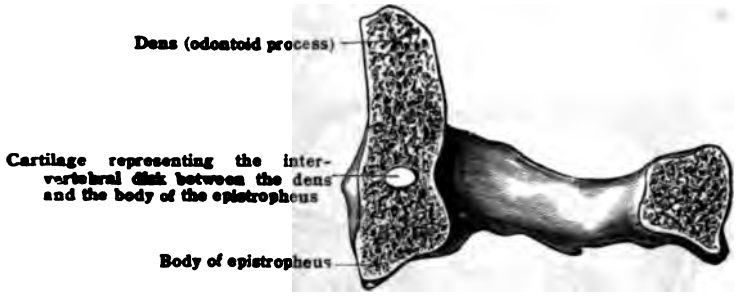
pear before birth for the anterior or costal divisions of the transverse processes. In the other cervical vertebræ the costal processes are ossified by extension of the lateral nuclei. The costal processes of the seventh cervical sometimes remain separate, constituting cervical ribs.

FIG. 108.—THE EPISTROPHEUS AT FOUR YEARS OF AGE, SHOWING THE SIZE AND EXTENT OF THE DENS. (Natural size.)



Lumbar vertebræ (fig. 111).—In the lumbar vertebræ the neurocentral suture is almost transverse, and to the usual number of centers of ossification, two other epiphyses for the mammillary tubercles are added, the centers appearing about puberty. The transverse process of the first lumbar vertebra is occasionally developed from an independent center.

FIG. 109.—THE EPISTROPHEUS (FROM AN ADULT) IN SAGITTAL SECTION.


Dens (odontoid process)
Cartilage representing the intervertebral disk between the dens and the body of the epistropheus
Body of epistropheus

The fifth lumbar exhibits in some cases a special mode of ossification in the arch. Instead of two centers, there are four—one on each side for the root, transverse process, and supe-

FIG. 110.—AN IMMATURE CERVICAL VERTEBRA.

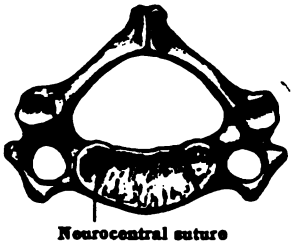
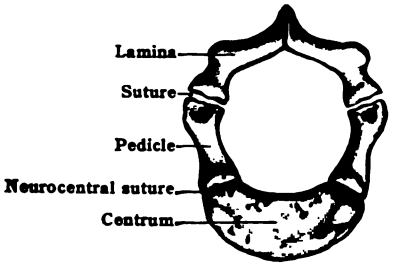


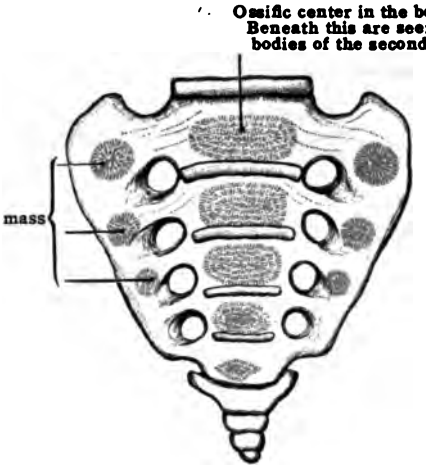
FIG. 111.—OSSIFICATION OF THE FIFTH LUMBAR VERTEBRA.



rior articular process, and another on each side for the lamina, inferior articular process, and the lateral half of the spinous process (fig. 111). There may be failure of union of roots with the laminæ or of the laminæ with one another.

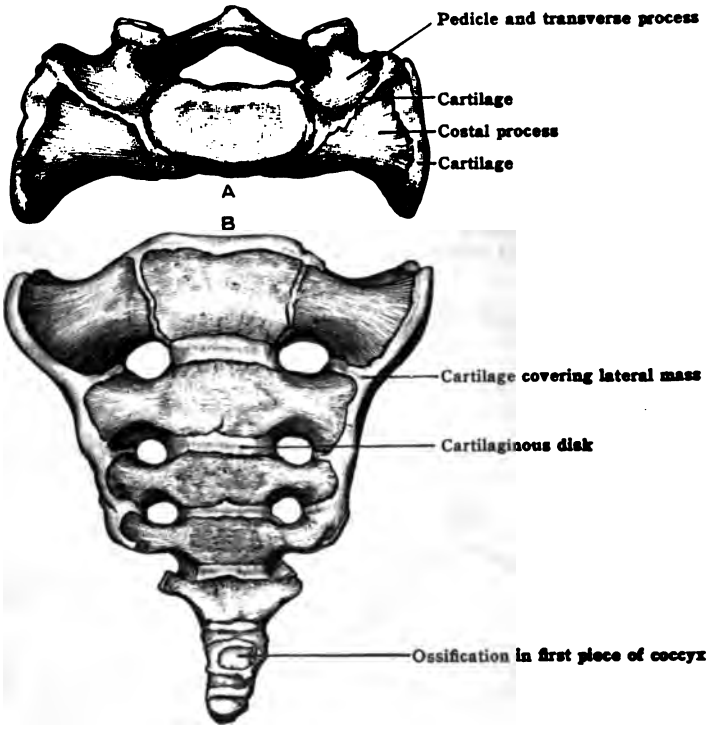
Sacral vertebræ (figs. 112–114).—The sacrum ossifies from thirty-five centers, which may be classified as follows:—In each of the five vertebræ there are three primary nuclei—one for the body and two for the arch; in each of the first three the costal element of the lateral mass on each side is formed from a separate nucleus; associated with each body are two epiphysial plates; and on each lateral margin are two irregular epiphyses, one for the auricular surface and another

FIG. 112.—SACRUM AT BIRTH TO SHOW CENTERS OF OSSIFICATION. (Enlarged one-third.)


Ossific center in the body of first sacral vertebra. Beneath this are seen in succession the centers in the bodies of the second, third, fourth, and fifth vertebræ
Ossific centers in the lateral mass

for the rough edge below. The centers for the bodies appear about the eighth or ninth week and for the vertebral arches from the third to the fifth month. The arches join the bodies at different times in the different vertebræ, ranging from the second year below, to the fifth or sixth year above, and union of the laminæ takes place behind some years later, from about the ninth to the fifteenth year.

FIG. 113.—THE SACRUM AT FOUR YEARS OF AGE (B). THE FIGURE AT THE TOP (A) SHOWS THE BASE DRAWN FROM ABOVE. ($\times\frac{3}{4}$.)



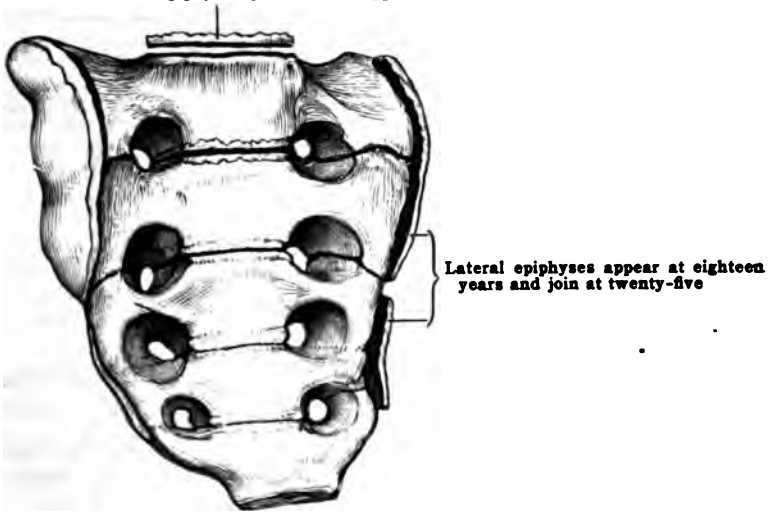
The centers for the costal elements appear outside the anterior sacral foramina, from the fifth to the seventh month, and these unite with the bodies somewhat later than the arches.

The centers for the epiphysial plates appear about the fifteenth year, and for the auricular epiphyses and the edges below, from the eighteenth to the twentieth year.

Consolidation begins soon after puberty by fusion of the costal processes, and this is followed by ossification from below upward in the intervertebral disks, resulting in the union of the adjacent bodies and the epiphysial plates, the ossific union of the first and second being completed by the twenty-fifth year or a little later. The marginal epiphyses are also united to the sacrum by the twenty-fifth year. Even in advanced life intervertebral disks persist in the more central parts of the bone and can be well seen in sections.

Coccygeal vertebræ.—The coccygeal vertebræ are cartilaginous at birth and each is usually ossified from a single center, though there may be two for the first piece. Ossification begins soon after birth in the first segment, and in the second from the fifth to the tenth year. The centers for the third and fourth segments appear just before, and after, puberty respectively. As age advances the various pieces become united with each other, the three lower uniting before middle life and the upper somewhat later. In advanced life the coccyx may join with the sacrum, the union occurring earlier and more frequently in the male than in the female.

FIG. 114.—SACRUM AT ABOUT TWENTY-TWO YEARS. (×⅜.)


Epiphysial plate on the upper surface of body of first sacral vertebra
Lateral epiphyses appear at eighteen years and join at twenty-five

The Serial Morphology of the Vertebræ

Although at first sight many of the vertebræ exhibit peculiarities, nevertheless a study of the mode by which they develop, and their variations, indicates the serial homology of the constituent parts of the vertebræ in each region of the column.

The body (centrum) of the vertebra is that part which immediately surrounds the notochord. This part is present in all the vertebræ of man, but the centrum of the atlas is dissociated from its arch, and ankylosed (as the dens) to the body of the epistropheus.

The *arches* and *spinous processes* are easily recognized throughout the various parts of the column in which complete vertebræ are present. The *articular processes* or *zygapophyses* are of no morphological interest.

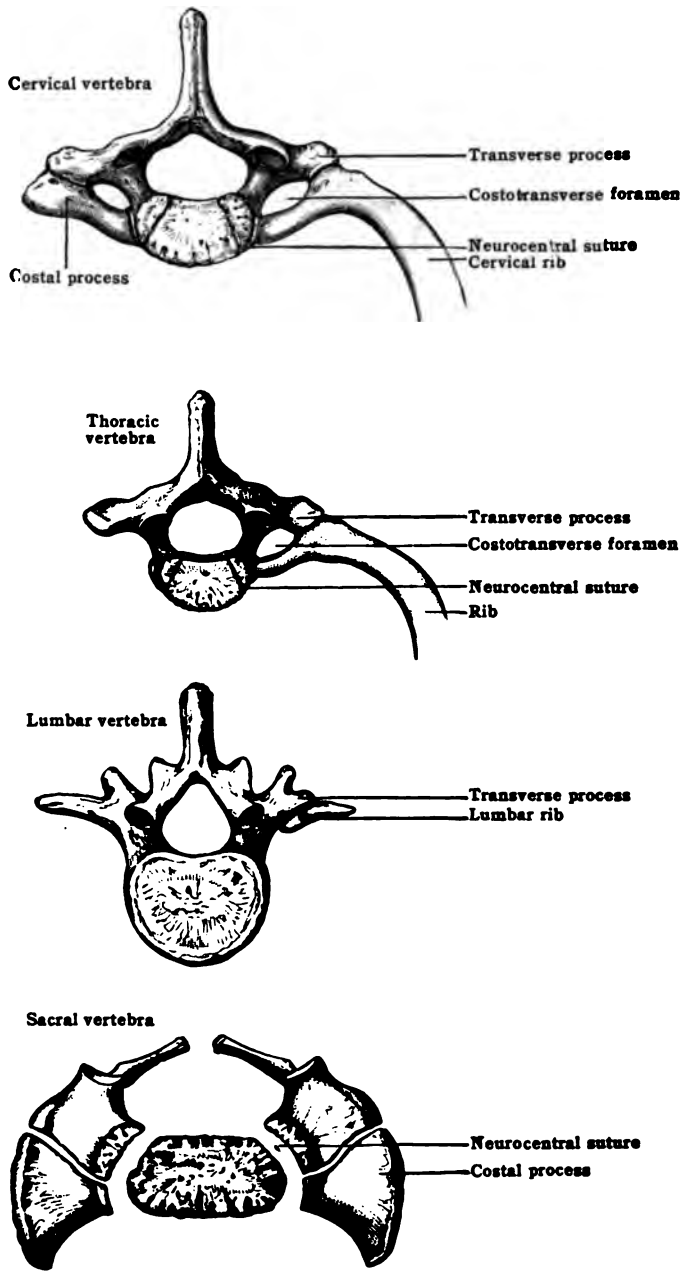
The *transverse processes* (fig. 115) offer more difficulty. They occur in the simplest form in the thoracic series. Here they articulate with the tubercles of the ribs, whence the term *tubercular processes* or *diapophyses* has been given them (the place of articulation of the head of the rib with the vertebra is the *capitular process* or *parapophysis*), and the transverse process and the neck of the rib enclose an arterial foramen named the costotransverse foramen. In the cervical region the costal element (*pleurapophysis*) and the transverse process are fused together, and the conjoint process thus formed is pierced by the costotransverse foramen. The compound nature of the process is indicated by the fact that the anterior or costal processes in the lower cervical vertebræ arise from additional centers and occasionally retain their independence as cervical ribs, and in Sauropsida (birds and reptiles) these processes are represented by free ribs. In the lumbar region, the compound nature of the transverse process is further marked. The true transverse process is greatly suppressed, and its extremity is indicated by the accessory tubercle. Anterior to this in the adult vertebræ a group of holes represents the costotransverse foramen, and the portion in front of this is the costal element. Occasionally it persists as an independent ossicle, the lumbar rib.

In the sacral series the costal elements are coalesced in the first three vertebræ to form the greater part of the lateral portion for articulation with the ilium, the costotransverse foramina being completely obscured. In rare instances the first sacral vertebra will articulate with the ilium on one side, but remain free on the other, and under such conditions the free process exactly resembles the elongated transverse process of a lumbar vertebra. The first three sacral vertebræ which develop costal processes for articulation with the ilium are termed *true sacral* vertebræ, while the fourth and fifth are termed *pseudosacral*. A glance at fig. 115 will show the homology of the various parts of a vertebra from the cervical, thoracic, lumbar, and sacral regions.

B. THE CRANIUM OR SKULL

The bony framework of the head, termed the cranium or skull, presents the most complex structure of the skeleton. This condition is the result mainly of the presence and close association in the head of the brain and group of sense organs on the one hand and, on the other, the highly specialized entrance to the

FIG. 115.—MORPHOLOGY OF THE TRANSVERSE AND ARTICULAR PROCESSES.



digestive and respiratory systems, the mouth and nasal cavities. In adaptation to the huge, rounded brain of man a bony capsule, the *cerebral cranium*, has been formed, consisting mostly of flat bones rigidly united by special joints called sutures. (For structure of cranial wall, see p. 81.) The cerebral cranium is directly supported by the vertebral column, and where the two come together a certain degree of transition of form of adjacent parts can be distinguished. The

erebral cranium passes without sharp line of demarcation into the *visceral ranium*, or facial skeleton, which includes the jaws and the bony support of the ongue, the hyoid bone.

Both subdivisions of the cranium in this zone of contact are concerned in providing the keletal support for the nose, the eyes and ears. Many individual bones, some singly, but nost of them in pairs, go to make up the skull; and whereas some of those entering into the erebral division are confined entirely to that division and some of the bones constituting the isceral skeleton are purely visceral in relation and function, other elements are both cerebral nd visceral in position and use. It follows that a sharp distinction of cerebral and visceral imits can hardly be made and that attempts to range all cranial bones in one of two categories nust lead in some instances to arbitrary choice. The term cranium is frequently restricted to he cerebral cranium, the visceral cranium being then designated as the facial skeleton.

THE SKULL AS A WHOLE

The skull, consisting of the cerebral and visceral crania, may first be considered s a whole. Taking a general view, it is spheroidal in shape, smooth above, ompressed from side to side, flattened and uneven below, and divisible into six egions: a superior region or vertex, a posterior or occipital region, an anterior or rontal region, an inferior region or base, and two lateral regions.

(1) The Superior Region

Viewed from above (*norma verticalis*) the skull presents an oval outline with he broader end behind, and includes the **frontal,** the two **parietal,** and the inter- arietal portion of the **occipital bones.** The lateral limits of the superior region nay be set at the **temporal lines** which pass through the **parietal eminences.** The surface is smooth and rounded and covered by the scalp. In a skull of verage width the zygomatic arches are visible, but in very broad skulls they are bscured.

The **sutures** of the vertex are the following:

The **metopic,** which is, in most skulls, merely a median fissure in the frontal bone just bove the **glabella;** occasionally it involves the whole length of the bone. It is due to the per- istence of the fissure normally separating the two halves of the bone in the infant.

The **sagittal** is situated between the two parietals, and extends from the bregma to the ambda. The single or paired **parietal foramen** lies close to the sagittal suture a short distance nterior to the bregma.

The **coronal** lies between the frontal and parietals, and extends from pterion to pterion.

The **lambdoid** is formed by the parietals and interparietal portion of the occipital. It xtends from asterion to asterion.

The **occipital** suture is only present when the interparietal bone exists as a separate element fig. 135).

The more important anthropometric points are:—

The **bregma,** which indicates the situation of the frontal (greater) fontanelle, and marks he confluence of the coronal, the sagittal, and, when present, the metopic sutures.

The **lambda,** where the sagittal enters the lambdoid suture; it marks the situation of the ccipital (lesser) fontanelle.

The **obelion,** a little anterior to the lambda, is usually indicated by a flat area between the aired parietal foramina.

(2) The Posterior Region

Viewed from behind (*norma occipitalis*) the skull is somewhat pentagonal in orm. Of the five angles, the superior or median is situated in the line of the agittal suture; the two upper lateral angles coincide with the parietal eminences nd the two lower with the mastoid processes of the temporal bones. Of the ides, four are somewhat rounded, and one, forming the basal line, running etween the mastoid processes, is flattened.

The center is occupied by the lambda, and radiating from this point are three sutures, he **sagittal,** and the two parts of the **lambdoid.** Each half of the lambdoid suture bifurcates t the mastoid portion of the temporal bone, the two divisions constituting the **parietomastoid** nd **occipitomastoid** sutures; the point of bifurcation is known as the **asterion.**

In the lower part of the view is seen the **external occipital protuberance** (inion), the **occipital rest,** and the three pairs of **nuchal lines,** which give it a rough and uneven appearance. The **ccipital point** is the point of the occiput furthest from the glabella in the median plane. It s situated above the external occipital protuberance.

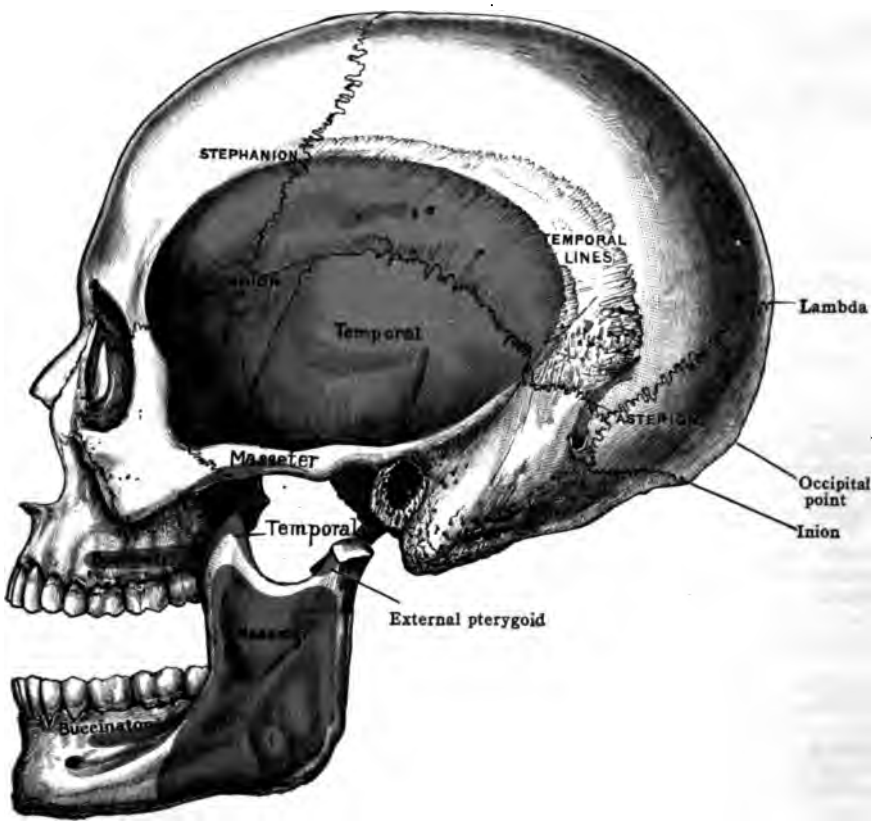
(3) The Lateral Region

The **lateral region** (*norma lateralis*) (fig. 116) may be divided into a cerebral and a visceral (facial) portion by a line extended between the root of the nose and the tip of the mastoid process. The cerebral portion presents two regions: that of the **temporal fossa** and that of the **external auditory meatus.**

The **temporal fossa** is occupied in the recent state by the body of the **temporal** muscle to which it is adapted. It is somewhat semilunar in shape, is bounded *above* and *behind* by the **temporal lines** in *front* by the frontal and zygomatic bones, and great wing of sphenoid, and *laterally* by the zygomatic arch, by which it is separated superficially from the infratemporal fossa; more deeply the infratemporal ridge of the sphenoid separates the two fossæ.

The fossa is formed by parts of five bones, the zygomatic, temporal, parietal, frontal, great wing of sphenoid, and is traversed by six sutures, coronal, sphenozygomatic, sphenosquamosal, sphenoparietal, squamosal, and sphenofrontal. The temporal lines, two in number, run a somewhat parallel course, separated by a narrow smooth tract of bone. The lower line

Fig. 116.—The Skull. Norma lateralis.



begins at the temporal crest of the frontal bone, passes onto the parietal and terminates by joining the *supramastoid crest* of the temporal bone; it marks the limit of the *temporal* muscle above and behind. The point where the lower temporal line is crossed by the coronal suture is the **stephanion,** and the region where the frontal, sphenoid, temporal, and parietal bones meet is the **pterion.** The latter is sometimes occupied in the adult by the **epipteric bone.**

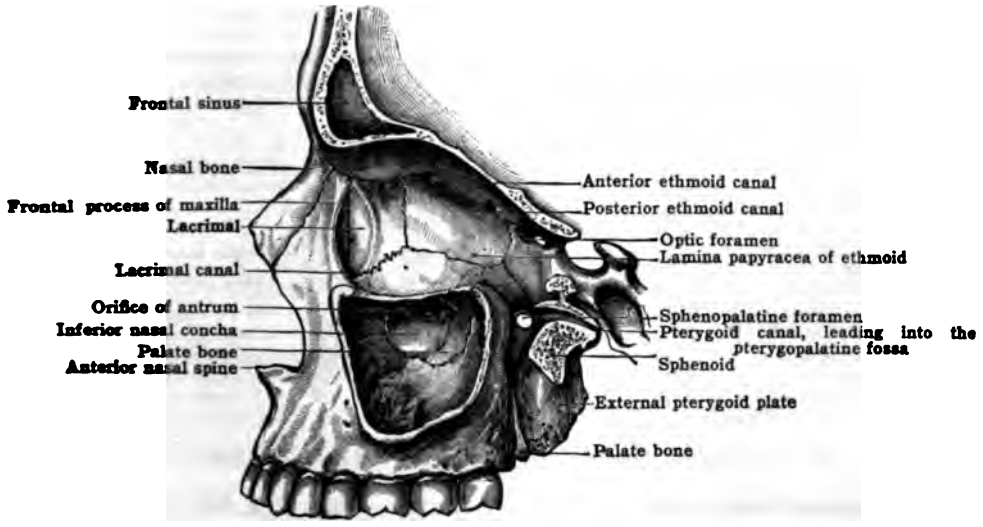
The **external auditory meatus** [meatus acusticus externus] is a short canal in the lateral region of the skull confined to the temporal bone and leading to the tympanic cavity. Its walls are formed for the most part by the tympanic portion of the temporal bone, above to some extent by the squamous portion. The entrance to the canal [porus acusticus externus] is bounded by the roughened, free margin of the tympanic, known as the *external auditory process,* to which is fixed the cartilaginous auricle. At the bottom of the meatus, a slight groove [*sulcus tympanicus*] can be seen which receives the inferior part of the circumference of the tympanic membrane Anterior to the external auditory meatus and separated from it by the tympanic is a deep concavity, the **mandibular fossa,** the anterior portion of which, made by the squamous portion of the temporal, is adapted to the articulation of the lower jaw; the posterior part, contributed by the tympanic, lodges an extension of the parotid gland. These two portions are separated by the *petrotympanic* (*Glaserian*) *fissure,* a narrow gap separating the squamous from the tympanic. Regarding the latter, it is further to be observed that it is quite thin in its middle, sometimes perforated; and that it presents medially a free irregular margin [*vagina processus styloidei*] in relation to the base of the styloid process.

Behind the external auditory meatus is the *mastoid portion* of the temporal bone, projecting downward in the conical *mastoid process*. Its surface is rough, affording attachment to muscles. A *mastoid foramen*, at or near the posterior margin of this portion, gives passage to a vein from the transverse sinus. The mastoid portion is demarcated from the temporal fossa by the supramastoid crest which continues forward over the entrance to the external auditory meatus and into the posterior root of the zygoma.

The *visceral (facial) portion of the lateral region* is concerned with mastication and includes the articulation of the mandible and the surfaces and processes to which are attached the masticatory muscles. It is directly continuous above with the temporal fossa, which, as has been pointed out, gives origin to the *temporal* muscle, and presents the form of a deep hollow the **infratemporal fossa.**

The infratemporal fossa (zygomatic fossa), irregular in shape, is situated below and to the medial side of the zygoma, covered in part by the ramus of the mandible. It is bounded *in front* by the lower part of the medial surface of the zygomatic, and by the infratemporal surface of the maxilla, on which are seen the orifices of the posterior superior alveolar canals; *behind* by the posterior border of the lateral pterygoid plate, the spine of the sphenoid, and the articular tubercle; *above* by the infratemporal ridge, a small part of the squamous portion of the temporal, the great wing of the sphenoid perforated by the foramen ovale and foramen spinosum; *below* by the alveolar border of the maxilla; *laterally* by the ramus of the mandible and the zygoma formed by zygomatic and temporal; *medially* by the lateral pterygoid plate, a line from which to the spine of the sphenoid separates the infratemporal fossa from the base of

FIG. 117.—A SECTION OF THE SKULL SHOWING THE MEDIAL WALL OF THE ORBIT, THE MEDIAL WALL OF THE ANTRUM, AND THE PTERYGOPALATINE FOSSA.



the skull. It contains the lower part of the *temporal* muscle and the coronoid process of the mandible, the *external* and *internal pterygoid muscles*, the internal maxillary vessels, and the mandibular division of the trigeminal nerve with numerous branches. At the upper and medial part of the infratemporal fossa are seen the inferior orbital and pterygopalatine fissures.

The zygomatic arch (zygoma) functions chiefly as the origin of the *masseter* muscle and in the articulation of the mandible. It is formed by the broad, zygomatic process of the zygomatic bone articulating with the slender zygomatic process of the temporal bone. Beneath the zygomatic arch, between it and the wall of the cranium, is a wide opening leading from the temporal into the infratemporal fossa which accommodates the lower portion of the *temporal* muscle and the coronoid process of the mandible into which it is inserted.

The ramus of the mandible is adapted in form for articulation with the base of the cranium and for the insertion of the masticatory muscles. This stout, flat plate stands up from the body of the mandible, and ends above in two processes separated by the broad mandibular notch. The posterior process, condyloid, is articular; the anterior, coronoid, slender and pointed. For detailed description of the mandible see p. 163.

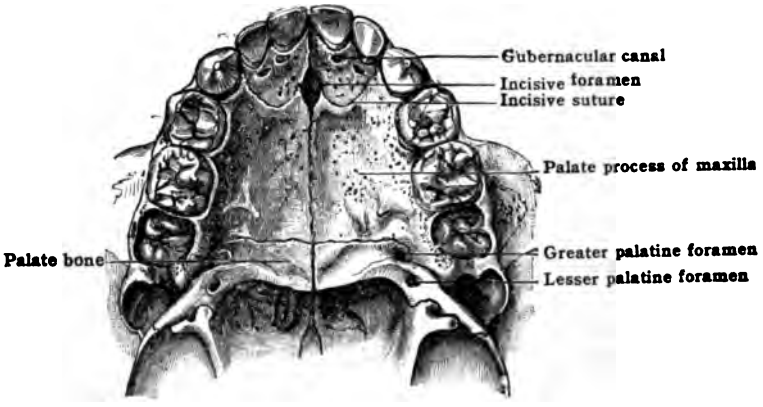
The inferior orbital (or sphenomaxillary) **fissure** is horizontal in position, and lies between the maxilla and the great wing of the sphenoid; laterally it is usually completed by the zygomatic, though in some cases the sphenoid joins the maxilla, and in this way excludes the zygomatic bone from the fissure; medially it is terminated by the infratemporal surface of the orbital process of the palate bone. Through this fissure the orbit communicates with the pterygopalatine (sphenomaxillary), infratemporal, and temporal fossæ. It transmits the infraorbital nerve and vessels, the zygomatic nerve, ascending branches from the sphenopalatine ganglion to the orbit, and a communicating vein from the ophthalmic to the pterygoid plexus.

The pterygopalatine (pterygomaxillary) **fissure** forms a right angle with the inferior orbital fissure and is situated between the maxilla and the anterior border of the pterygoid process of

the sphenoid. At its lower angle, where the two lips of the fissure approximate, the lateral pterygoid plate occasionally articulates with the maxilla, but they are usually separated by a thin portion of the pyramidal process of the palate. The pterygopalatine fissure, which serves to connect the infratemporal fossa with the pterygopalatine fossa, is bounded medially by the perpendicular part of the palate; it transmits branches of the internal maxillary artery, and the corresponding veins, to and from the pterygopalatine fossa.

The **pterygopalatine** (sphenomaxillary) **fossa** (fig. 117) is a small space, of the form of an inverted pyramid, situated at the angle of junction of the inferior orbital (sphenomaxillary) with the pterygopalatine (pterygomaxillary) fissure, below the apex of the orbit. It is bounded *in front* by the infratemporal surface of the maxilla; *behind*, by the base of the pterygoid process and the lower part of the anterior surface of the great wing of the sphenoid; medially by the perpendicular part of the palate with its orbital and sphenoidal processes; *above* by the lower surface of the body of the sphenoid. Three fissures terminate in it—viz., the superior orbital, pterygopalatine, and inferior orbital; through the superior orbital fissure it communicates with the cranium, through the pterygopalatine fissure with the infratemporal fossa, through the inferior orbital fissure with the orbit, and through the sphenopalatine foramen on the medial wall it communicates with the upper and back part of the nasal fossa. Including the **sphenopalatine** foramen six foramina open into the fossa. Of these, three are on the posterior wall: enumerated from without inward, and from above downward, they are the **foramen rotundum,** the **pterygoid (Vidian) canal,** and the **pharyngeal** (pterygopalatine) **canal.** The apex of the pyramid leads below into the **pterygopalatine canal** and the **accessory palatine canals** which branch from it; and anteriorly is the orifice of the **infraorbital canal.** The fossa contains the sphenopalatine ganglion, the maxillary nerve, and the terminal part of the internal maxillary artery, and the various foramina and canals in relation with the fossa serve for the transmission of the numerous branches which these vessels and nerves give off.

FIG. 118.—HARD PALATE OF A CHILD FIVE YEARS OLD.



(4) INFERIOR REGION OR EXTERNAL BASE OF SKULL

The **external base** of the skull (*norma basilaris*) (figs. 119, 120) extends from the incisor teeth to the occipital protuberance, and is bounded on each side by the alveolar arch, zygomatic bone, zygoma, temporal bone, and the superior nuchal line of the occipital bone. It may be divided into three portions: (a) anterior or visceral, (b) middle or subcerebral, and (c) posterior or suboccipital.

(a) The **anterior portion** includes portions of the mandible, the maxilla and the hyoid bone. (For description of the hyoid, see p. 167.)

Mandible.—The inferior margin and medial surface of the body of the mandible can be seen in an examination of the inferior aspect of the cranium. The two halves of the body extending from the ramus forward in a parabolic curve meet at the *symphysis of the chin.* Their rounded, thick, inferior edges are subcutaneous. At the back of the symphysis, the *mental tubercles* give attachment to muscles of the tongue and hyoid bone. Lateral to the midplane, a shallow depression, *digastric fossa*, marks the origin of the anterior belly of the *digastric* muscle. The oblique *mylohyoid line* indicates the origin of the *mylohyoid* muscle, which enters into the formation of the floor of the mouth. The region of the medial surface of the jaw above this line is related to the mouth cavity: the sublingual salivary gland lies in this region, its place near the symphysis being marked by a shallow fossa. The region below the mylohyoid line is in relation to structures of the neck: a fossa posteriorly indicates the position of the submaxillary salivary gland and opposite it the inferior margin of the body of the bone is often slightly grooved where the external maxillary artery passes from the neck onto the face. The posterior portion of the mylohyoid line stands at the level of the transition between the mouth and pharynx, giving attachment to the *superior constrictor* muscle of the pharynx and the pterygomandibular ligament.

The teeth and alveolar processes of the mandible are best studied from the anterior aspect of the skull. The *alveolar processes* of the *maxillæ* together form an elliptic curve. They pre-

he dental *alveoli* adapted to the form of the roots of the eight pairs of permanent teeth
e adult. Between the processes of the two sides extends the **hard palate** [palatum durum]
separates the mouth and nasal cavity. It is composed of the palatine processes of the
la and palate bones meeting their fellows in a median suture. A transverse suture con-
the palate process of the maxilla with that of the palate bone behind it. The roughened
e of the hard palate denotes the presence of many glands in the mucosa which covers it,
he grooves and foramina are adapted to the passage of palatine vessels and nerves. A
median foramen anteriorly (*incisive foramen*) communicates with the nasal fossæ on each
y the *incisive canals*. The large opening of the pterygopalatine canal between the palate
naxilla and the lower openings of the canals in the palate bone itself (greater and lesser
ne foramina) give passage to nerves and vessels. The soft palate is fixed to the posterior
margin of the hard palate, which is extended backward in the midline to form the *posterior spine*.

The middle or subcerebral portion of the external base of the skull presents
ntral region adapted largely to the nasopharynx and lateral areas traversed
ne cerebral vessels and nerves entering and leaving the cranial cavity. When
ed in profile the subcerebral portion appears as a deep fossa sunk between
nore elevated anterior and posterior portions.

he *central region* presents the stout basilar part of the occipital bone, continuous anteriorly
the body of the sphenoid, the pterygoid processes of the latter, and the apices of the
sal parts of the temporal bones. This region communicates with the nasal fossæ by the
d openings (choanæ), limited by palate processes of the palate bones below, by the vaginal
sses of the pterygoids and alæ of the vomer above, laterally by the medial pterygoid
æ and medially by the vomer (see fig. 126). With the exception of the vomer, these also
support to the upper part of the pharynx. A *notch* in the upper part of the free margin of
nedial pterygoid plate is adapted to the cartilaginous portion of the auditory tube which
nearby in the lateral wall of the nasopharynx and leads to the adjacent *groove* [semicanalis
auditivæ] in the angle between the petrosal part of the temporal and the great wing
e sphenoid. The pharyngeal aponeurosis (see p. 1159) is attached to the external cranial
in this region. The *pharyngeal tubercle* of the pars basilaris, the free edge of the medial
goid plate and its *hamulus* give origin to the *superior constrictor* muscle of the pharynx.
eas the lateral plate of the pterygoid process is adapted to the origin of masticatory
les, the medial lamina is related to pharyngeal structures. From its base in the *scaphoid*
arises the tensor veli palatini muscle whose tendon is deflected by the hamulus. Bran-
of the sphenopalatine artery and sphenopalatine ganglion reach the roof of the nasopharynx
ne *pharyngeal canal*, running beneath the vaginal process of the medial pterygoid plate.
intimately connected with the pharynx is the pterygoid (Vidian) nerve which occupies
terygoid canal directed forward through the base of the pterygoid process. This canal
s anteriorly into the pterygopalatine fossa and posteriorly into the *foramen lacerum*, the
given to the space (occupied by the basal fibrocartilage) with jagged margins between
ars basilaris of the occipital and the great wing of the sphenoid on the one hand and the
mity of the pars petrosa of the temporal on the other.
he central region of the subcerebral division, close to the occipital foramen, gives insertion
scles of the vertebral column and, under cover of the occipital condyles, passage by way of
ypoglossal canals to the hypoglossal nerves.
he *paired lateral areas* of the subcerebral region intervene between the infratemporal fossæ
nandibular fossæ laterally and the nasopharyngeal region medially. These areas present
nber of foramina for the passage of vessels and nerves. Most anteriorly the *foramen ovale*
s the great wing of the sphenoid behind the base of the pterygoid process. It transmits
andibular division of the trigeminal nerve. The middle meningeal branch of the internal
llary artery enters the cranium by the *foramen spinosum*, which perforates the posterior
of the sphenoid between the foramen ovale and the *spina angularis* (for the sphenoman-
ar ligament). The orifice of the *carotid canal*, occupied by the internal carotid artery
ars on the inferior surface of the pars petrosa of the temporal bone. Behind this orifice
large *jugular foramen* in which the internal jugular vein is formed and through which
the glossopharyngeal, vagus and accessory nerves. The anterior wall of the foramen,
by the petrous portion of the temporal bone, presents two fossæ; a larger oval one, the
ar fossa occupied by the superior bulb of the internal jugular vein, and a smaller notch-like
ssion, *canaliculus cochleæ*, medial to the jugular fossa, transmitting a vein from the cochlea
e internal jugular. Upon the lateral wall of the jugular fossa, a minute foramen leads to
astoid canaliculus, transmitting the auricular branch of the vagus. On the ridge between
gular fossa and orifice of the carotid canal is the *fossula petrosa*, in the bottom of which
he opening of the *tympanic canaliculus* carrying the tympanic branch of the glossopharyn-
nerve. At the side of the jugular foramen and behind the base of the styloid process is
tylomastoid foramen, the inferior opening of the facial canal, the passageway through the
al wall for the facial nerve. The slender *styloid process*, ensheathed at its base by the
al process, springs from the temporal bone, beneath the tympanic cavity.

The posterior portion of the external cranial base presents the joint for
ulation with the neck and the great areas for the attachment of the muscles
h move the head and neck. The foramen magnum lies within this region.
he paired *occipital condyles*, oval in form and elevated above the general
lie upon either side of the foramen magnum chiefly in the *lateral parts* of the
ital bone. They articulate with the atlas; a tubercle on the margin gives

FIG. 119.—THE SKULL. Norma basilaris. (To show muscular attachments.)

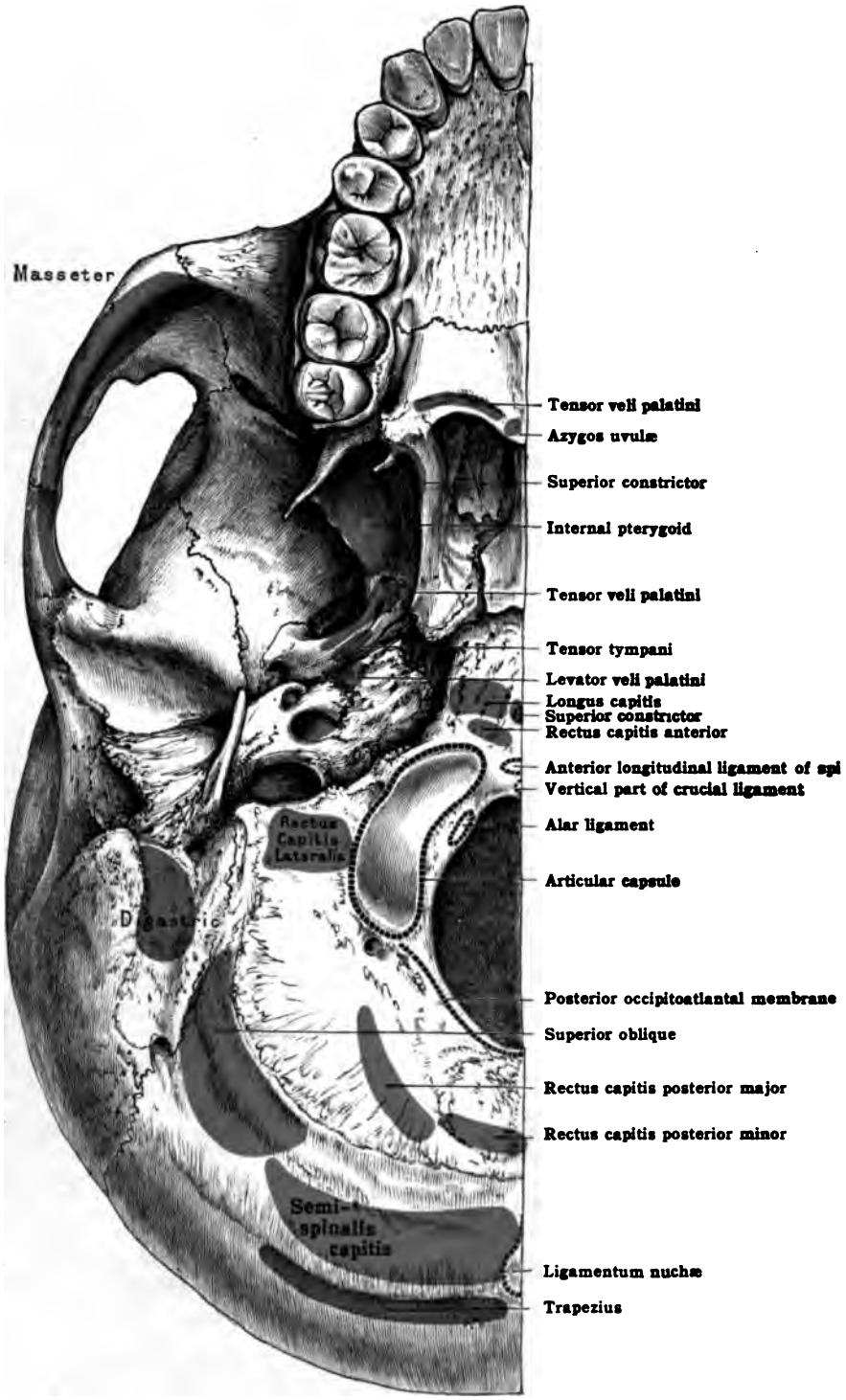
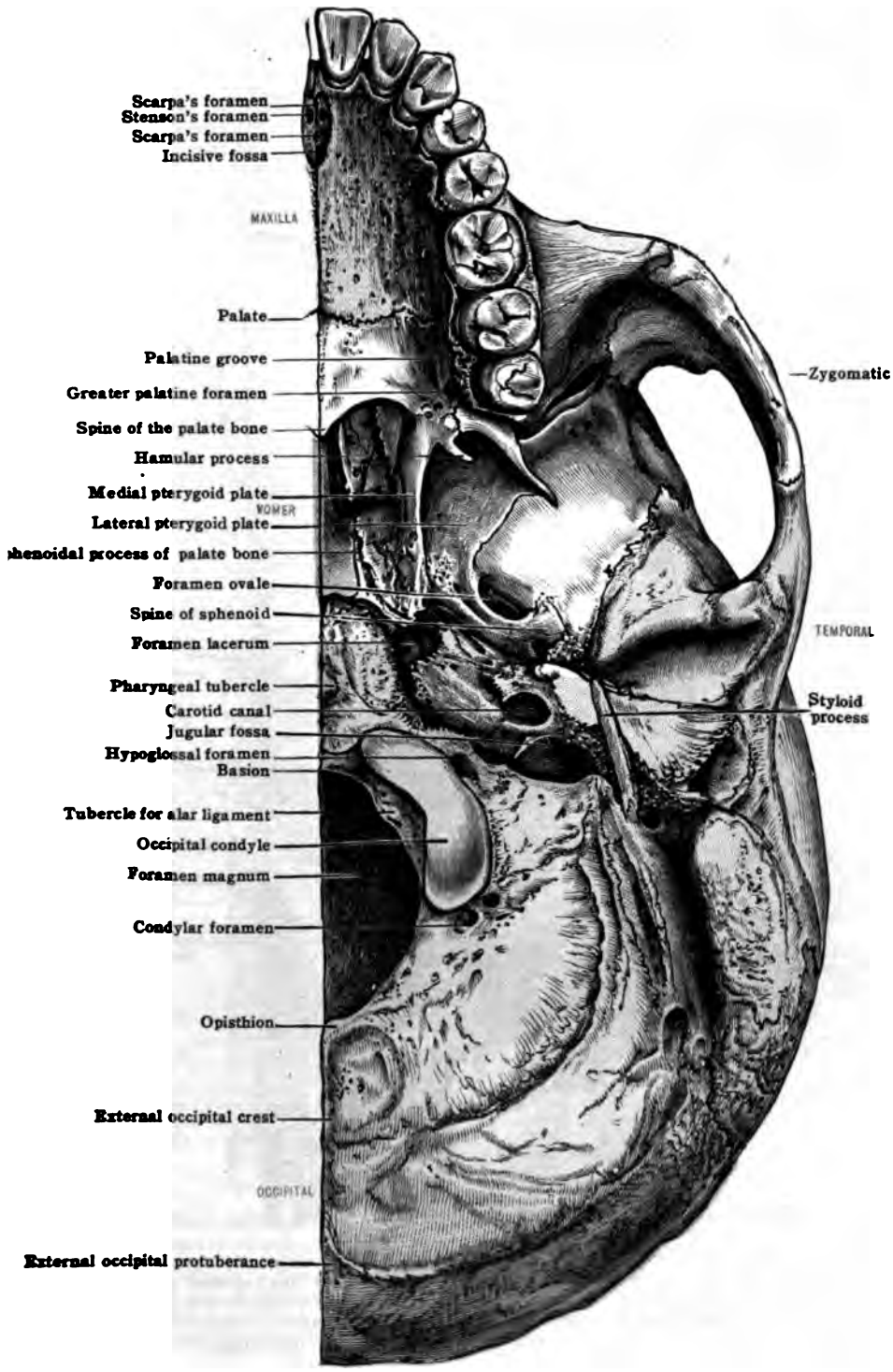


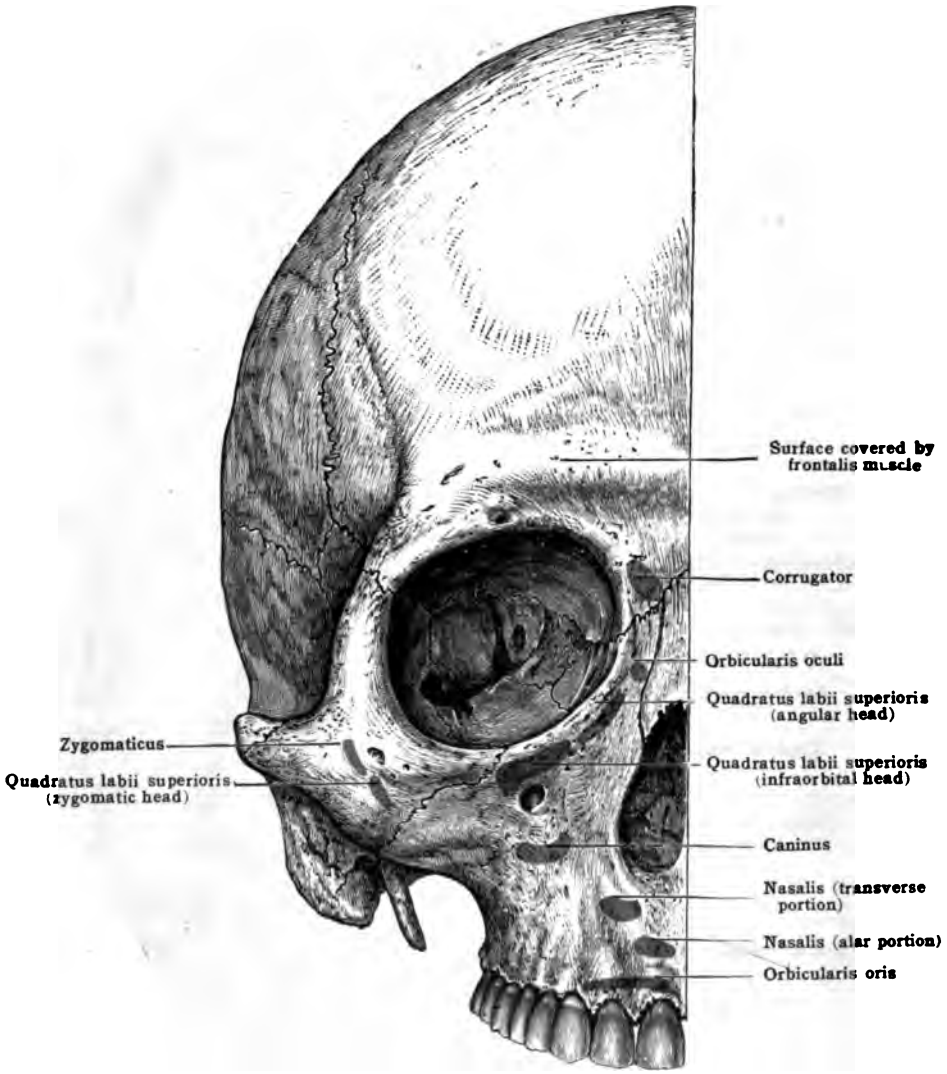
FIG. 120.—THE SKULL. Norma basilaris. Bones colored.



attachment to the alar ligament. Lateral to the condyle, the rough surface of the *jugular process* gives insertion to the *rectus capitis lateralis* muscle. This process articulates laterally with the pars mastoidea of the temporal; in front it enters into the boundary of the jugular foramen. Behind the jugular process and condyle is the *condylar fossa*, adapted to receive the edge of the superior articular process of the atlas.

Regarding the areas for the attachment of muscles: the posterior belly of the *digastric* arises from the *digastric fossa* of the mastoid portion medial to the mastoid process. The *squamous part* (squama occipitalis), behind the foramen magnum and lateral parts, convex and rough, is mapped out by ridges indicating the limits of muscular insertion and sites of ligament-

FIG. 121.—THE SKULL. Norma facialis. To show origin of muscles.



ous attachment. The *external occipital crest*, in the midline from the external occipital protuberance to the foramen magnum, gives attachment to the ligamentum nuchæ. From the external *occipital protuberance*, the *superior nuchal line* reaches to the lateral angle of the occipital bone; from the middle of the crest, the *inferior nuchal line* arches toward the jugular process. The names of the muscles inserted here will be found in the description of the occipital bone (p. 122).

Within this region of the external base, openings for the passage of so-called emissary veins are present: the *mastoid foramen* near the posterior margin of the pars mastoidea, communicating with the transverse sinus; a *condylar canal* often found in the bottom of the condylar fossa opening into the terminal part of the same sinus. The occipital artery occupies the *occipital groove* of the pars mastoidea medial to the digastric fossa.

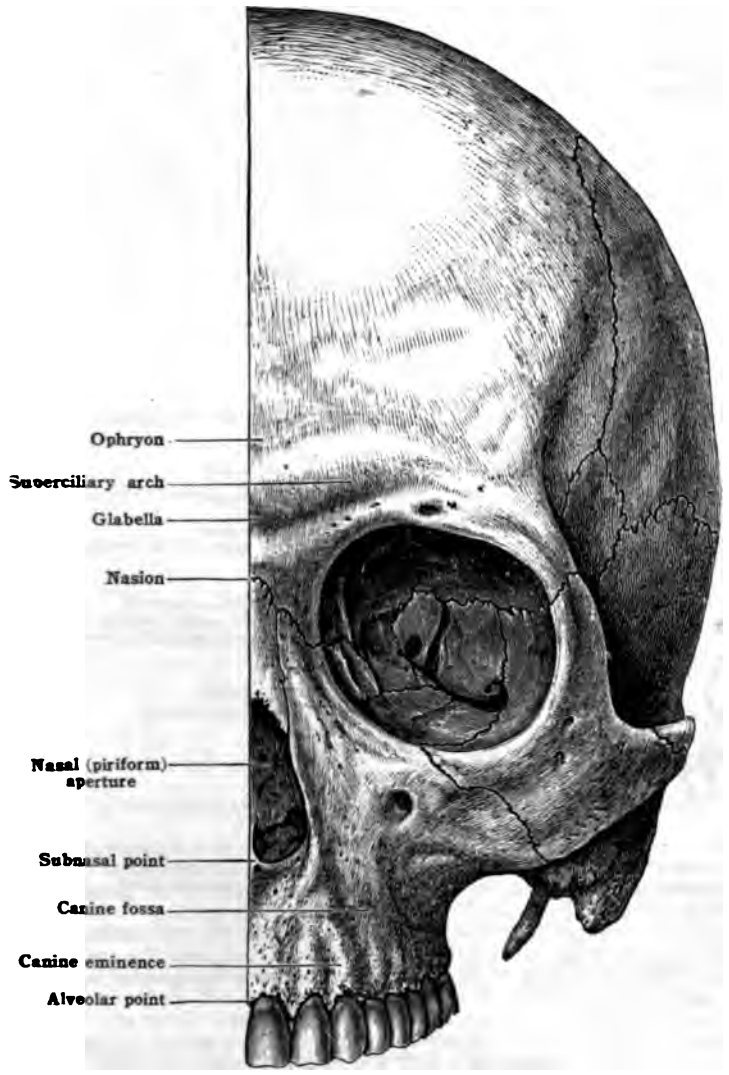
For description of the *foramen occipitale magnum*, see p. 125.

(5) The Anterior Region

The **anterior region** (*norma facialis*) (figs. 121, 122) comprises the anterior end of the cerebral cranium, or forehead, and the skeleton of the face. The configuration of this region is determined by the presence of the nose, eyes and mouth, the **nasal skeleton, orbits** and **jaws** giving support to these organs.

The upper part or forehead, narrowest between the temporal crests about half an inch above the zygomatic processes of the frontal, presents at this level

Fig. 122.—The Skull. Norma facialis.



the two **transverse sulci,** above which are the **frontal eminences** corresponding to the anterior poles of the frontal lobes of the brain.

The **bones** entering into formation of the *norma facialis* are:—the frontal, nasals, lacrimals, orbital surfaces of the small and the great wings, and a portion of the body of the sphenoid, the laminæ papyraceæ of the ethmoids, the orbital processes of the palate bones, the zygomatics, maxillæ, inferior nasal conchæ, and the mandible.

THE ORBITS

Below the forehead are the openings of the **orbits** [orbitæ] (figs. 122, 123) two cavities of pyramidal shape, with their bases directed forward and laterally and their apices backward and medially. Each cavity forms primarily a socket

for the eyeball and the muscles, nerves, and vessels associated with it, but also contains vessels and nerves not directly related to the eye, but which pass through to other regions.

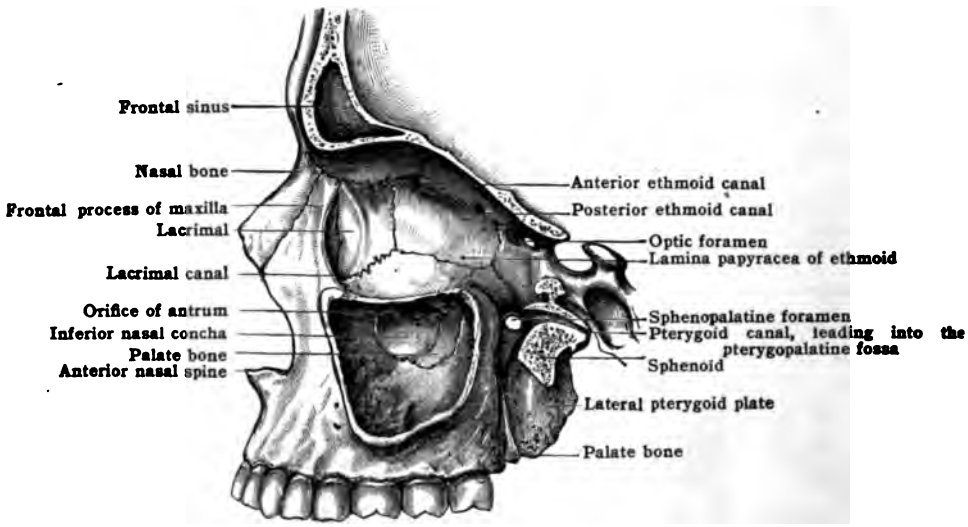
Seven bones enter into formation of its walls, viz., the frontal, zygomatic, sphenoid, ethmoid, lacrimal, palate, and maxilla; but as three of these—the frontal, sphenoid, and ethmoid—are single median bones which form parts of each cavity, there are only eleven bones represented in the two orbits. Each orbit presents four walls, a circumference or base, and an apex.

The **apex** of each orbit corresponds to the **optic foramen**, a circular orifice between the two roots of the lesser wing of the sphenoid bone, which transmits the optic nerve and ophthalmic artery. From the circumference of the optic foramen the straight muscles (*recti*) of the eyeball arise.

The **superior wall** or **roof**, vaulted and smooth, is formed mainly by the orbital plate of the frontal and is completed posteriorly by the small wing of the sphenoid. At the lateral angle it presents the **fossa of the lacrimal gland**, and at the medial angle a depression [fovea trochlearis] or a spine for the pulley of the *superior oblique* muscle of the eye.

The **inferior wall** or **floor** is directed upward and laterally and is not so large as the roof. It is formed by the orbital plate of the maxilla, the orbital process of the zygomatic, and the orbital process of the palate bone. At its medial angle it presents the *nasolacrimal canal*, occupied by the nasolacrimal duct between the orbit and nasal fossa; and near this, a depression for the origin of the *inferior oblique* muscle. It is marked near the middle by a furrow for the

FIG. 123.—THE MEDIAL WALL OF THE ORBIT.



infraorbital artery and the maxillary nerve, terminating anteriorly in the *infraorbital canal*, through which the nerve and artery emerge on the face. Near the commencement of the canal a narrow passage, the anterior alveolar canal, runs forward and downward in the anterior wall of the antrum, transmitting nerves and vessels to the incisor and canine teeth.

The **lateral wall**, directed forward and medially, is formed by the orbital surface of the great wing of the sphenoid, and the zygomatic. Between it and the roof, near the apex, is the **superior orbital** (sphenoidal) **fissure**, a narrow gap intervening between the greater and lesser wings of the sphenoid, and connecting the orbit and cranial cavity. It transmits several structures, including the ophthalmic, oculomotor, trochlear and abducent nerves and the ophthalmic vein or veins; it also transmits some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery and recurrent branches of the lacrimal artery. The lower margin of the fissure presents near the middle a small tubercle, from which the inferior head of the *lateral rectus* muscle arises. Between the lateral wall and the floor, near the apex, is the **inferior orbital** (sphenomaxillary) **fissure**, through which pass the maxillary nerve and its zygomatic branch, and the infraorbital vessels from the pterygopalatine fossa. A connection is established through the fissure between the orbital veins and the pterygoid plexus in the infratemporal fossa. The great wing of the sphenoid forms the posterior margin of the fissure, the orbital plate of the maxilla its anterior edge, and the zygomatic its lateral boundary. On the latter bone are seen the zygomatico-orbital orifices of the zygomaticotemporal and zygomaticofacial canals, which traverse the zygomatic bone, transmitting the nerves of the same name to the temporal fossa and cheek. The commencement of the zygomaticotemporal canal is sometimes seen in the sphenozygomatic suture.

The **medial wall**, narrow and nearly vertical, is formed from before backward by the frontal process of the maxilla, the lacrimal, the lamina papyracea of the ethmoid, and the body of the sphenoid. It is traversed by three vertical sutures:—one between the frontal process of the maxilla and the lacrimal, a second between lacrimal and lamina papyracea, and a third between

the **lamina papyracea** and the sphenoid. Occasionally the sphenoidal concha appears in the orbit between the ethmoid and the body of the sphenoid. Anteriorly is the **fossa of the lacrimal sac,** hollowed out of the lacrimal bone and frontal process of the maxilla; behind this the **posterior lacrimal crest,** from which the *lacrimal part of the orbicularis oculi* muscle arises. At the junction of the medial wall with the roof, and in the suture between the ethmoid and frontal, are seen the orifices of the **anterior** and **posterior ethmoidal canals,** the anterior, transmitting the anterior ethmoidal vessels and nerve; and the posterior, the posterior vessels and nerve.

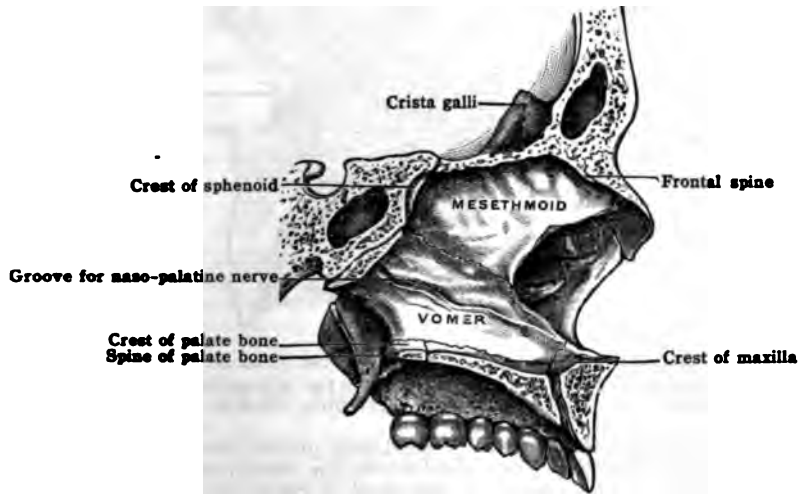
The **base** or circumference is quadrilateral in form and corresponds to the **aditus orbitæ.** It is bounded by the frontal bone above, presenting the sharp **supraorbital margin,** broken by the **supraorbital notch** (sometimes a foramen) giving passage to the supraorbital branch of the ophthalmic nerve and the supraorbital artery. Above the margin the **superciliary arch** extends medially into the prominence of the **glabella.** The frontal process of the maxilla and the medial angular process of the frontal are on the medial side, the zygomatic bone and the zygomatic process of the frontal on the lateral side of the aditus orbitæ. The zygomatic and the body of the maxilla form the inferior boundary which is in the shape of a sharp raised edge, **infraorbital margin,** between the orbital and facial surfaces of these bones. The infraorbital margin is continued medially into the **anterior lacrimal crest,** in front of the fossa of the lacrimal sac, which gives origin to the orbicularis oculi, pars orbitalis. Below the infraorbital margin is to be seen the facial opening of the infraorbital canals, the **infraorbital foramen** for the nerve and artery of the same name.

The orbit communicates with the cranial cavity by the optic foramen and superior orbital fissure; with the nasal fossa, by means of the nasolacrimal canal; with the infratemporal and pterygopalatine fossæ, by the inferior orbital fissure. In addition to these large openings, the orbit has five other foramina—the infraorbital, zygomatico-orbital, and the anterior and posterior ethmoidal canals—opening into it or leading from it. The following points may also be noted:—The suture between the zygomatic process of the frontal bone and the zygomatic; the suture between the frontal bone and the frontal process of the maxilla; and in the lower segment, the zygomaticomaxillary suture.

NASAL SKELETON

The **nasal skeleton** includes the bony and cartilaginous support of the external nose, the nasal fossæ and the paranasal sinuses.

FIG. 124.—SECTION THROUGH THE NASAL FOSSA TO SHOW THE SEPTUM. LEFT HALF, WITH SEPTUM LOOKING TOWARD RIGHT NASAL FOSSA.



Skeleton of the external nose.—The cartilaginous framework is described in the section on the Respiratory System, p. 1225. The bony skeleton forms the bridge of the nose which is composed medially of the **nasal bones** articulating with each other in the **internasal suture,** and laterally of the **frontal processes** of the **maxillæ** articulating with the nasal bones. These elements unite above with the frontal bone in the **nasofrontal** and **frontomaxillary sutures.**

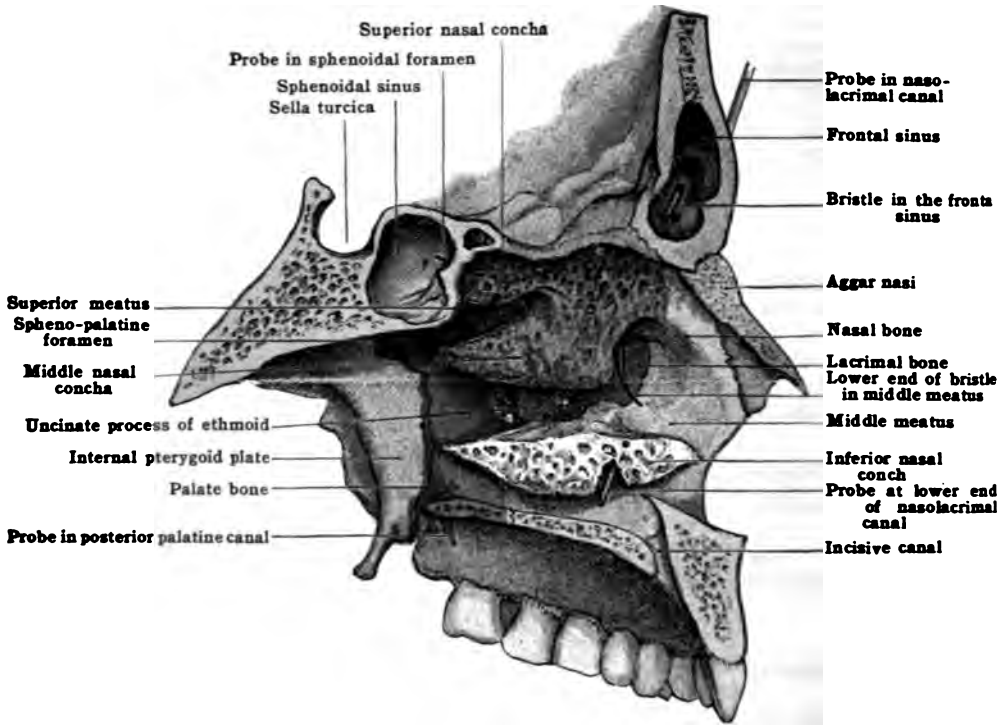
Below the bridge of the nose the cartilaginous portion projects from the margins of the **piriform aperture.** This large opening leads into the bony-walled nasal fossæ, is higher than wide and is bounded by the nasal bones above and the maxillæ laterally and below. In the midline below is the **anterior nasal spine** which supports the extremity of the cartilaginous nasal septum. For muscular attachments in this region, see fig. 121.

The **nasal fossæ** (figs. 124, 125, 975, 1086) are two irregular cavities situated

on each side of a median vertical septum. They open in front by the piriform aperture and communicate behind with the pharynx by the choanæ. They are somewhat oblong in transverse section, and extend vertically from the anterior part of the base of the cranium above to the superior surface of the hard palate below. Their transverse extent is very limited, especially in the upper part. Each fossa presents a roof, floor, medial and lateral walls, and communicates with the paranasal sinuses of the frontal, sphenoid, maxilla, and ethmoid bones.

The **roof** is horizontal in the middle, but sloped downward in front and behind. The anterior slope is formed by the posterior surface of the nasal bone and the nasal process of the frontal; the horizontal portion corresponds to the **cribriform plate of the ethmoid** and the **sphenoidal concha**; the posterior slope is formed by the inferior surface of the body of the sphenoid, the ala of the vomer, and a small portion of the **sphenoidal process of the palate.** The sphenoidal sinus opens at the upper and back part of the roof into the sphenoethmoidal recess, above the superior meatus.

FIG. 125.—SECTION THROUGH THE NASAL FOSSA TO SHOW THE LATERAL WALL WITH THE MEATUSES.



The **floor** is concave from side to side, and in the transverse diameter wider than the roof. It is formed mainly by the palatine process of the maxilla and completed posteriorly by the horizontal part of the palate bone. Near its anterior extremity, close to the septum is the incisive canal.

The **septum** or medial wall is formed by the perpendicular plate of the ethmoid, the vomer, the rostrum of the sphenoid, the crest of the nasal bones, the frontal spine, and the median crest formed by the apposition of the palatine processes of the maxillæ and the horizontal parts of the palate bones. The anterior border has a triangular outline limited above by the perpendicular plate of the ethmoid and below by the vomer, and in the recent state the deficiency is filled up by the septal cartilage of the nose. The posterior border is formed by the pharyngeal edge of the vomer, which separates the two choanæ. The septum, which is usually deflected from the middle line to one side or the other, is occasionally perforated, and in some cases a strip of cartilage, continuous with the triangular cartilage, extends backward between the vomer and perpendicular plate of the ethmoid (*posterior* or *sphenoidal process*).

The **lateral wall** is the most extensive and the most complicated on account of the formation of the meatuses of the nose. It is formed by the frontal process and the medial surface of the maxilla, the lacrimal, the superior and inferior conchæ of the ethmoid, the inferior nasal concha, the vertical part of the palate bone, and the medial surface of the medial pterygoid plate. The three conchæ (frequently four, see p. 1233), which project medially, overhang the three recesses known as the **meatuses** of the nose. The **superior meatus**, the shortest of the three, is situated between the superior and middle nasal conchæ, and into it open the **posterior ethmoidal cells.** The **middle meatus** lies between the middle and inferior **conchæ.** It presents a prominent groove, the **hiatus semilunaris**, bounded by the **ethmoidal bulla above and the uncinate process** of the ethmoid below, and leading into a cleft-like space, **the ethmoidal**

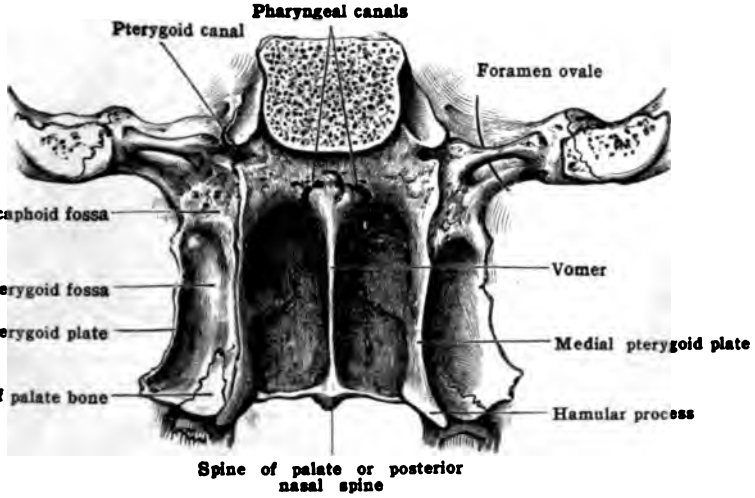
ulum. Into the middle meatus open the **anterior ethmoidal cells** (including the middle · group), the **frontal sinus** and the **maxillary sinus** (frequently by two apertures). (For details concerning the paranasal sinuses, see descriptions under the individual bones; **er Respiratory System,** p. 1233.) Anterior to the middle meatus is a slight elevation, **r nasi,** on the frontal process of the maxilla. The **inferior meatus,** longer than the others, en the inferior nasal concha and the floor of the nasal fossa. Anteriorly and laterally its the lower orifice of the **nasolacrimal canal.**

common meatus of the nose is the narrow space between the conchæ and the nasal the name **nasopharyngeal meatus** is given to the region of the nasal fossa located on e behind the level of the conchæ. The lateral wall is formed by the perpendicular the palate; here the **sphenopalatine foramen,** standing just behind the posterior end iddle conchæ, puts the nasal fossa into communication with the pterygopalatine fossa es passage to the sphenopalatine artery and nasal branches of the sphenopalatine

nasal fossæ open on the face by means of the **apertura piriformis** and into the pharynx **hoanæ.** The paired choanæ (fig. 126) are bounded superiorly by the alæ of the vomer, enoidal processes of the palate, and the inferior surface of the body of the sphenoid; by the medial pterygoid plates; and inferiorly by the posterior edge of the horizontal the palate bones. They are separated from each other by the posterior border of the

nasal fossæ communicate with all the more important fossæ and the air-sinuses of the By means of the foramina in the roof they are in connection with the cranial cavity; niddle meatus each fossa is in communication with the maxillary and frontal sinuses

FIG. 126.—THE CHOANÆ. (Viewed from behind.)



erior ethmoidal cells; the posterior ethmoidal cells open into the superior meatuses and enoidal sinuses into the recesses above; the sphenopalatine foramina connect them with ygopalatine fossæ. The nasolacrimal canals connect with the orbits, and the incisive ith the oral cavity.

SUTURES OF THE ANTERIOR REGION

sutures of the anterior region are numerous and for the most part unimportant:—
transverse suture (fig. 122) extends from one zygomatic process of the frontal to the The upper part of the suture is formed by the frontal bone; below are the zygomatic, d small wings of the sphenoid, lamina papyracea, lacrimal, maxillary, and nasal bones. n of this complex suture, lying between the sphenoidal and frontal bones, appears in rior cranial fossa.

following anthropometric points may also be noticed:—
glabella, a smooth space between the converging superciliary arches.
ophryon, the most anterior point of the metopic suture.
nasion, the middle of the nasofrontal suture.
subnasal point, the middle of the inferior border of the piriform aperture.
alveolar point, the center of the anterior margin of the upper alveolar arch.

THE INTERIOR OF THE CRANIUM

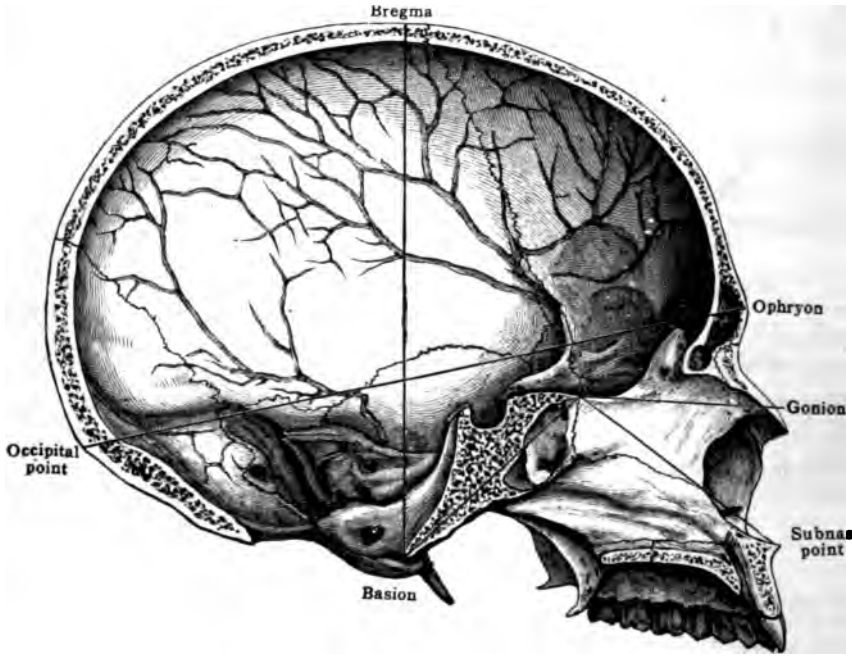
size of the cranial cavity is in relation to that of the contained brain and elopes. The cavity conforms rather closely to the shape of the brain, ger divisions of which all leave their marks upon the base and walls.

Median section (fig. 127).—In this section conditions are presented for an advantageous review of the structure of the cranial wall, and of the size and form of the cranial cavity. The walls of the brain-case are built up mainly from the parietal, frontal and occipital bones; to a lesser extent by the temporals, the sphenoid and ethmoid.

The following anthropometric points and measurements are best understood in the median section. The black line (fig. 127) drawn from the **basion** (anterior margin of the foramen magnum) to the the anterior extremity of the sphenoid represents the **basicranial axis**; whilst the line drawn from this extremity to the **subnasal point** lies in the **basifacial axis.** These two axes form an angle termed the **craniofacial,** which is useful in making comparative measurements of crania. A line prolonged vertically upward from the **basion** will strike the **bregma.** This is the **basibregmatic** axis, and gives the greatest height of the cranial cavity. A line drawn from the **ophryon** to the **occipital point** indicates the greatest length of the cranium.

The structure of the bony capsule in the midplane shows considerable variation. It is thinnest at the cribriform plate of the ethmoid, and thickest through the basilar portion of the occipital and body of the sphenoid. In the cranial walls may be seen the diploë, between the outer and inner tables [laminæ]; also the frontal and sphenoidal air sinuses. For structure of the cranial wall, see also p. 81.

FIG. 127.—THE SKULL IN MEDIAN SECTION.



The inner surface of the cranium presents slight depressions corresponding to the convolutions [gyri] of the cerebrum. A series of branching grooves are occupied by **meningeal vessels;** the largest, for the **middle meningeal vessels,** may be traced to the foramen spinosum in the base. The shallow groove for the **superior sagittal sinus** [sulcus sagittalis] occupies the midline of the roof; and on each side are small pits [foveolæ granulares] for the Pacchionian bodies of the arachnoid. Posteroinferiorly on each side the groove for the **transverse sinus** crosses the occipital, angle of the parietal, and mastoid portion of the temporal bones.

The **floor** [basis cranii interna] of the cranial cavity presents three irregular subdivisions termed the anterior, middle, and posterior fossæ (figs. 128 and 129) in adaption to the contour of the base of the brain.

THE ANTERIOR CRANIAL FOSSA.—The floor of this fossa is on a higher level than the rest of the cranial floor. It is formed by the horizontal plate of the frontal bone, the cribriform plate of the ethmoid, the lesser wings of the sphenoid and the fore part of the body of the sphenoid. It supports the frontal lobes of the cerebrum. The **sutures** traversing the floor of the fossa are the frontoethmoidal, forming three sides of a rectangle, that portion of the transverse facial suture which traverses the roof of the orbit, and the ethmosphenoidal suture, the center of which corresponds to the **gonion.**

In the midline of the floor is the **crista galli,** its alæ articulating with the **frontal and so completing the boundaries of the foramen cecum** (lodging an emissary vein); **beyond, is the**

frontal crest to which as well as to the crista galli the falx cerebri is attached. On either side of the crista galli, the **cribriform plate** presents numerous foramina for filaments of the olfactory nerve. The lateral parts of the floor are constituted by the horizontal parts of the frontal bone, which at the same time form the **roofs of the orbits.** This region is convex here and shows marked grooves and ridges for the cerebral gyri and sulci. In the frontoethmoidal suture are the cerebral openings of the **anterior and posterior ethmoidal canals** transmitting ethmoidal arteries, the anterior carrying besides, the anterior ethmoidal nerve.

The posterior margin of the lesser wing of the sphenoid corresponds to the anterior part of the Sylvian fissure of the cerebrum, separating the frontal lobe occupying the anterior cranial fossa, from the temporal lobe which projects downward and forward into the middle fossa.

The MIDDLE CRANIAL FOSSA, situated on a lower level than the anterior, consists of a central and two lateral portions. In front it is limited by the posterior borders of the lesser wings of the sphenoid and the anterior margin of the optic groove, behind by the dorsum sellæ and the upper margin of the petrous portion of both temporal bones. Laterally it is bounded on each side by the squamous portion of the temporal, great wing of the sphenoid, and the parietal bone, whilst the floor is formed by the body and great wings of the sphenoid and the anterior surface of the petrous portion of the temporals. It contains the following sutures:—sphenoparietal, petrosphenoidal, squamosphenoidal, squamous, and a part of the transverse suture.

In general the form of the lateral portion corresponds to that of the temporal lobe of the brain. A conspicuous groove lodges the middle meningeal vessels in their course from the **foramen spinosum.** The semilunar (Gasserian) ganglion of the trigeminus occupies a slight **depression** on the part of the apex of the petrous bone; its mandibular branch passes to the infratemporal fossa by the **foramen ovale**; its maxillary branch passes into the pterygopalatine fossa via the **foramen rotundum**; its ophthalmic branch goes through the **superior orbital fissure** into the orbit.

Upon the anterior face of the petrous portion is a small opening, **hiatus canalis facialis,** which gives passage to the great superficial petrosal nerve; this runs in a groove to the irregular **lacerated foramen** in the base of the cranium. The internal carotid artery enters the cranial cavity from the **carotid canal** at the apex of the petrous bone, and runs in the **carotid groove** upon the side of the body of the sphenoid, together with the cavernous sinus. Lateral to the carotid aperture is a slender bony process, the **lingula sphenoidalis.** Lateral to the hiatus canalis facialis is the **tegmen tympani,** the thin roof of the middle ear cavity; behind which is the **eminentia arcuata,** made by the superior semicircular canal.

The middle portion of the middle cranial fossa is occupied mainly by the **hypophyseal fossa** (*sella turcica*) lodging the hypophysis or pituitary gland. The fossa is limited in front by a rounded eminence, the **tuberculum sellæ,** and posteriorly by a quadrilateral plate, the **dorsum sellæ.** The **lateral angles** of the dorsum sellæ form the **posterior clinoid processes.** The **anterior clinoid processes** project backward from the lesser wings of the sphenoid. The carotid groove terminates opposite the last-named process. Here the ophthalmic artery is given off which accompanies the optic nerve through the **optic foramen** between the two roots of the lesser wing, into the orbit. A transverse groove [**sulcus chiasmatis**] joins the optic foramina.

The POSTERIOR CRANIAL FOSSA is the deepest and largest of the series. It is bounded in front by the dorsum sellæ of the sphenoid and on each side by the superior border of the petrosal, and the mastoid portion of the temporal bone, the posterior inferior angle of the parietal, and the groove on the occipital bone for the transverse sinus. These bones take part in the formation of its floor, including the petro-occipital, occipitomastoid and parietomastoid sutures.

In the recent state the fossa lodges the cerebellum, pons, and medulla, and is roofed in by the tentorium cerebelli, a tent-like process of the dura mater attached to the superior boundaries of the fossa. It communicates with the general cranial cavity by means of the **foramen ovale of Pacchionius,** a large opening bounded anteriorly by the clivus (basilar groove) and posterolaterally by the free edge of the tentorium; and inferiorly it communicates with the vertebral canal by the **foramen magnum.**

Between the posterior cranial fossa and the middle cranial fossa on each side is the **pyramid,** formed by the petrous portion of the temporal bone and enclosing the inner ear. The features on its anterior surface were mentioned above. On the posterior surface, the most conspicuous mark is the **internal auditory meatus,** which transmits the acoustic, facial and glossopalatine nerves. Posterolateral to this are the *fossa subarcuata* and the *aquaeductus vestibuli* (see fig. 156). The superior margin of the pyramid is grooved for the superior petrosal sinus; the posterior margin for the inferior petrosal sinus.

Through the **foramen magnum** the spinal cord passes into the brain-stem, resting upon the basilar portion of the occipital between two paired eminences, the **jugular tubercles;** higher up this surface is called the **clivus** and continues upon the dorsum sellæ. The cerebellum occupies the greater part of the remaining space of the posterior fossa. A low ridge in the midline of the squama extends from the **internal occipital protuberance** to the foramen magnum and gives attachment to the falx cerebelli. On either side of the foramen magnum is the internal orifice

FIG. 128.—FLOOR OF THE CRANIUM. (Bones colored.)

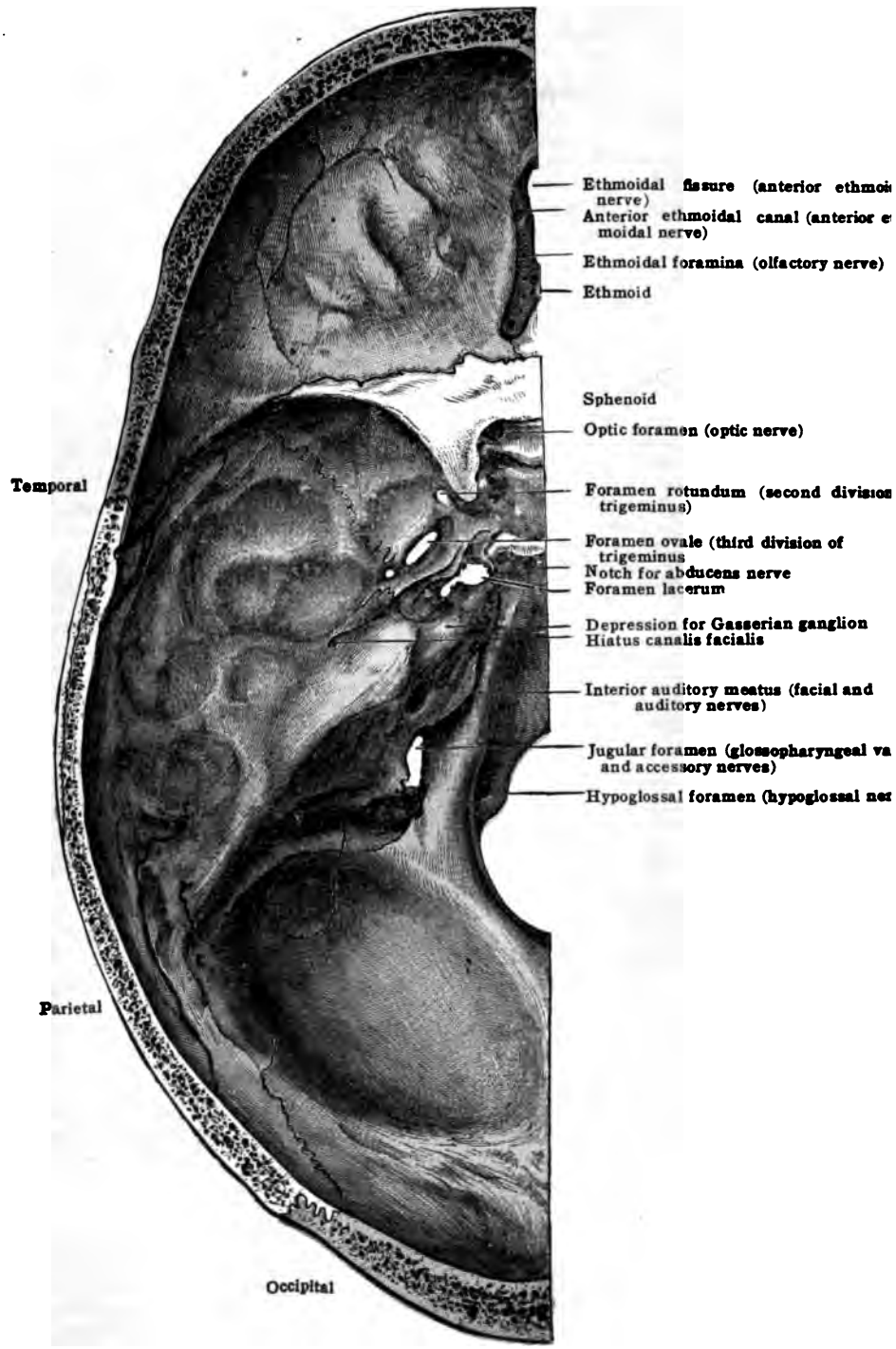
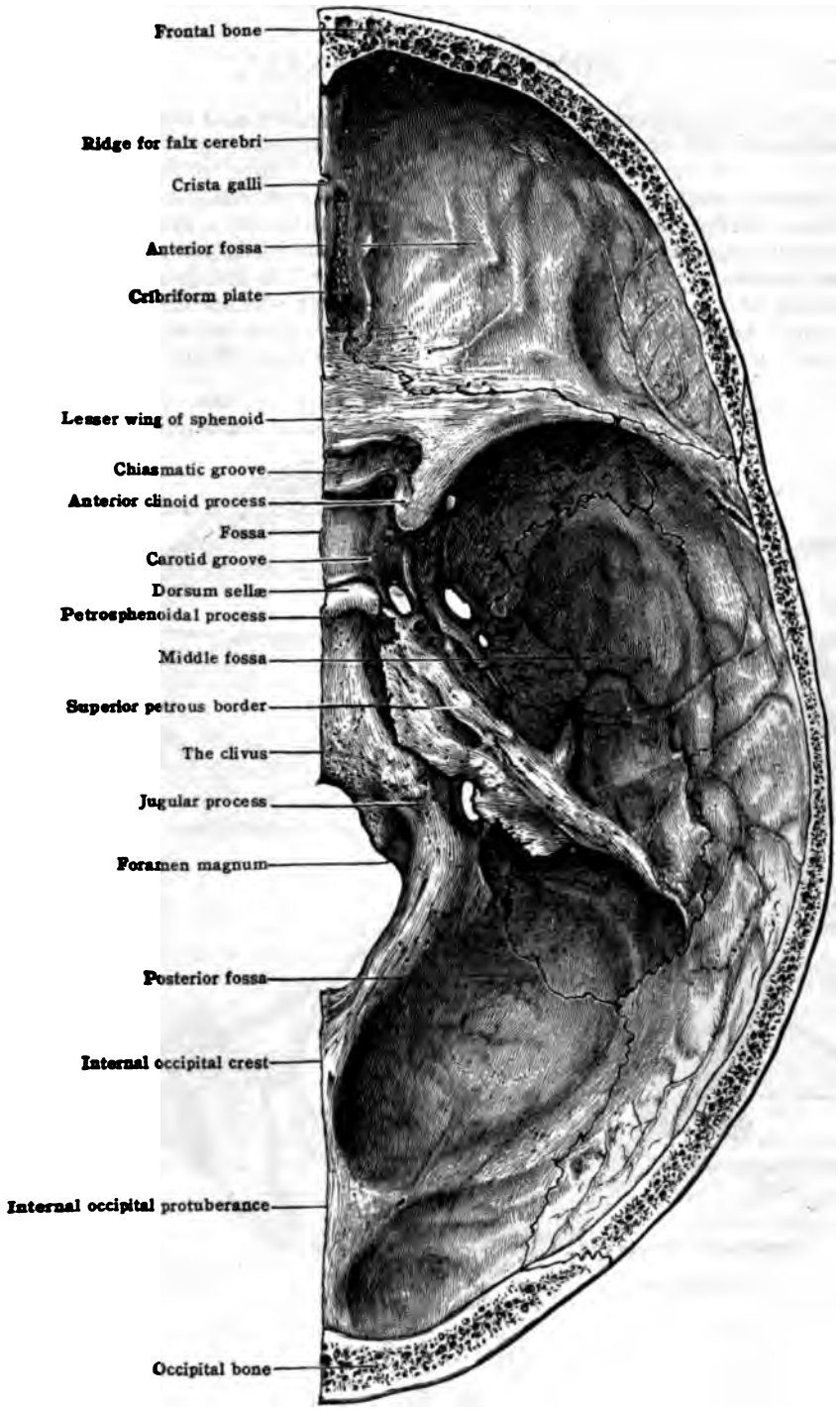


FIG. 129.—FLOOR OF THE CRANIUM.

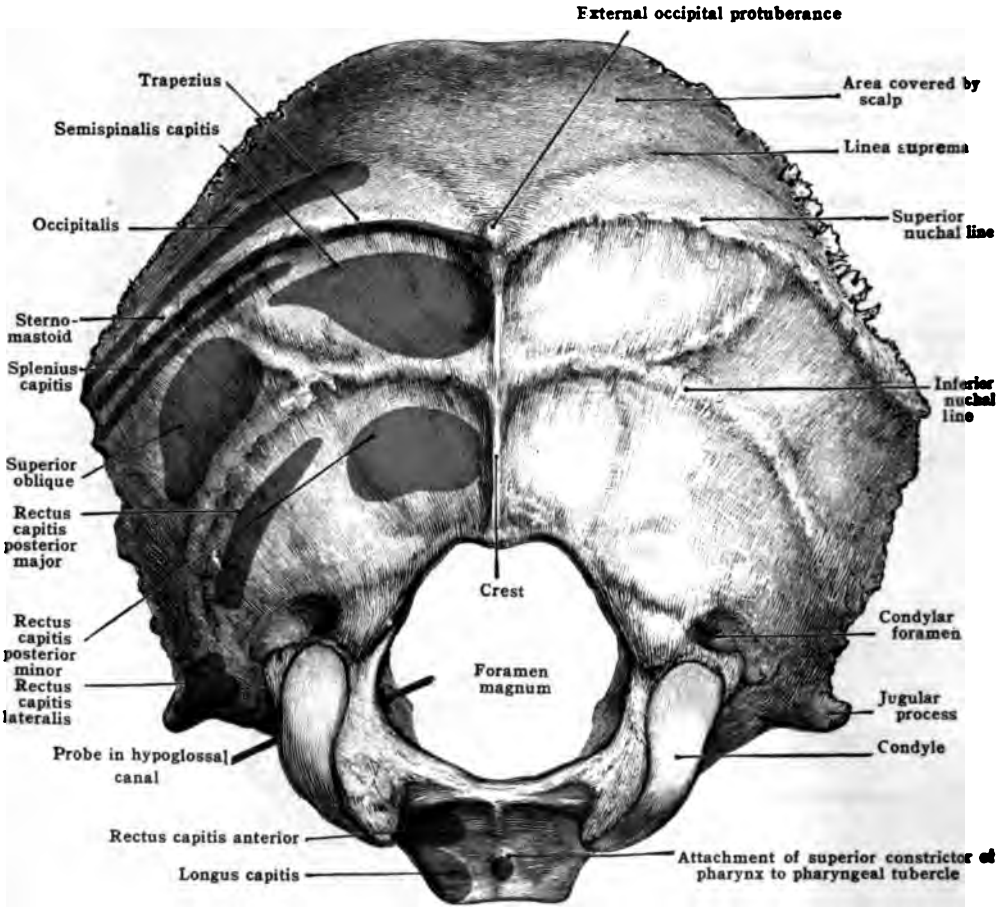


of the **hypoglossal canal,** transmitting the hypoglossal nerve. Still more laterally is the **jugular foramen,** a large opening between the occipital and petrous bones, which transmits the **vagus,** glossopharyngeal and accessory nerves and the transverse sinus. The groove for this sinus is shallow at its beginning (near the internal occipital protuberance) but deeper in its terminal portion [**sulcus sigmoideus**], where it presents a small foramen for the mastoid emissary vein.

BONES OF THE SKULL

The skull or cranium includes the cerebral cranium and the visceral cranium. The bones of the **cerebral cranium** are eight in number—viz., *occipital,* two *parietal, frontal,* two *temporal, sphenoid, ethmoid.* Those of the **visceral cranium** (facial bones), surrounding the mouth and nose, and forming with the cranium the orbital cavity for the reception of the eye, are fourteen in number—viz., two *maxillæ,* two *zygomatic* (*malar*), two *nasal,* two *lacrimal,* two *palate,* two *inferior conchæ* (*turbinates*), the *mandible,* and the *vomer.* A group of movable bones, comprising the *hyoid,* suspended from the basilar surface of the cranium, and three small bones, the *incus, malleus,* and *stapes,* situated in the middle ear or tympanic cavity, are also included in the enumeration of the bones of the skull.

FIG. 130.—THE OCCIPITAL. (External view.)



THE OCCIPITAL

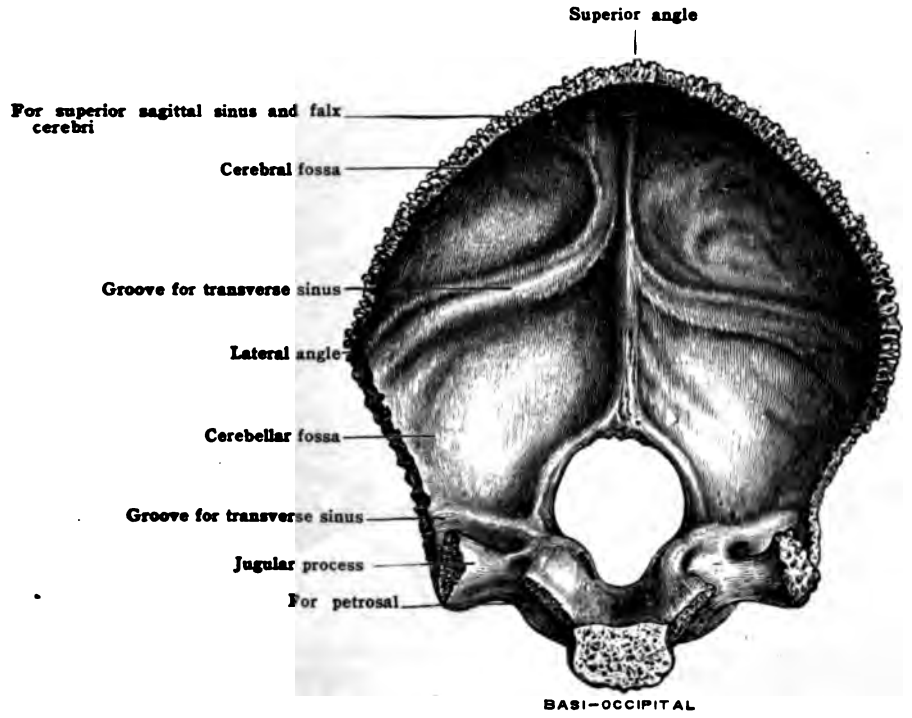
The **occipital bone** [os occipitale] (fig. 130) is situated at the **posterior and inferior** part of the cranium. In general, it is flattened and **trapezoid in shape,** curved upon itself so that one surface is convex and directed **backward** and somewhat downward, while the other is concave and looks in the **opposite** direction. It is pierced in its lower and front part by a large aperture, **the foramen magnum,** by which the vertebral canal communicates with **the cranial** cavity.

The occipital bone is divisible into four parts, **basilar, squamous,** and two **lateral** (or condylar), so arranged around the foramen magnum that the basilar part lies in front, the lateral parts on either side, and the squamous part above and behind.

Speaking generally, this division corresponds to the four separate parts of which the bone consists at the time of birth (fig. 134), known as the **basioccipital, supraoccipital,** and **exoccipital.** In early life these parts fuse together, the lines of junction of the supraoccipital and exoccipitals extending lateralward from the posterior margin of the foramen magnum, and those of the exoccipitals and basioccipital passing through the condyles near their anterior extremities. It must be noted, however, that the upper portion of the squamous part represents an additional bone, the **interparietal.**

The **squamous part** [squama occipitalis] (supraoccipital and interparietal) presents on its convex **posterior surface,** and midway between the superior angle and the posterior margin of the foramen magnum, a prominent tubercle known as the **external occipital protuberance** (or inion), from which a vertical ridge—the **external occipital crest**—runs downward and forward as far as the foramen. The protuberance and crest give attachment to the ligamentum nuchæ.

FIG. 131.—OCCIPITAL BONE, INTERNAL OR CEREBRAL SURFACE.



Arching lateralward on each side from the external occipital protuberance toward the lateral angle of the bone is a semicircular ridge, the **superior nuchal line** [linea nuchæ superior], which divides the surface into two parts—an upper [planum occipitale] and a lower [planum nuchale]. Above this line is a second less distinctly marked ridge—the **highest nuchal line** [linea nuchæ suprema].

It is the most curved of the three lines on this surface and gives attachment to the epicranial aponeurosis and to a few fibers of the *occipitalis* muscle. Between the superior and highest curved lines is a narrow crescentic area in which the bone is smoother and denser than the rest of the surface, whilst the part of the bone above the linea suprema is convex and covered by the scalp.

The lower part of the surface is very uneven and subdivided into an upper and a lower area by the **inferior nuchal line,** which runs laterally from the middle of the crest to the jugular process.

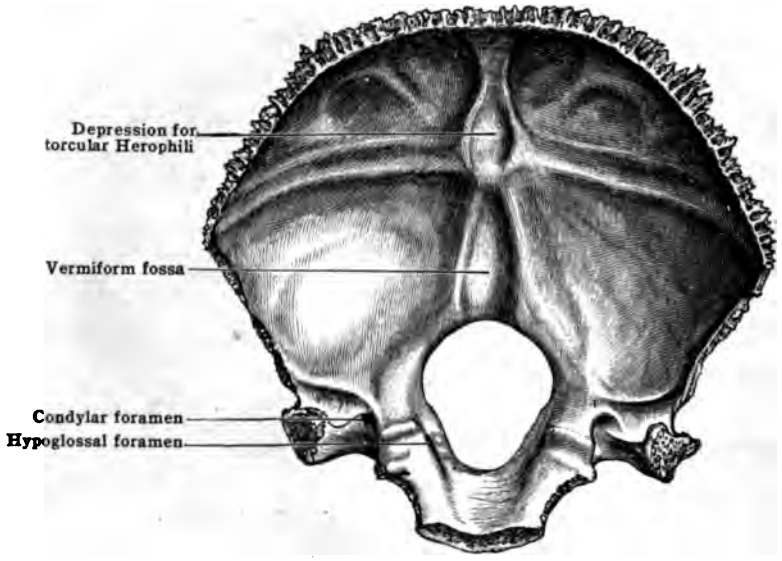
The curved lines and the areas thus mapped out between and below them give attachment to several muscles. To the superior nuchal line are attached, medially the *trapezius,* and laterally the *occipitalis* and *sternocleidomastoid;* the area between the superior and inferior

curved lines receives the *semispinalis capitis* (*complexus*) medially, and *splenius capitis* and *obliquus capitis superior* laterally; the inferior nuchal line and the area below it afford insertion to the *rectus capitis posterior minor* and *major*.

The **internal** or **cerebral surface** is deeply concave and marked by two grooved ridges which cross one another and divide the surface into four fossæ of which the two upper, triangular in form, lodge the occipital lobes of the cerebrum, and the two lower, more quadrilateral in outline, the lobes of the cerebellum. The vertical ridge extends from the superior angle to the foramen magnum and the transverse ridge from one lateral angle to the other. Their intersection forms the **eminentia cruciata,** the midpoint forming the **internal occipital protuberance.** The upper part of the vertical ridge is grooved [sulcus sagittalis] for the superior sagittal (longitudinal) sinus and gives attachment, by its margins, to the falx cerebri; the lower part is sharp and known as the **internal occipital crest,** and affords attachment to the falx cerebelli.

Approaching the foramen magnum the ridge divides, and the two parts become lost upon its margin. The angle of divergence sometimes presents a shallow fossa for the extremity of the vermis of the cerebellum, and is called the **vermiform fossa.** The two parts of the transverse ridge are deeply grooved [sulcus transversus] for the transverse (lateral) sinuses, and the

FIG. 132.—CEREBRAL SURFACE OF THE OCCIPITAL, SHOWING AN OCCASIONAL DISPOSITION OF THE CHANNELS.



margins of the groove give attachment to the tentorium cerebelli. To one side of the internal occipital protuberance is a wide space, where the vertical groove is continued into one of the lateral grooves (more frequently the right), for the confluens sinuum or *torcular Herophili;* it is sometimes exactly in the middle line (fig. 132).

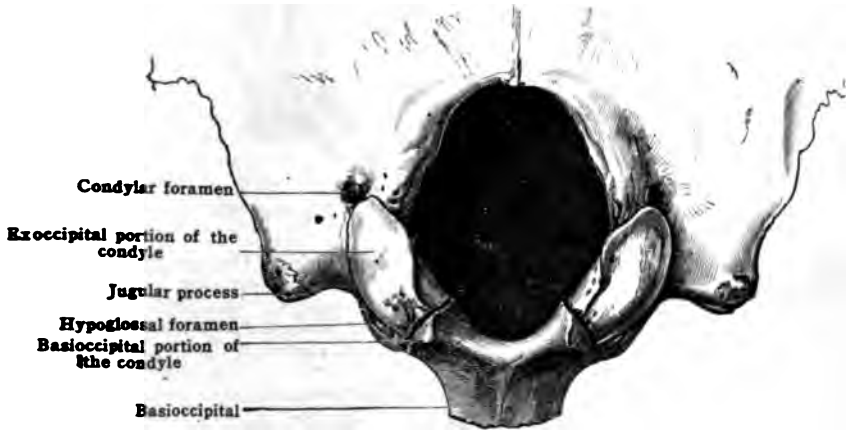
The squamous portion has three angles and four borders. The **superior angle** forming the summit of the bone is received into the space formed by the union of the two parietals. The **lateral angles** are very obtuse and correspond in situation with the lateral ends of the transverse ridges. Above the lateral angle on each side the margin is deeply serrated, forming the **lambdoid** or **superior border** which extends to the superior angle and articulates with the posterior border of the parietal in the lambdoid suture. The **mastoid** or **inferior border** extends from the lateral angle to the jugular process and articulates with the mastoid portion of the temporal.

The **lateral portions** [partes laterales] (exoccipitals) form the lateral boundaries of the foramen magnum and bear the condyles on their inferior surfaces. The **condyles** are two convex oval processes of bone with smooth articular surfaces, covered with cartilage in the recent state, for the superior articular processes of the atlas. They converge in front, and are somewhat everted. Their margins give attachment to the capsular ligaments of the occipitoatlantal joints and on the medial side of each is a prominent tubercle for the alar (lateral odontoid)

ligament. The anterior extremities of the condyles extend beyond the exoccipitals on the basioccipital portion of the bone. The **hypoglossal** (anterior condyloid) **foramen** or **canal** [canalis hypoglossi] perforates the bone at the base of the condyle, and is directed from the interior of the cranium, just above the foramen magnum, forward and laterally; it transmits the hypoglossal nerve and a twig of the ascending pharyngeal artery.

The hypoglossal foramen is sometimes double, being divided by a delicate spicule of bone. Above the canal is a smooth convexity known as the **tuberculum jugulare** sometimes marked by an oblique groove for the ninth, tenth and eleventh cranial nerves. Posterior to each condyle is a pit, the **condylar fossa,** which receives the hinder edge of the superior articular process of the atlas when the head is extended. The floor of the depression is occasionally perforated by the **condylar** (posterior condyloid) **canal** or **foramen** [canalis condyloideus], which transmits a vein from the transverse sinus. Projecting laterally opposite the condyle is a quadrilateral portion of bone known as the **jugular process,** the extremity of which is rough for articulation with the jugular facet on the petrous portion of the temporal bone. Up to twenty-five years the bones are united here by means of cartilage; about this age ossification of the cartilage takes place, and the jugular process thus becomes fused with the petrosal. Its anterior border is deeply notched to form the posterior boundary of the jugular foramen, and the notch is directly continuous with a groove on the upper surface which lodges the termination of the transverse sinus. In or near the groove is seen the inner opening of the condylar foramen. The lower surface of the process gives attachment to the *rectus capitis lateralis* and the oblique occipitoatlantal ligament. Occasionally the mastoid air-cells extend into this process and rarely a process of bone, representing the *paramastoid process* of many mammals, projects downward from its under aspect and may be so long as to join or articulate with the transverse process of the atlas.

FIG. 133.—THE FORAMEN MAGNUM AT THE SIXTH YEAR.



The **basilar portion** (basioccipital) is a quadrilateral plate of bone projecting forward and upward in front of the foramen magnum. Its superior surface presents a deep groove—the **basilar groove** [**clivus**]; it supports the medulla oblongata and gives attachment to the tectorial membrane (occipitoaxial ligament). The lower surface presents in the middle line a small elevation known as the **pharyngeal tubercle** for the attachment of the fibrous raphé of the pharynx.

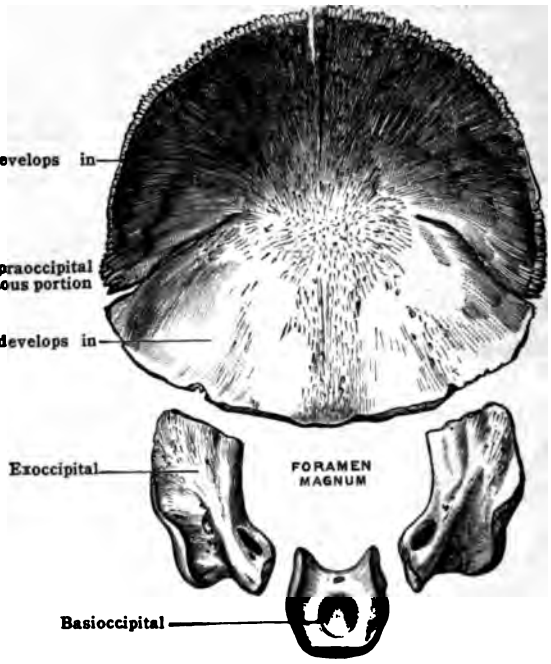
On each side of the middle line are impressions for the insertions of the *longus capitis* (*rectus capitis anterior major*) and *rectus capitis anterior* (*minor*), the impression for the latter being nearer to the condyle, and near the foramen magnum this surface gives attachment to the anterior occipitoatlantal ligament. Anteriorly the basilar process articulates by synchrondrosis with the body of the sphenoid up to twenty years of age, after which there is complete bony union. Posteriorly it presents a smooth rounded border forming the anterior boundary of the foramen magnum. It gives attachment to the apical odontoid ligament, and above this to the ascending portion of the crucial ligament. In the occipital bone at the sixth year the lateral extremities of this border are enlarged to form the basilar portion of the condyles. The lateral borders are rough below for articulation with the petrous portion of the temporal bones, but above, on either side of the basilar groove, is a half-groove, which, with a similar half-groove on the petrous portion of the temporal bone, lodges the inferior petrosal sinus.

The **foramen magnum** is oval in shape, with its long axis in a sagittal direction. It transmits the medulla oblongata and its membranes, the accessory nerves (spinal portions), the vertebral arteries, the anterior and posterior spinal arteries, and the tectorial membrane (occipitoaxial ligament). It is widest

behind, where it transmits the medulla, and is narrower in front, where it is encroached upon by the condyles.

Occasionally a facet is present on the anterior margin, forming a *third occipital condyle* for articulation with the dens. Between the condyles and behind the margin of the foramen magnum the posterior occipitoatlantal ligament obtains attachment.

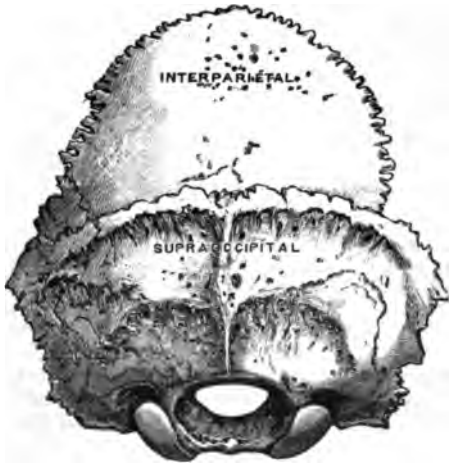
FIG. 134.—THE OCCIPITAL AT BIRTH. (Internal view.)


Interparietal portion (develops in membrane)
The interparietal and supraoccipital portions form the squamous portion of the adult
Supraoccipital portion (develops in cartilage)
Exoccipital
FORAMEN MAGNUM
Basioccipital

Blood-supply.—The occipital bone receives its blood-supply from the occipital, posterior auricular, middle meningeal, vertebral and the ascending pharyngeal arteries.

Articulations.—The occipital bone is connected by suture with the two parietals, the two temporals and the sphenoid; the condyles articulate with the atlas, and exceptionally the occipital articulates with the dens of the epistropheus by means of the third occipital condyle.

FIG. 135.—THE OCCIPITAL WITH A SEPARATE INTERPARIETAL.



Ossification.—The occipital bone develops in four pieces. The squamous portion is ossified from four centers, arranged in two pairs, which appear about the eighth week. The upper pair are deposited in membrane, and this part of the squamous portion represents the interparietal bone of many animals. The lower pair, deposited in cartilage, form the true supraoccipital element, and the four parts quickly coalesce near the situation of the future occipital protuberance. For many weeks two deep lateral fissures separate the interparietal and supraoccipital portions, and a membranous space extending from the center of the squamous

portion to the foramen magnum partially separates the lateral portions of the supraoccipital. This space is occupied later by a spicule of bone, and is of interest as being the opening through which the form of hernia of the brain and its meninges, known as occipital meningocele or encephalocele, occurs. The basioccipital and the two exoccipitals are ossified each from a single nucleus which appears in cartilage from the eighth to the tenth week.

At birth the bone consists of four parts united by strips of cartilage, and in the squamous portion fissures running in from the upper and lateral angles are still noticeable (fig. 134). The osseous union of the squamous and exoccipital is completed in the fifth year, and that of the exoccipitals with the basioccipital before the seventh year. Up to the twentieth year the basioccipital is united to the body of the sphenoid by an intervening piece of cartilage, but about that date ossific union begins and is completed in the course of two or three years.

Variations.—A shallow fossa occasionally found on the ventral surface of the basilar portion in front of the pharyngeal tubercle has been interpreted as a vestige of the canal of the notochord. The cerebral fossæ may be of unequal size and dissimilar in form. Various structures comparable to parts of an atlas have been observed about the foramen magnum. The occipital bears many resemblances in its development to an atlas vertebra and some of its varieties become intelligible when seen from this standpoint (Terry, Jour. Morph., 1917, 29: 281). Elevation of the area between the highest two curved lines gives rise to a *torus occipitalis*. Occasionally the interparietal portion remains separate throughout life (fig. 135), forming what has been termed the *inca bone*, or it may be represented by numerous detached ossicles or Wormian bones. In some cases a large Wormian bone, named the preinterparietal, is found, partly replacing the interparietal bone. A preinterparietal bone is found in some mammals, and it has occasionally been observed in the human fetal skull, rarely in the adult.

THE PARIETAL

The two **parietal bones** (figs. 136, 137), interposed between the frontal before and the occipital behind, form a large portion of the roof and sides of the cranium. Each parietal bone [os parietale] is quadrilateral in form, convex externally, concave internally, with two surfaces, four borders, and four angles.

The **parietal surface** is smooth and is crossed, just below the middle, by two curved lines known as the **temporal lines.** The superior line gives attachment to the temporal fascia; the lower, frequently the better marked, limits the origin of the *temporal* muscle; the narrow part of the surface enclosed between them is smoother than the rest. Immediately above the ridges is the most convex part of the bone, termed the **parietal eminence** [tuber parietale], best marked in young bones, and indicating the point where ossification began. Of the two divisions on the parietal surface marked off by the temporal lines, the upper is covered by the scalp, and the lower, somewhat striated, affords origin to the *temporal* muscle. Close to the upper border and near to the occipital angle is a small opening—the **parietal foramen**—which transmits a vein to the superior sagittal (longitudinal) sinus.

The **cerebral surface** is marked with slight depressions corresponding to the cerebral convolutions and by numerous deep, narrow furrows, running upward and backward from the sphenoidal angle and the lower border, for the middle meningeal vessels. A shallow depression running close to the superior border forms, with the one of the opposite side, a channel for the superior sagittal sinus, at the side of which are small irregular pits for the Pacchionian bodies [foveolæ granulares]. The pits are usually present in adult skulls, but are best marked in those of old persons. The margins of the groove for the superior sagittal sinus give attachment to the falx cerebri.

Borders.—The **sagittal** or **superior border,** the longest and thickest, is deeply serrated to articulate with the opposite parietal, with which it forms the **sagittal suture.** The **frontal** or **anterior border** articulates with the frontal to form the **coronal suture.** It is deeply serrated and bevelled, so that it is overlapped by the frontal above, but overlaps the edge of that bone below. The **occipital** or **posterior border** articulates with the occipital to form the **lambdoid suture,** and resembles the superior and anterior in being markedly serrated. The **squamosal** or **inferior border** is divided into three portions:—the anterior, thin and bevelled, is overlapped by the tip of the great wing of the sphenoid; the middle portion, arched and also bevelled, is overlapped by the squamous part of the temporal; and the posterior portion, thick and serrated, articulates with the mastoid portion of the temporal bone.

Angles.—The **frontal** or **anterior superior,** almost a right angle, occupies that part of the bone which at birth is membranous and forms part of the anterior fontanelle. The **sphenoidal** or **anterior inferior** angle is thin and prolonged

downward to articulate with the tip of the great wing of the sphenoid. Its inner surface is marked by a deep groove, sometimes converted into a canal for a short distance for the middle meningeal vessels (chiefly for the sinus). The **occipital** or **posterior superior** angle is obtuse and occupies that part which during fetal life

FIG. 136.—THE LEFT PARIETAL. (Outer surface.)

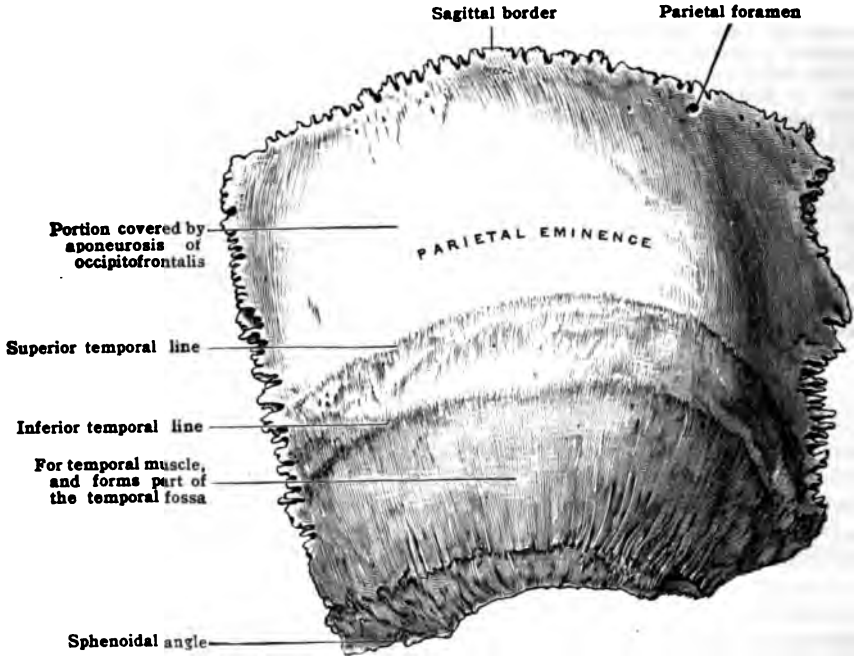
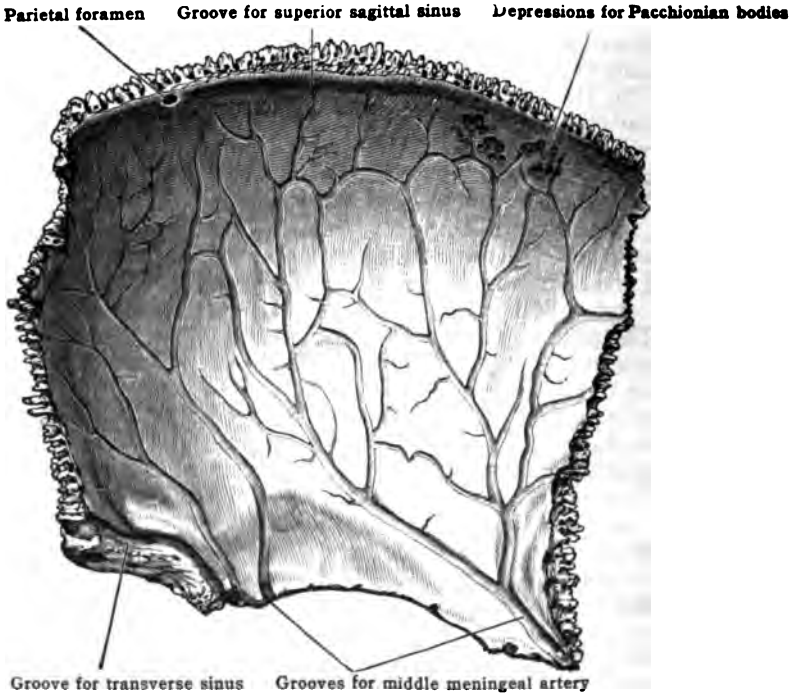


FIG. 137.—THE LEFT PARIETAL. (Inner surface.)


Parietal foramen
Groove for superior sagittal sinus
Depressions for Pacchionian bodies
Groove for transverse sinus
Grooves for middle meningeal artery

enters into the formation of the posterior fontanelle. The **mastoid** or **posterior inferior** angle is thick and articulates with the mastoid portion of the temporal bone. Its inner surface presents a shallow groove which lodges a part of the transverse (lateral) sinus.

Blood-supply.—The parietal bone receives its blood-supply from the middle meningeal, occipital and supraorbital arteries.

Articulations.—The parietal articulates with the occipital, frontal, sphenoid, temporal, its fellow of the opposite side, and the epipteric bone when present. Occasionally the temporal and epipteric bones exclude the parietal from articulation with the great wing of the sphenoid.

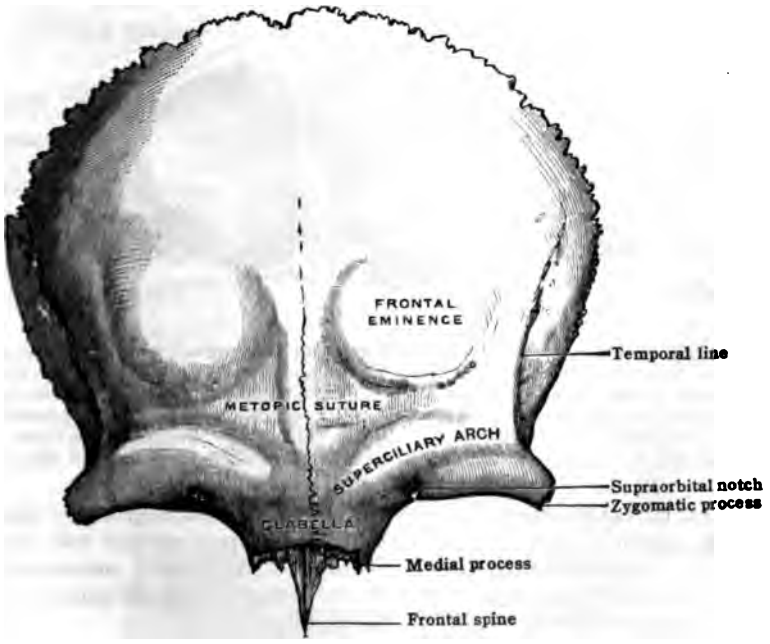
Ossification.—The parietal ossifies from two nuclei, one above the other, which appear in the outer layer of the membranous wall of the skull about the seventh week and fuse to form a single center in the third month. The ossification radiates in such a way as to leave a cleft at the upper part of the bone in front of the occipital angle, the cleft of the two sides forming a lozenge-shaped space across the sagittal suture known as the **sagittal fontanelle.** This is usually closed about the fifth month of intrauterine life, but traces may sometimes be recognized at the time of birth, and the parietal foramina are to be regarded as remains of the cleft. According to Dr. A. W. W. Lea, a well-developed sagittal fontanelle is present in 4.4 per cent. of infants at birth. In such cases it closes within the first two months of life, but at times it may remain open for at least eight months after birth and possibly longer (see p. 29).

Variations.—In addition to those referred to above, the following variations are of interest: conversion of the meningeal sulcus at the anteroinferior angle into a bony-walled canal; the occurrence of an *os bregmaticum;* symmetrical thinning over a large area of both parietals in the aged. Rarely the parietal bone is composed of two pieces, one above the other, and separated by an anteroposterior suture (subsagittal suture), more or less parallel with the sagittal suture. (Cf. Terry, Jour. Anat. & Phys., 1899, 33: 413.) In such cases the two primary centers of ossification fail to fuse.

THE FRONTAL

The **frontal bone** [os frontale] closes the cranium in front and is situated above the skeleton of the face. It consists of two portions—a **frontal** (*vertical*) **portion**

FIG. 138.—THE FRONTAL. (Anterior view.)

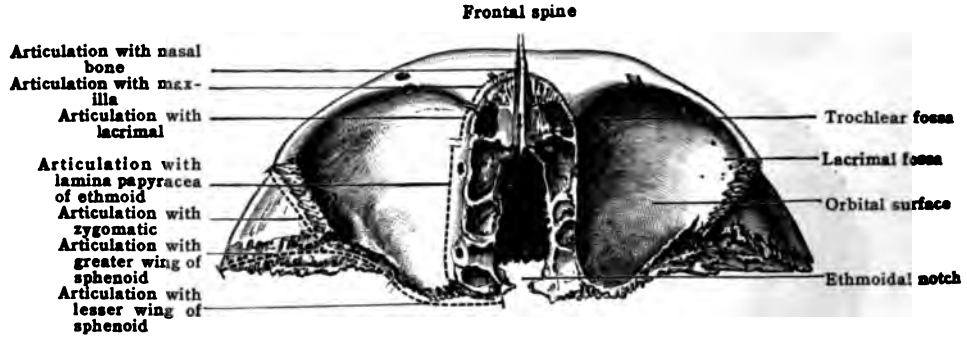


[squama frontalis], forming the convexity of the forehead, and an **orbital** (*horizontal*) **portion,** which enters into formation of the roof of each orbit (figs. 138, 139).

Frontal (*vertical*) **portion.**—The **frontal surface** is smooth and convex, and usually presents in the middle line above the root of the nose some traces of the suture which in young subjects traverses the bone from the upper to the lower part. This suture, known as the **frontal** or **metopic suture,** indicates the line of junction of the two lateral halves of which the bone consists at the time of birth; in the adult the suture is usually obliterated except at its lowest part. On each side is a rounded elevation, the **frontal eminence** [tuber frontale], very prominent in young bones, below which is a shallow groove, the **sulcus transversus,** separating the frontal eminence from the **superciliary arch.** The latter forms an arched projection above the margin of the orbit and corresponds to an air-cavity within

the bone known as the **frontal sinus.** The ridges of the two sides converge toward the median line, but are separated by a smooth surface called the **glabella** (nasal eminence). Below the arch the bone presents a sharp curved margin, the **supraorbital border,** forming the upper boundary of the circumference of the orbit and separating the frontal from the orbital portion of the bone. At the junction of its medial and intermediate third is a notch, sometimes converted into a foramen, and known as the **supraorbital notch** or **foramen;** it transmits the supraorbital nerve, artery, and vein, and presents a small opening for a vein of the diploe. Sometimes, a second less marked notch is present, medial to the supraorbital, and known as the **frontal notch;** it transmits one of the divisions of the supraorbital nerve. The extremities of the supraorbital border are directed downward and form the **medial** and **zygomatic** (**lateral angular**) **processes.** The prominent zygomatic process articulates with the zygomatic bone and receives superiorly two well-marked lines which converge somewhat as they curve downward and forward across the bone. These are the **superior** and **inferior temporal lines,** continuous with the temporal lines on the partietal bone, the upper giving attachment to the temporal fascia and the lower to the temporal muscle. Behind the lines is a slight concavity which forms part of the floor of the temporal fossa (**temporal surface**) and gives origin to the *temporal* muscle. The medial processes articulate with the lacrimals and form the lateral limits of the **nasal notch,** bounded in front by a rough, semilunar surface which articulates with the upper ends of the nasal bones and the frontal (nasal) processes of the maxillæ.

FIG. 139.—THE FRONTAL BONE. (Inferior view.)



In the concavity of the notch lies the **nasal portion** of the frontal, which projects somewhat beneath the nasal bones and the nasal processes of the maxillæ. It is divisible into three parts; —a median **frontal** (nasal) **spine,** which descends in the nasal septum between the crest of the nasal bones in front and the vertical plate of the ethmoid behind, and, on the posterior aspect of the process, two grooved surfaces, one on either side of the median ridge from which the frontal (nasal) spine is continued. Each surface enters into the formation of the roof of the nasal fossa.

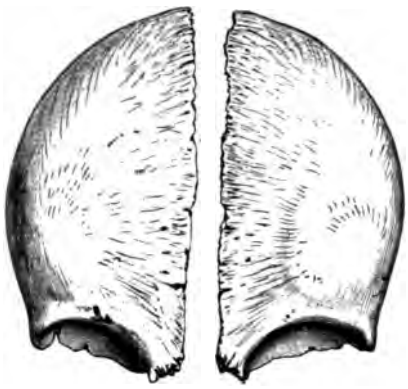
The **cerebral surface** presents in the middle line a vertical groove—the **sagittal sulcus**—which descends from the middle of the upper margin and lodges the superior sagittal (longitudinal) sinus. Below, the groove is succeeded by the **frontal crest,** which terminates near the lower margin at a small notch, converted into a foramen by articulation with the ethmoid.

The foramen is called the **foramen cecum,** and is generally closed below, but sometimes transmits a vein from the nasal fossæ to the superior sagittal (longitudinal) sinus. The frontal crest serves for the attachment of the anterior part of the falx cerebri. On each side of the middle line the bone is deeply concave, presenting depressions for the cerebral convolutions and numerous small furrows which, running medially from the lateral margin, lodge branches of the middle meningeal vessels. At the upper part of the surface, on either side of the frontal sulcus, are some depressions for Pacchionian bodies.

The **horizontal portion** consists of two somewhat triangular plates of bone called the **orbital plates,** which, separated from one another by the **ethmoidal notch** [incisura ethmoidalis], form the greater part of the roof of each orbit. When the bones are articulated, the notch is filled up by the cribriform plate of the ethmoid, and the half-cells on the upper surface of the lateral mass of the ethmoid are completed by the depressions or half-cells which occupy the irregular margins of the notch. Traversing these edges transversely are two grooves which com-

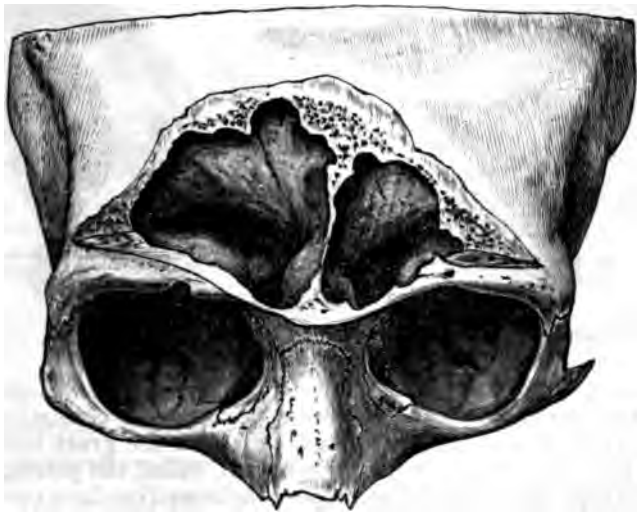
plete, with the ethmoid, the **anterior** and **posterior ethmoidal canals.** The anterior transmits the anterior ethmoidal nerve and vessels; the posterior transmits the posterior ethmoidal nerve and vessels, and both canals open on the medial wall of the orbit. Farther forward, on either side of the nasal spine, are the openings of the **frontal sinuses,** two irregular air-spaces (fig. 141) which extend within the bone for a variable distance and give rise to the superciliary arches. Each is lined by mucous membrane and communicates with the nasal fossa. (Cf. pp. 1235 and 1335.)

FIG. 140.—THE FRONTAL BONE AT BIRTH.



The **inferior surface** of each orbital plate, smooth and concave, presents immediately behind the lateral angular process the **lacrimal fossa,** for the lacrimal gland. Close to the medial angular process is a depression called the **trochlear fossa** [fovea trochlearis], which gives attachment to the cartilaginous pulley for the *superior oblique* muscle. The **superior surface** of each plate is convex and strongly marked by eminences and depressions for the convolutions on the orbital surface of the cerebrum.

FIG. 141.—UNUSUALLY LARGE FRONTAL SINUSES.



Borders.—The articular border of the frontal portion (**parietal margin**) forms a little more than a semicircle. It is thick, strongly serrated, and bevelled so as to overlap the parietal above and to be overlapped by the edge of that bone below. The border is continued inferiorly into a triangular rough surface on either side, which articulates with the great wing of the sphenoid. The posterior border of the orbital portion is thin and articulated with the lesser wing of the sphenoid.

Blood-supply.—The blood-vessels for the supply of the vertical portion are derived from the frontal and supraorbital arteries, which enter on the outer surface, and from the middle and small meningeal, which enter on the cerebral surface. The horizontal portion receives branches from the ethmoidal, and other branches of the ophthalmic, as well as from the meningeal.

Articulations.—The frontal articulates with the parietal, sphenoid, ethmoid, lacrimal, zygomatic (malar), maxilla, and nasal bones. Also, with the epipteric bones when present, and occasionally with the squamous portion of the temporal, and with the sphenoidal concha when it reaches the orbit.

Ossification.—The frontal is ossified from two nuclei deposited in the outer layer of the membranous wall of the cranium, in the situations of the future frontal eminences. These nuclei appear about the eighth week, and ossification spreads quickly through the membrane. At birth the bones are quite distinct, but subsequently they articulate with each other in the median line to form the metopic suture. In the majority of cases the suture is obliterated by osseous union, which commences about the second year, though in a few cases the bones remain distinct throughout life.

After the two halves of the bone have united, osseous material is deposited at the lower end of the metopic suture to form the frontal spine, which is one of the distinguishing features of the human frontal bone. The spine appears about the twelfth year, and soon consolidates with the frontal bone above. Accessory nuclei are sometimes seen between this bone and the lacrimal and may persist as Wormian ossicles.

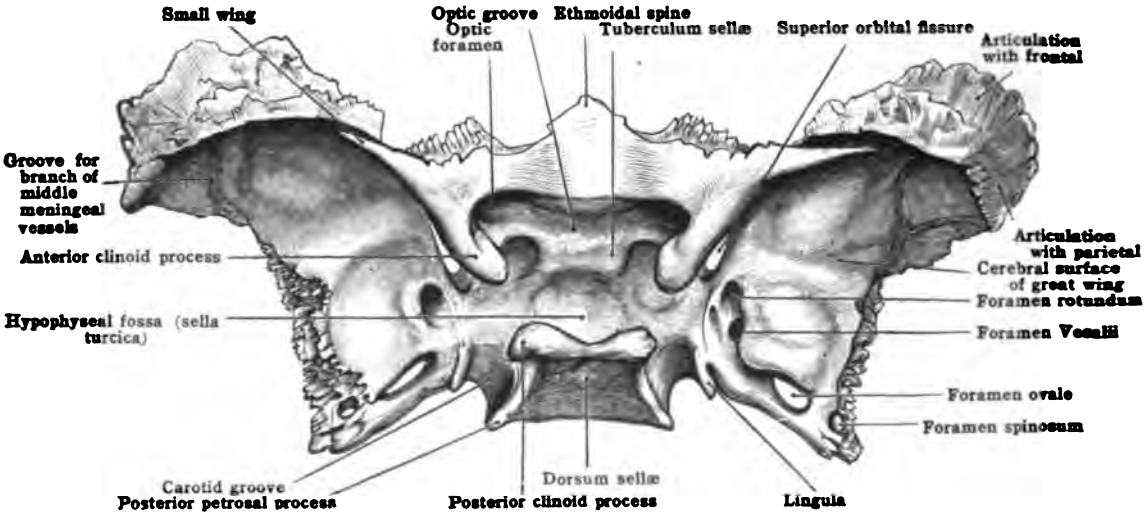
The frontal sinuses appear in the fetus but do not become conspicuous until the seventh year as prolongations upward from the middle nasal meatus (see p. 1238). They increase in size up to old age. As they grow they extend in three directions, viz., upward, laterally, and backward along the orbital roof. A bony septum, usually complete, separates the sinuses of the two sides, and they are larger in the male than in the female. The superciliary arches are not altogether reliable guides as to the size of the sinuses, since examples are seen in which the arches are low and the sinuses large.

Variations.—The frontal sinuses may be extraordinarily large (fig. 141), extending through the orbital plates, into the zygomatic processes and high up into the squama: or they may be quite small or absent entirely. Metopism occurs most frequently in the white races.

THE SPHENOID

The **sphenoid** [os sphenoidale] (figs. 142–145) is situated in the base of the skull and takes part in the formation of the floor of the anterior, middle, and

FIG. 142.—THE SPHENOID, FROM ABOVE.

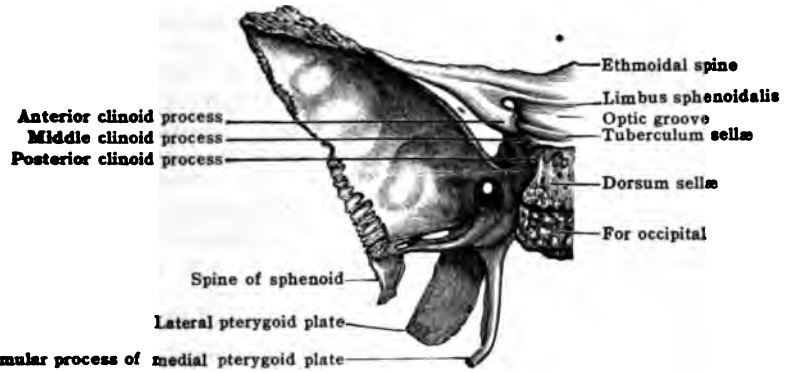


posterior cranial fossæ, of the temporal and nasal fossæ, and of the cavity of the orbit. It is very irregular in shape and is described as consisting of a central part or **body,** two pairs of lateral expansions called the **great** and **small wings,** and a pair of processes which project downward, called the **pterygoid processes.**

The **body,** irregularly cuboidal in shape, is hollowed out into two large cavities known as the **sphenoidal sinuses,** separated by a thin **sphenoidal septum** and opening in front by two large apertures into the nasal fossæ. The **superior surface** presents the following points of interest: In front is seen a prominent spine, the **ethmoidal spine,** which articulates with the hinder edge of the cribriform plate of the ethmoid. The surface behind this is smooth and frequently presents two longitudinal grooves, one on either side of the median line, for the olfactory bulbs; it is limited posteriorly by a ridge, the **limbus sphenoidalis,** which forms the anterior border of the narrow transverse **optic groove** [sulcus chiasmatis], above and behind which lies the optic commissure. The groove terminates on

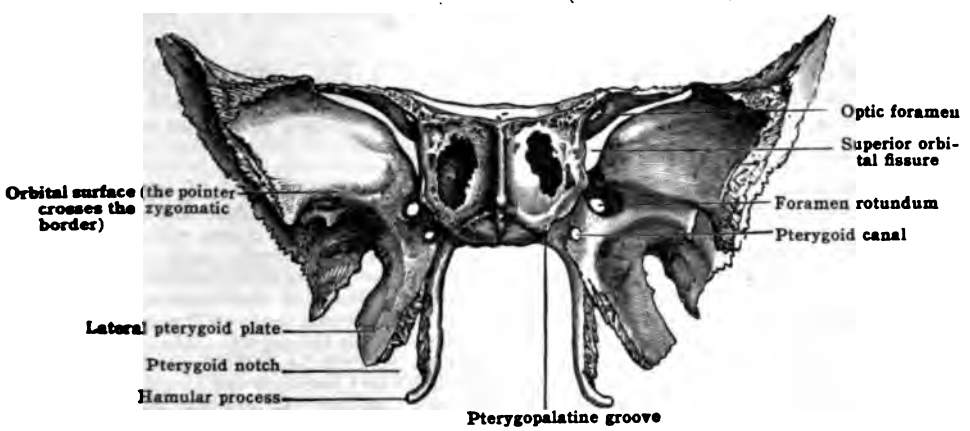
each side in the **optic foramen,** which perforates the root of the small wing and transmits the optic nerve and the ophthalmic artery. Behind the optic groove is the **tuberculum sellæ,** indicating the line of junction of the two parts of which the body is formed (pre- and postsphenoid) and presenting laterally the inconstant **middle clinoid processes;** still further back is a deep depression, the **hypophyseal fossa** [**sella turcica**], which lodges the hypophysis cerebri. The floor of the fossa presents numerous foramina for blood-vessels, and in the fetus the superior orifice of a narrow passage called the **craniopharyngeal canal.** The posterior boundary of the fossa is formed by a quadrilateral plate of bone, the **dorsum**

FIG. 143.—THE LEFT HALF OF THE SPHENOID. (Posterior view.)



sellæ (dorsum ephippii), the posterior surface of which is sloped in continuation with the basilar groove of the occipital bone. The superior angles of the plate are surmounted by the **posterior clinoid processes,** which give attachment to the tentorium cerebelli and the interclinoid ligaments. Below the clinoid process, on each side of the dorsum sellæ (sometimes at the suture between the sphenoid and apex of petrosal), a notch is seen, converted into a foramen by the dura mater, for the passage of the abducens nerve, and at the inferior angle the **posterior petrosal process,** which articulates with the apex of the petrous portion of the temporal bone, forming the medial boundary of the **foramen lacerum.** The dorsum sellæ

FIG. 144.—THE SPHENOID. (Anterior view.)



is slightly concave posteriorly (the clivus) and supports the pons Varoli and the basilar artery.

The inferior surface presents in the middle line a prominent ridge known as the **rostrum,** which is received into a deep depression between the alæ of the vomer. On each side is the **vaginal process** of the medial pterygoid plate, directed horizontally and medially, which, with the alæ of the vomer, covers the greater part of this surface. The remainder is rough and clothed by the mucous membrane of the roof of the pharynx.

The anterior surface is divided into two lateral halves by the **sphenoidal**

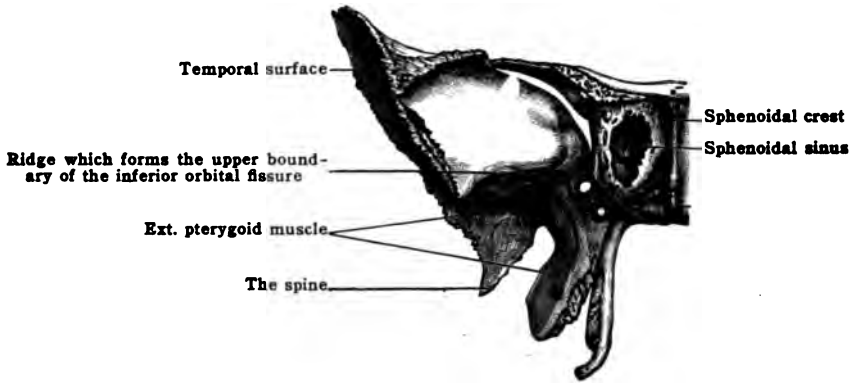
crest, a vertical ridge of bone continuous above with the ethmoidal spine, below with the rostrum, and articulating in front with the perpendicular plate of the ethmoid. The surface on each side presents a rough lateral margin for articulation with the lateral mass of the ethmoid and the orbital process of the palate bone. Elsewhere it is smooth, and enters into the formation of the roof of the nasal fossæ, presenting superiorly the irregular apertures of the sphenoidal sinuses.

The body is not much hollowed until after the sixth year, but from that time the sinuses increase in size as age advances. Except for the apertures just mentioned, they are closed below and in front by the two **sphenoidal conchæ** (turbinate bones) originally distinct, but in the adult usually incorporated with the sphenoid.

The **posterior surface** is united to the basioccipital, up to the twentieth year, by a disk of hyaline cartilage forming a synchondrosis, but afterward this becomes ossified and the two bones then form one piece.

The **lateral surface** of the body gives attachment to the two wings, and its fore part is free where it forms the medial boundary of the superior orbital fissure and the posterior part of the medial wall of the orbit. Above the line of attachment of the great wing is a broad groove which lodges the internal carotid artery and the cavernous sinus, called the **carotid groove.** It is deepest where it curves behind the root of the process, and this part is bounded along its lateral margin by a slender ridge of bone named the **lingula** (fig. 142), which projects backward in the angle between the body and the great wing.

FIG. 145.—RIGHT HALF OF SPHENOID. (Anterior view.)



The **small or orbital wings** [alæ parvæ] are two thin, triangular plates of bone extending nearly horizontally and laterally on a level with the front part of the upper surface of the body. Each arises medially by two processes or roots, the upper thin and flat, the lower thick and rounded.

Near the junction of the lower root with the body is a small tubercle for the attachment of the common tendon of three ocular muscles—viz., the *superior, medial,* and upper head of *lateral rectus*—and between the two roots is the **optic foramen.** The lateral extremity, slender and pointed, approaches the great wing, but, as a rule, does not actually touch it. The superior surface, smooth and slightly concave, forms the posterior part of the anterior fossa of the cranium. The inferior surface constitutes a portion of the roof of each orbit and overhangs the **superior orbital (or sphenoidal) fissure,** the elongated opening between the small and great wings. The anterior border is serrated for articulation with the orbital plate of the frontal, and the posterior border, smooth and rounded, is received into the Sylvian fissure of the cerebrum. Moreover, the posterior border forms the boundary between the anterior and middle cranial fossæ and is prolonged at its medial extremity to form the **anterior clinoid process.** Between the tuberculum sellæ and the anterior clinoid process is a semicircular notch which represents the termination of the carotid groove. It is sometimes converted into a foramen, the **caroticoclinoid foramen,** by a spicule of bone which bridges across from the anterior clinoid to the **middle clinoid process**; the latter is a small tubercle frequently seen on each side, in front of the hypophyseal fossa, and lateral to the tuberculum sellæ; the foramen transmits the internal carotid artery, and the spicule of bone which may complete the foramen is formed by ossification of the caroticoclinoid ligament.

The **great** or **temporal wings** [alæ magnæ], arising from the lateral surface of the body, extend laterally and then upward and forward. The posterior part is placed horizontally and projects backward into the angle between the squamous and petrous portions of the temporal bone. From the under aspect of its pointed

extremity the **spine,** which is grooved medially by the chorda tympani nerve (Lucas), projects downward. The spine serves for the attachment of the sphenomandibular ligament and a few fibers of the *tensor veli palatini*. Each wing presents four surfaces and four borders.

The **cerebral** or **superior surface** is smooth and concave. It enters into the formation of the middle cranial fossa, supports the temporal lobe of the cerebrum, and presents several foramina. At the anterior and medial part is the **foramen rotundum** for the second division of the fifth nerve, and behind and lateral to it, near the posterior margin of the great wing, is the large **foramen ovale,** transmitting the third division of the trigeminal nerve, the small meningeal artery, and an emissary vein from the cavernous sinus.

Behind and lateral to the foramen ovale is the small circular **foramen spinosum,** sometimes incomplete, for the passage of the middle meningeal vessels, and the recurrent branch of the third division of the trigeminal. Between the foramen ovale and the foramen rotundum is the inconstant **foramen Vesalii,** which transmits a small emissary vein from the cavernous sinus; and on the plate of bone, behind and medial to the foramen ovale (sphenopetrosal lamina), a minute canal is occasionally seen—the **canaliculus innominatus**—through which the small superficial petrosal nerve escapes from the skull. When the canaliculus is absent, the nerve passes through the foramen ovale.

The **anterior surface** looks medially and forward and consists of two divisions—a quadrilateral or **orbital** surface, which forms the chief part of the lateral wall of the orbit, and a smaller, inferior or **sphenomaxillary** surface, situated above the pterygoid process and perforated by the foramen rotundum; this inferior part forms the posterior wall of the pterygopalatine fossa.

The lateral or **squamozygomatic surface** is divided by a prominent **infratemporal ridge** into a superior portion, which forms part of the temporal fossa and affords attachment to the *temporal* muscle, and an inferior part, which looks downward into the zygomatic fossa and gives attachment to the *external pterygoid* muscle; the inferior part joins the lateral surface of the lateral pterygoid plate, and presents the inferior orifices of the foramen ovale, foramen spinosum, and foramen of Vesalius.

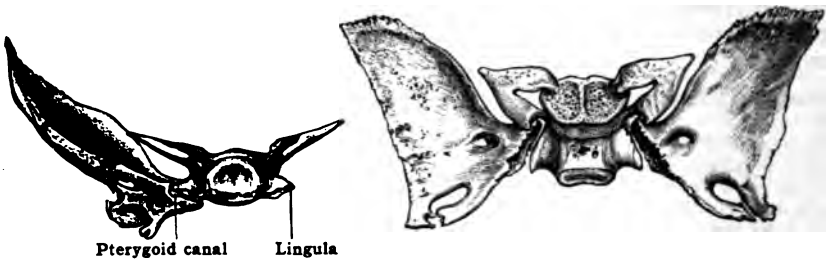
Borders of the great wing.—The **posterior border** extends from the body to the spine. By its lateral third it articulates with the petrous portion of the temporal bone, whilst the medial two-thirds form the anterior boundary of the foramen lacerum. The **squamosal border** is serrated behind and bevelled in front for articulation with the squamous portion of the temporal bone, whilst its upper extremity, or summit, is bevelled on its inner aspect, for the anterior inferior angle of the parietal. Immediately in front of the upper extremity is a rough, triangular, sutural area for the frontal, the sides of which are formed by the upper margins of the superior, anterior, and lateral surfaces respectively. The **zygomatic** or **anterior border** separates the orbital and temporal surfaces and articulates with the zygomatic, and by its lower angle, in many skulls, also with the maxilla. Below the anterior border is a short horizontal ridge, non-articular, which separates the sphenomaxillary and zygomatic surfaces. Above and medially, where the orbital and cerebral surfaces meet, is the sharp **medial border,** which forms the lower boundary of the **superior orbital fissure,** serving for the passage of the third, fourth, three branches of the first division of the trigeminal, and the abducens cranial nerves, the orbital branch of the middle meningeal artery, a recurrent branch from the lacrimal artery, some twigs from the cavernous plexus of the sympathetic, and one or two ophthalmic veins. Near the middle of the border is a small tubercle for the origin of the lower head of the *lateral rectus* muscle.

The **pterygoid processes** project downward from the junction of the body and the great wings. Each consists of two plates, one shorter and broader, the **lateral pterygoid plate** [lamina lateralis], the other longer and narrower, the **medial pterygoid plate** [lamina medialis]. They are united in front, but diverge behind so as to enclose between them the **pterygoid fossa** in which lie the *internal pterygoid* and *tensor veli palatini* muscles. The lateral pterygoid plate is turned a little laterally and by its lateral surface, which looks into the infratemporal fossa, affords origin to the *external pterygoid* muscle, and from its medial surface the *internal pterygoid* takes origin.

In front, the two plates are joined above, but diverge below, leaving a gap—the **pterygoid notch**—occupied, in the articulated skull, by the pyramidal process of the palate. Superiorly, they form a triangular surface which looks into the pterygopalatine fossa and presents the anterior orifice of the pterygoid canal. The anterior border of the medial pterygoid plate articulates with the posterior border of the vertical plate of the palate. The medial pterygoid plate is prolonged below into a slender, hook-like or **hamular process** [hamulus pterygoideus], smooth on the under aspect for the tendon of the *tensor veli palatini*, which plays round it. Superiorly, the medial plate extends medially on the under surface of the body, forming the

vaginal process, which articulates with the ala of the vomer and the sphenoidal process of the palate. The vaginal process presents, on the under surface, a small groove which, with the sphenoidal process of the palate, forms the **pharyngeal canal** for the transmission of branches of the sphenopalatine vessels and ganglion. The medial surface of the medial pterygoid plate forms part of the lateral boundary of the nasal fossa, and the lateral surface, the medial boundary of the pterygoid fossa. The posterior border presents superiorly a well-marked prominence, the **pterygoid tubercle,** above and to the lateral side of which is the posterior orifice of the **pterygoid canal.** The latter pierces the bone in the sagittal direction at the root of the medial

FIG. 146.—THE SPHENOID AT BIRTH.



pterygoid plate and transmits the Vidian vessels and nerve. Some distance below the tubercle is a projection, called the **processus tubarius,** which supports the cartilage of the tuba auditiva (Eustachian tube). From the lower third of the posterior border and from the hamular process, the *superior constrictor* of the pharynx takes origin, and from the depression known as the **scaphoid fossa,** situated in the upper part of the recess between the two pterygoid plates, the *tensor veli palatini* arises.

Blood-supply.—The sphenoid is supplied by branches of the middle and small meningeal arteries, the deep temporal and other branches of the internal maxillary artery—viz., the Vidian and sphenopalatine. The body of the bone also receives twigs from the internal carotid.

FIG. 147.—THE JUGUM SPHENOIDALE.

Articulations.—The sphenoid articulates with all the bones of the cranium—viz., occipital, parietal, frontal, ethmoid, temporal, and sphenoidal conchæ; also with the palate, vomer, zygomatic, epipteric bone when present, and occasionally with the maxilla.

Ossification.—The sphenoid is divided, up to the seventh or eighth month of intrauterine life, into an anterior or **presphenoid** portion, including the part of the body in front of the tuberculum sellæ and the small wings, and a **postsphenoid** portion, the part behind the tuberculum

FIG. 148.—THE INFERIOR SURFACE OF PRESPHENOID AT THE SIXTH YEAR.

sellæ including the hypophyseal fossa and the great wings. The two portions of the body join together before birth, but in many animals the division is persistent throughout life.

The presphenoid portion ossifies in cartilage from four centers, one of which gives rise to each lesser wing (**orbitosphenoid**) and a pair to the body of the presphenoid. In the formation of the postsphenoidal portion both cartilage and membrane bone participate, the pterygoid plates being formed in membrane, while the rest of the portion, together with the hamular process, ossifies from cartilage. (Fawcett.). At about the eighth week a center appears at the base of each greater wing (**alisphenoid**), and at about the same time a pair of centers appear in the body (**basisphenoid**) and later one in each lingula (**sphenotic**). The medial pterygoid

plates are formed from membrane investing the cartilage, in which a center appears for the hamulus. The lateral plate is formed in membrane and a considerable part of the greater wing is also membranous in origin (see epipteric bone).

At birth (fig. 146) the bone consists of three pieces. The median piece includes the basisphenoid and linguläe, conjoined with the presphenoid, carrying the orbitosphenoids. The two lateral pieces are the alisphenoids, carrying the medial pterygoid plates. The dorsum sellæ is cartilaginous. A canal, known as the **craniopharyngeal canal**, extends into the body from the sella turcica and sometimes reaches its under surface. It contains a process of dura mater, and represents the remains of the canal in the base of the cranium, through which the hypophyseal stalk extended upward to the hypophysis.

The great wings are joined to the linguläe by cartilage, but in the course of the first year bony union takes place. About the same time the orbitosphenoids meet and fuse in the midline to form the **jugum sphenoidale** (fig. 147), which thus excludes the anterior part of the presphenoid from the cranial cavity. For some years the body of the presphenoid is broad and rounded inferiorly (fig. 148). The posterior clinoid processes chondrify separately, a fact which throws some light on the occasional absence of these processes.

THE SPHENOIDAL CONCHÆ

The **sphenoidal conchæ (or turbinate bones;** bones of Bertin) (figs. 149, 150) may be obtained as distinct ossicles about the fifth year, and resemble in shape two hollow cones flattened in three planes. At this date each is wedged in between the under surface of the presphenoid and the orbital and sphenoidal processes of the palate bone, with the apex of the cone directed backward as far as the vaginal process of the medial pterygoid plate. Of its three surfaces, the lateral is in relation with the pterygopalatine fossa, and occasionally extends upward between the sphenoid and the lamina papyracea of the ethmoid, to appear on the medial wall of the orbit (fig. 168). The inferior surface forms the upper boundary of the sphenopalatine foramen and enters into formation of the posterior part of the roof of the nasal fossa. The superior surface lies flattened against the under surface of the presphenoid, while the base of the cone is in contact with the lateral mass of the ethmoid.

FIG. 149.—THE SPHENOIDAL CONCHA AT THE SIXTH YEAR.

FIG. 150.—THE SPHENOIDAL CONCHÆ FROM AN OLD SKULL.

The deposits of earthy matter from which the sphenoidal conchæ are formed appear at the fifth month. At birth each forms a small triangular lamina in the perichondrium of the ethmovomerine plate near its junction with the presphenoid, and partially encloses a small recess from the mucous membrane of the nose, which becomes the sphenoidal sinus. By the third year the bone has surrounded the sinus, forming an osseous capsule, conical in shape, the circular orifice which represents the base becoming the sphenoidal foramen. As the cavity enlarges the medial wall is absorbed, and the medial wall of the sinus is then formed by the presphenoid. The bones are subsequently ankylosed in many skulls with the ethmoid, whence they are often regarded as parts of that bone. More frequently they fuse with the presphenoid, and less frequently with the palate bones. After the twelfth year they can rarely be separated from the skull without damage. In many disarticulated skulls they are so broken up that a portion is found on the sphenoid, fragments on the palate bones, and the remainder attached to the ethmoid. Sometimes, even in old skulls, they are represented by a very thin triangular plate on each side of the rostrum of the sphenoid (fig. 150).

Variations.—The variability of the middle clinoid process has been mentioned. The superior part of the dorsum sellæ may consist of a separate bar of bone, or may be connected with the apex of the petrous bone. Foramina brought about by bridges of bone between the posterior margin of the greater wing and the spine (pterygospinous, transmitting the nerve of the internal pterygoid) and between the process and the great wing (crotaphitico-buccinatorius, for the lesser division of the mandibular nerve) are rarely observed. Persistence of the craniopharyngeal canal is sometimes seen.

THE EPIPTERIC AND WORMIAN BONES

The **epipterics** are scale-like bones which occupy anterolateral fontanelles. Each epipteric bone is wedged between the squamozygomatic portion of the temporal, frontal, great wing of sphenoid, and the parietal, and is present in most skulls between the second and fifteenth year. After that date it may persist as a separate ossicle, or unite with the sphenoid, the frontal, or the squamozygomatic. The epipteric bone is preformed in membrane, and appears as a series of bony granules in the course of the first year.

The **Wormian or sutural bones** (ossa suturarum) are small, irregularly shaped ossicles, often found in the sutures of the cranium, especially those in relation with the parietal bones. They sometimes occur in great numbers; as many as a hundred have been counted in one skull. They are rarely present in the sutures of the face.

THE TEMPORAL BONE

The **temporal bone** [os temporale], situated at the side and the base of the cranium, contains the organ of hearing and articulates with the lower jaw. It is

FIG. 151.—THE TEMPORAL BONE AT BIRTH. (Constituent parts.)

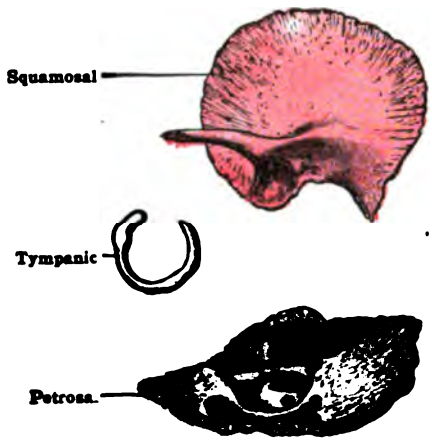
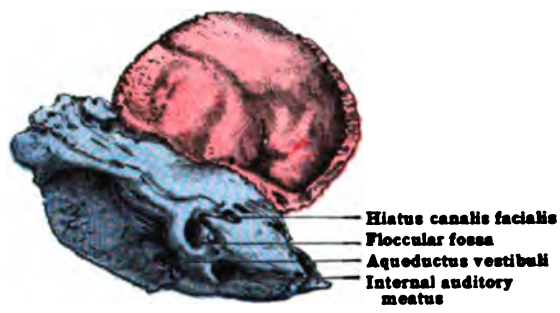


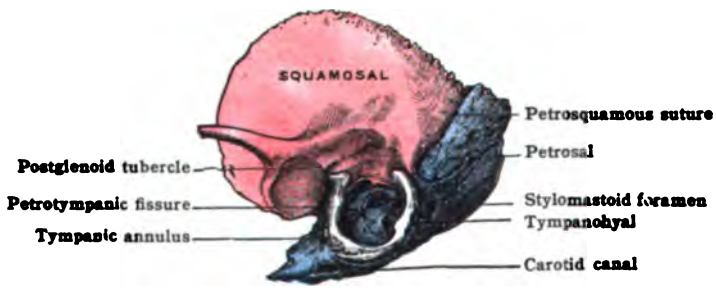
FIG. 152.—TEMPORAL BONE AT BIRTH. (Inner view.)



usually divided into three parts—viz., the **squamous portion,** forming the anterior and superior part of the bone, thin and expanded and prolonged externally into the zygomatic process; the **mastoid portion,** the thick conical posterior part, behind the external aperture of the ear; and a pyramidal projection named the **petrous portion,** situated in a plane below and to the medial side of the two parts already mentioned, and forming part of the base of the skull.

When it is considered in reference to its mode of development, the temporal bone is found to be built up of three parts (figs. 151–153), which, however, do not altogether correspond to the arbitrary divisions of the adult bone. The three parts are named **squamosal, petrosal,** and **tympanic,** and a knowledge of their arrangement in the early stages of growth greatly facilitates the study of the fully formed bone.

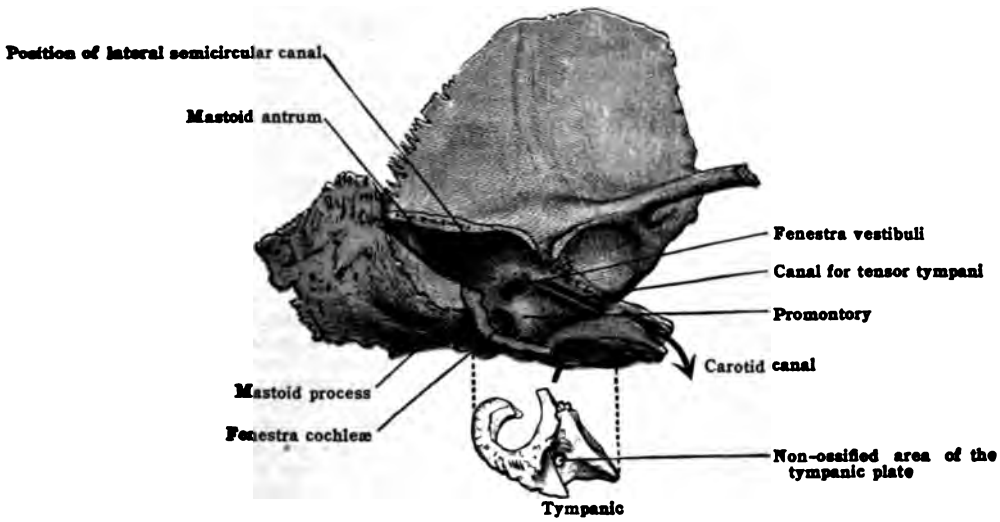
FIG. 153.—THE TEMPORAL BONE AT BIRTH. (Outer view,)



The more important division of the temporal bone is the **petrous portion.** It is pyramidal in shape, and contains the essential part of the organ of hearing, around which it is developed as a cartilaginous capsule. This is known as the **periotic capsule** or **petrosal** element, and its **base** abuts on the outer aspect of the cranium, where it forms a large part of the so-called mastoid portion of the temporal bone. Besides containing the internal ear, it bears on its cranial side a foramen (internal auditory meatus) for the facial and auditory nerves, and on its outer side two openings—the fenestra vestibuli and fenestra cochleæ (fig. 154). The **squamosal** is a superadded element and is formed as a membrane bone in the lateral wall of the cranium. It is especially developed in man in consequence of

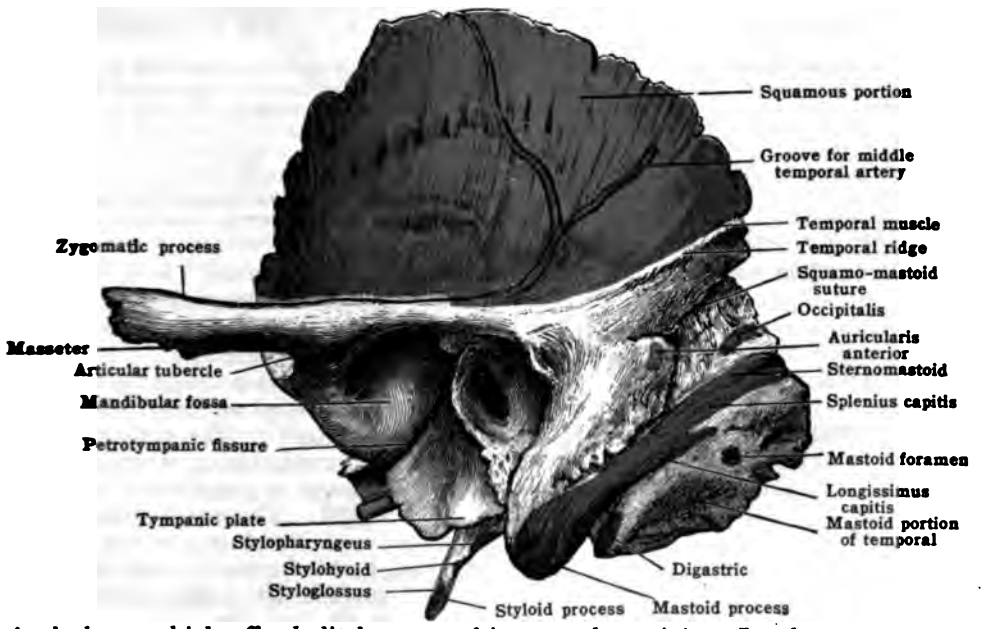
the large size of the brain, and forms the squamous division of the adult bone, and by a triangular shaped process which is prolonged behind the aperture of the ear it also contributes to the formation of the mastoid portion. It is obvious, therefore, that the mastoid is not an independent element, but belongs in part to the petrous,

FIG. 154.—RIGHT TEMPORAL BONE AT ABOUT SIX YEARS.
The tympanic plate has been separated and drawn below. A portion of the postauditory process of the squamosal has been removed to show the mastoid antrum.



and in part to the squamous. The **tympanic** portion, also superadded, is a ring of bone developed in connection with the external auditory meatus, and eventually forms a plate constituting part of the bony wall of this passage. These three parts are easily separable at birth, but eventually become firmly united to form a

FIG. 155.—THE LEFT TEMPORAL BONE. (Outer view.)



single bone which affords little trace of its complex origin. Lastly a process of bone, developed in the second visceral arch, coalesces with the under surface of the temporal bone and forms the **styloid process.**

The **squamous portion** [squama temporalis] is flat, scale-like, thin, and translucent. It is attached almost at right angles to the petrous portion, forms part

of the side wall of the skull and is limited above by an uneven border which describes about two-thirds of a circle. The *outer surface* is smooth, slightly convex near the middle, and forms part of the temporal fossa. Above the external auditory meatus it presents a nearly vertical groove for the middle temporal artery. Connected with its lower part is a narrow projecting bar of bone known as the **zygomatic process.** At its base the process is broad, directed laterally, and flattened from above downward. It soon, however, becomes twisted on itself and runs forward, almost parallel with the squamous portion. This part is much narrower and compressed laterally so as to present medial and lateral surfaces with upper and lower margins. The lateral surface is subcutaneous; the medial looks toward the temporal fossa and gives origin to the *masseter* muscle. The lower border is concave and rough for fibers of the same muscle, whilst the upper border, thin and prolonged further forward than the lower, receives the temporal fascia. The extremity of the process is serrated for articulation with the zygomatic bone. At its base the zygomatic process presents three roots—anterior, middle, and posterior.

The *anterior root* continuous with the lower border, is short, broad, convex, and directed medially to terminate in the **articular tubercle,** which is covered with cartilage in the recent state, for articulation with the condyle of the lower jaw. The *middle root,* sometimes very prominent, forms the **postglenoid process.** It separates the articular portion of the mandibular fossa from the external auditory meatus and is situated immediately in front of the **petrotympanic (Glaserian)** fissure. The *posterior root,* prolonged from the upper border, is strongly marked and extends backward as a ridge above the external auditory meatus. It is called the **temporal ridge** (supramastoid crest), and marks the arbitrary line of division between the squamous and mastoid portions of the adult bone. It forms part of the posterior boundary of the temporal fossa, from which, as well as from the ridge, fibers of the *temporal* muscle arise. Where the anterior root joins the zygomatic process is a slight tubercle—the **preglenoid tubercle**—for the attachment of the temporomandibular ligament, and between the anterior and middle roots is a deep oval depression, forming the part of the mandibular fossa for the condyle of the lower jaw. The **mandibular fossa** is a considerable hollow, bounded in front by the articular tubercle and behind by the tympanic plate which separates it from the external auditory meatus. It is divided into two parts by a narrow slit—the **petrotympanic (Glaserian) fissure.** The anterior part [facies articularis], which belongs to the squamous portion, is articular, and, like the articular tubercle, is coated with cartilage. The posterior part, formed by the tympanic plate, is non-articular and lodges a lobe of the parotid gland. Immediately in front of the articular tubercle is a small triangular surface which enters into the formation of the roof of the zygomatic fossa.

The inner or *cerebral surface* of the squamous portion is marked by furrows for the convolutions of the brain and grooves for the middle meningeal vessels.

At the upper part of the surface the inner table is deficient and the outer table is prolonged some distance upward, forming a thin scale, with the bevelled surface looking inward to overlap the corresponding edge of the parietal. Anteriorly the border is thicker, serrated, and slightly bevelled on the outer side for articulation with the posterior border of the great wing of the sphenoid. Posteriorly it joins the rough serrated margin of the mastoid portion to form the parietal notch. The line separating the squamous from the petrous portion is indicated at the lower part of the inner surface by a narrow cleft, the internal **petrosquamous suture,** the appearance of which varies in different bones according to the degree of persistence of the original line of division.

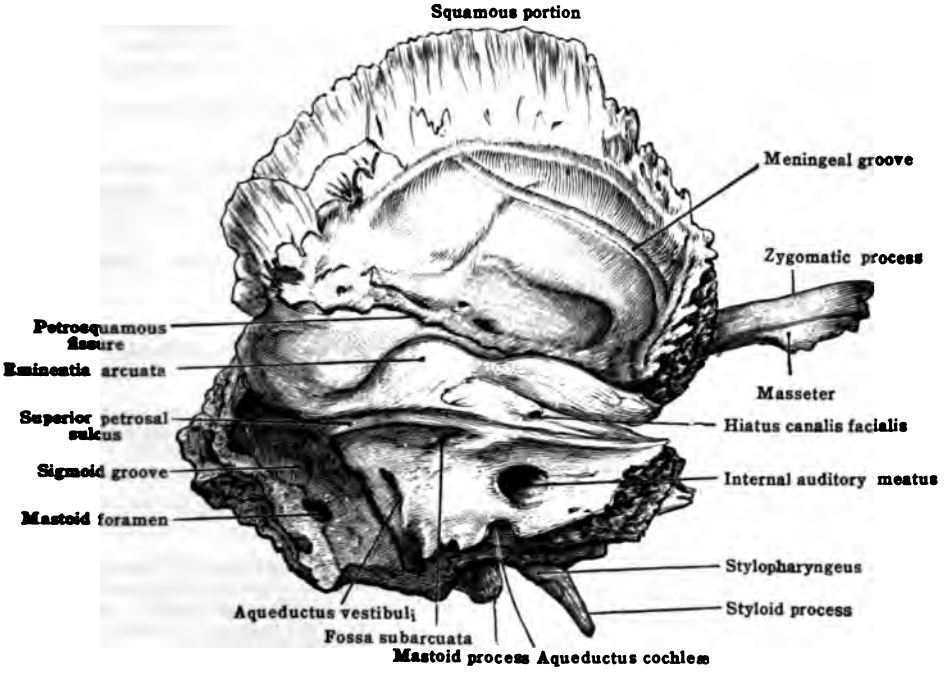
The **mastoid portion** [pars mastoidea] is rough and convex. It is bounded above by the temporal ridge and the parietomastoid suture; in front, by the external auditory meatus and the **tympanomastoid** fissure; and behind, by the suture between the mastoid and occipital. As already pointed out, it is formed by the squamous portion in front and by the base of the petrosal behind, the line of junction of the two component parts being indicated on the outer surface by the **external petrosquamous suture** (squamomastoid). The appearance of the suture varies, being in some bones scarcely distinguishable, in others, a series of irregular depressions, whilst occasionally it is present as a well-marked fissure (fig. 155) directed obliquely downward and forward. The mastoid portion is prolonged downward behind the external acoustic meatus into a nipple-shaped projection, the **mastoid process,** the tip of which points forward as well as downward. The process is marked, on its medial surface, by a deep groove, the **mastoid notch** (diagastric fossa), for the origin of the *digastric* muscle, and again medially by the **occipital groove** for the occipital artery.

The *outer surface* is perforated by numerous foramina, one, of large size, being usually situated near the posterior border and called the **mastoid foramen.** It transmits a vein to the transverse (lateral) sinus and the mastoid branch of the occipital artery. The **mastoid portion**

gives attachment externally to the *auricularis posterior* (*retrahens aurem*) and *occipitalis*, and, along with the mastoid process, to the *sternomastoid*, *splenius capitis*, and *longissimus capitis* (*trachelomastoid*). Projecting from the posterosuperior margin of the external auditory meatus there is frequently a small tubercle—the **suprameatal spine**—behind which the surface is depressed to form the **mastoid (suprameatal) fossa.**

The *inner surface* of the mastoid portion presents a deep curved **sigmoid groove,** in which is lodged a part of the transverse sinus; the mastoid foramen is seen opening into the groove. The interior of the mastoid portion, in the adult, is usually occupied by cavities, of which some are lined by mucous membrane and known as the **mastoid air-cells** (fig. 160). These open into a small chamber—the **mastoid antrum**—which communicates with the upper part of the tympanic cavity. The mastoid cells are arranged in three groups: (1) anterosuperior, (2) middle, and (3) apical. The apical cells, situated at the apex of the mastoid process, are small and usually contain marrow.

FIG. 156.—THE LEFT TEMPORAL BONE. (Seen from the inner side and above.)



Borders.—The superior border is broad and rough for articulation with the hinder part of the inferior border of the parietal bone. The posterior border, very uneven and serrated, articulates with the inferior border of the occipital bone, extending from the lateral angle to the jugular process.

The **petrous portion** [pars petrosa; pyramis] is a pyramid of very dense bone presenting a base, an apex, three (or four) surfaces, and three (or four) borders or angles. Two sides of the pyramid look into the cranial cavity, the posterior into the posterior cranial fossa, and the anterior into the middle cranial fossa. The inferior surface appears on the under surface of the cranium. The medial and posterior walls of the tympanic cavity in the temporal bone are sometimes described as a fourth side of the pyramid. The base forms a part of the lateral surface of the cranium; the apex is placed medially.

The **posterior surface** of the pyramid is triangular in form, bounded above by the superior angle and below by the posterior angle. Near the middle is an obliquely directed foramen [porus acusticus internus] leading into a short canal—the **internal auditory meatus**—at the bottom of which is a plate of bone, pierced by numerous foramina, and known as the **lamina cribrosa.** The canal transmits the facial, auditory and glossopalatine (pars intermedia) nerves, and the internal auditory artery. The bottom of the internal auditory meatus can be most advantageously studied in a temporal bone of the newborn, when the canal is shallow and the openings relatively wide.

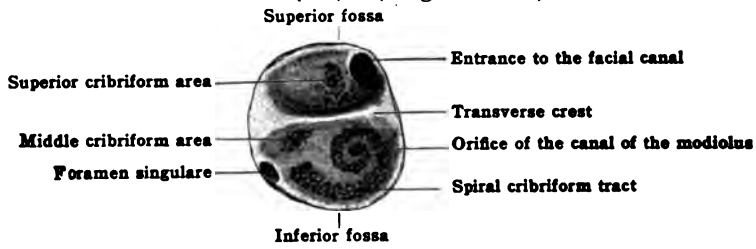
The fundus of the meatus (fig. 157) is divided by a transverse ridge of bone, the *transverse crest*, into a superior and inferior fossa. Of these, the superior is the smaller, and presents anteriorly the beginning of the **facial canal** (aqueduct of Fallopius), which transmits the facial nerve. The rest of the surface above the crest is dotted with small foramina (the superior vestibular area) which transmit nerve-twigs to the recessus ellipticus (fovea hemielliptica) and the ampullæ of the superior and lateral semicircular canals (vestibular division of the auditory nerve). Below the crest there are two depressions and an opening. Of these, an anterior curled tract (the spiral cribriform tract) with a central foramen (foramen centrale **cochleare**) marks the base of the cochlea; the central foramen indicates the orifice of the canal of the modiolus, and the smaller foramina transmit the cochlear twigs of the auditory nerve. The posterior opening (foramen singulare) is for the nerve to the ampulla of the posterior semicircular canal. The middle depression (inferior vestibular area) is dotted with minute foramina for the nerve-twigs to the saccule, which is lodged in the recessus sphæricus (fovea hemisphærica). The inferior fossa is subdivided by a low vertical crest. The fossa in front of the crest is the *fossula cochlearis*, and the recess behind it is the *fossula vestibularis*.

Behind and lateral to the meatus is a narrow fissure, the **aqueductus vestibuli**, covered by a scale of bone. In the fissure lies the ductus endolymphaticus, a small arteriole and venule, and a process of connective tissue which unites the dura mater to the sheath of the internal ear. Occasionally a bristle can be passed through it into the vestibule. Near the upper margin, and opposite a point about midway between the meatus and the aqueduct of the vestibule, is an irregular opening, the **fossa subarcuata**, the remains of the **floccular fossa**, a conspicuous depression in the fetal bone. In the adult the depression usually lodges a process of dura mater and transmits a small vein, though in some bones it is almost obliterated.

The **anterior surface** of the pyramid, sloping downward and forward, forms the back part of the floor of the middle fossa of the cranium.

Upon the anterior surface of the pyramid will be found the following points of interest, proceeding from the apex toward the base of the pyramid:—(1) a shallow **trigeminal impression** for the semilunar (Gasserian) ganglion of the trigeminal nerve; (2) two small grooves

FIG. 157.—THE FORAMINA IN THE FUNDUS OF THE LEFT INTERNAL AUDITORY MEATUS OF A CHILD AT BIRTH (×4). (Diagrammatic.)



running backward and laterally toward two small foramina overhung by a thin osseous lip, the larger and medial of which, known as the **hiatus canalis facialis**, transmits the great superficial petrosal nerve and the petrosal branch of the middle meningeal artery, whilst the smaller and lateral foramen is for the small superficial petrosal nerve; (3) behind and lateral to these is an eminence—the **eminentia arcuata**—best seen in young bones, corresponding to the superior semicircular canal in the interior; (4) still more laterally is a thin transulcent plate of bone, roofing in the tympanic cavity, and named the **tegmen tympani**.

The **inferior** or **basilar surface** of the pyramid is very irregular and presents numerous important structures, including the carotid canal, jugular fossa, stylomastoid process and foramen (fig. 158).

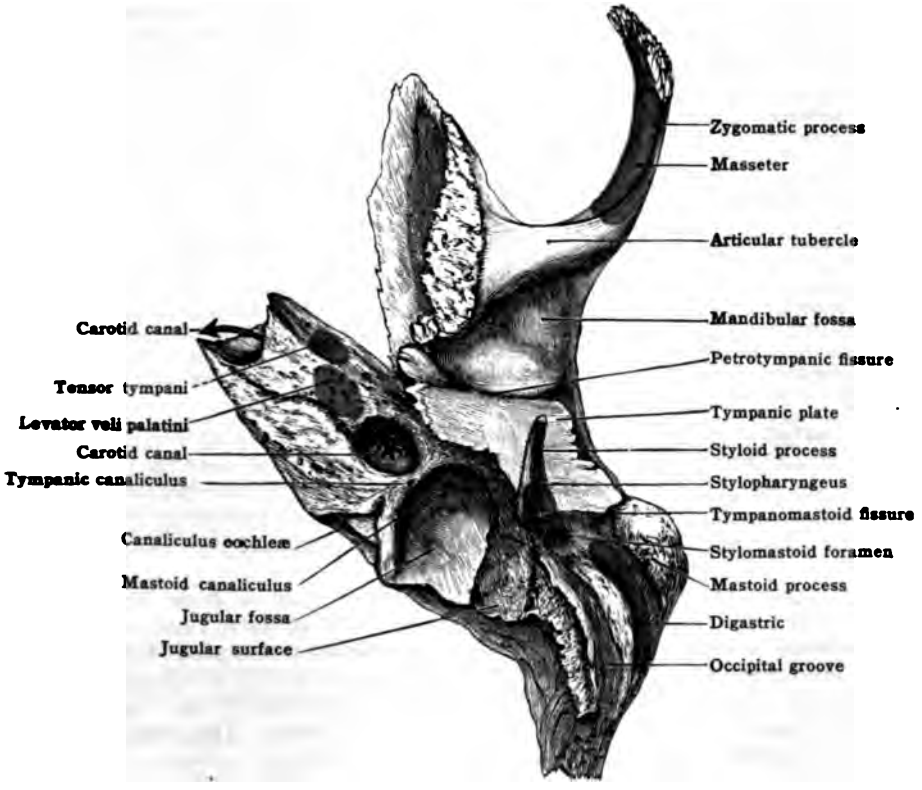
At the apex the basilar surface is rough, quadrilateral, and gives attachment to the *tensor tympani*, *levator veli palatini*, and the pharyngeal aponeurosis. Behind this is seen the large circular orifice of the **carotid canal** for the transmission of the carotid artery and a plexus of sympathetic nerves. On the same level, near the posterior border, is a small three-sided depression, the **canaliculus cochleæ**, which transmits a small vein from the cochlea to the internal jugular. Behind these two openings is the large elliptical **jugular fossa** which forms the anterior and lateral part of the bony wall of the jugular foramen, in which is contained a dilation on the commencement of the internal jugular vein; on the lateral wall of the jugular fossa is a minute foramen, the **mastoid canaliculus**, for the entrance of the auricular branch of the vagus (Arnold's nerve) into the interior of the bone. Between the inferior aperture of the carotid canal and the jugular fossa is the sharp **carotid ridge**, on which is a small depression, the **fossula petrosa**, and at the bottom of this a minute opening, the **tympanic canaliculus**, for Jacobson's nerve (tympanic branch of the glossopharyngeal) and the small tympanic branch from the ascending pharyngeal artery.

Behind the jugular fossa is the rough **jugular surface** for articulation with the **jugular process** of the occipital bone, on the lateral side of which is the prominent cylindrical spur known as the **styloid process** with the **stylomastoid** foramen at its base. This foramen, which is the external orifice of the facial canal, transmits the facial nerve, the stylomastoid artery and sometimes the auricular branch of the vagus. Running backward from the foramen are the **mastoid** and **occipital grooves** already described.

The **tympanic surface** of the pyramid, forming the medial and posterior **walls** [paries labyrinthica] of the tympanic cavity, is shown by removing the tympanic plate (fig. 154).

The tympanic surface presents near the base an excavation, known as the tympanic or mastoid antrum, covered by the triangular part of the squamous below and behind the temporal line. **The opening of the antrum into the tympanic cavity is situated immediately above the fenestra vestibuli,** an oval-shaped opening which receives the base of the stapes; below the **fenestra vestibuli is a convex projection or promontory,** marked by grooves for the tympanic **plexus of nerves and containing the commencement of the first turn of the cochlea. In the lower and posterior part of the promontory is the fenestra cochleæ,** closed in the recent state **by the secondary membrane** of the tympanum. Running downward and forward from the **front of the fenestra vestibuli is a thin curved plate of bone [septum canalis musculotubarii], separating two grooves converted into canals by the overlying tympanic plate. The lower is the groove for the Eustachian tube** [semicanalis tubæ auditivæ], the communicating passage **between the tympanum and the pharynx; the upper is the semicanalis m. tensoris tympani, and the lateral apertures of both canals are visible in the retiring angle, between thep etrous and squamous portions of the bone.**

FIG. 158.—THE LEFT TEMPORAL BONE. (Inferior view.)



The **apex** of the pyramid is truncated and presents the medial opening of the carotid canal. The latter commences on the inferior surface, and, after ascending for a short distance, turns forward and medially, tunnelling the bone as far as the apex, and finally opens into the upper part of the **foramen lacerum** formed between the temporal and sphenoid bones.

One or two minute openings in the wall of the carotid canal, known as the caroticotympanic canaliculi, transmit communicating twigs between the carotid and tympanic plexuses. The upper part of the apex is joined by cartilage to the posterior petrosal process of the sphenoid.

The **base** is the part of the pyramid which appears laterally at the side of the cranium and takes part in the formation of the mastoid portion. It is described above with that division of the bone.

Angles.—The superior angle (border) of the pyramid is the longest and separates the posterior from the anterior surface. It is grooved for the superior petrosal sinus, gives attachment to the tentorium cerebelli, and presents near the apex a semilunar notch upon which the trigeminal nerve lies. Near its medial end there is often a small projection for the attachment

of the petrosphenoidal ligament, which arches over the inferior petrosal sinus and the abducens nerve. The **posterior angle** separates the posterior from the inferior surface, and when articulated with the occipital, forms the groove for the inferior petrosal sinus, and completes the **jugular foramen** formed by the temporal in front and on the lateral side, and by the occipital behind and on the medial side. The **jugular foramen** is divisible into three compartments: an anterior for the inferior petrosal sinus, a middle for the glossopharyngeal, vagus and accessory nerves, and a posterior for the internal jugular vein and some meningeal branches from the occipital and ascending pharyngeal arteries. The **anterior angle** is the shortest and consists of two parts, one joined to the squamous in the petrosquamous suture and a small free part internally which articulates with the sphenoid. A fourth or inferior border may be distinguished which runs along the line of junction with the tympanic plate and is continued on to the rough area below the apex.

The **tympanic portion** [pars tympanica] is quadrilateral in form, hollowed out above and behind, and nearly flat, or somewhat concave, in front and below. It forms the whole of the anterior and inferior walls, and part of the posterior wall, of the external auditory meatus, and is separated behind from the mastoid process by the **tympanomastoid** (auricular) fissure through which the auricular branch of the vagus in some cases leaves the bone.

In front it is separated by the **petrotympanic** fissure from the squamous portion. Through the petrotympanic fissure the tympanic branch of the internal maxillary artery passes. The processus gracilis of the malleus is lodged within it, and a narrow subdivision at its inner end, known as the **canal of Huguier**, transmits the chorda tympani nerve. The tympanic part presents for examination two surfaces and four borders.

The **anteroinferior surface**, directed downward and forward, lodges part of the parotid gland. Near the middle it is usually very thin, and sometimes presents a small foramen (the foramen of Huschke), which represents a non-ossified portion of the plate. The **posterosuperior surface** looks into the external auditory meatus and tympanic cavity, and at its medial end is a narrow groove, the **sulcus tympanicus**, deficient above, which receives the membrana tympani.

The **lateral border** is rough and everted, forming the **external auditory process** for the attachment of the cartilage of the pinna; the **superior border** enters into the formation of the petrotympanic fissure; the **inferior border** is uneven and prolonged into the **vaginal process** [vagina processus styloidei] which surrounds the lateral aspect of the base of the styloid process and gives attachment to the front part of the fascial sheath of the carotid vessels; the **medial border**, short and irregular, lies immediately below and to the lateral side of the opening of the Eustachian tube, and becomes continuous with the rough quadrilateral area on the inferior aspect of the apex.

The **external auditory meatus** is formed partly by the tympanic and partly by the squamous portion. It is an elliptical bony tube leading into the tympanum, the extrance of which is bounded throughout the greater part of its circumference by the external auditory process of the tympanic plate. Above, the entrance is limited by the temporal ridge or posterior root of the zygomatic process.

The **styloid process** is a slender, cylindrical spur of bone fused with the inferior aspect of the temporal immediately in front of the stylomastoid foramen. It consists of two parts, **basal** (tympanohyal), which in the adult lies under cover of the tympanic plate, and a **projecting** portion (stylohyal), which varies in length from five to fifty millimeters. When short, it is hidden by the vaginal process, but, on the other hand, it may reach to the hyoid bone. The projecting portion gives attachment to three muscles and two ligaments.

The *stylopharyngeus* arises near the base from the medial and slightly from the posterior aspect; the *stylohyoid* from the posterior and lateral aspect near the middle; and the *styloglossus* from the front near the tip. The tip is continuous with the stylohyoid ligament, which runs down to the lesser cornu of the hyoid bone. A band of fibrous tissue—the **stylomandibular** ligament—passes from the process below the origin of the styloglossus to the **angle of the lower jaw.**

Blood-supply.—The arteries supplying the temporal bone are derived from various sources. The chief are:

Stylomastoid from posterior auricular: it enters the stylomastoid foramen.

Anterior tympanic from internal maxillary: it passes through the petrotympanic fissure.

Superficial petrosal from middle meningeal: transmitted by the hiatus canalis facialis.

Caroticotympanic from internal carotid whilst in the carotid canal.

Internal auditory from the basilar: it enters the internal auditory meatus, and is distributed to the cochlea and vestibule.

Other less important twigs are furnished by the middle meningeal, the meningeal branches of the occipital, and by the ascending pharyngeal artery. The squamous portion is supplied, on its internal surface, by the middle meningeal, and externally by the branches of the deep temporal from the internal maxillary.

Articulations.—The temporal bone articulates with the occipital, parietal, sphenoid, zygomatic, and, by a movable joint, with the mandible. Occasionally the squamous portion pre-

ents a process which articulates with the frontal. A frontosquamosal suture is common in ne skulls of the lower races of men, and is normal in the skulls of the chimpanzee, gorilla, and ibbon.

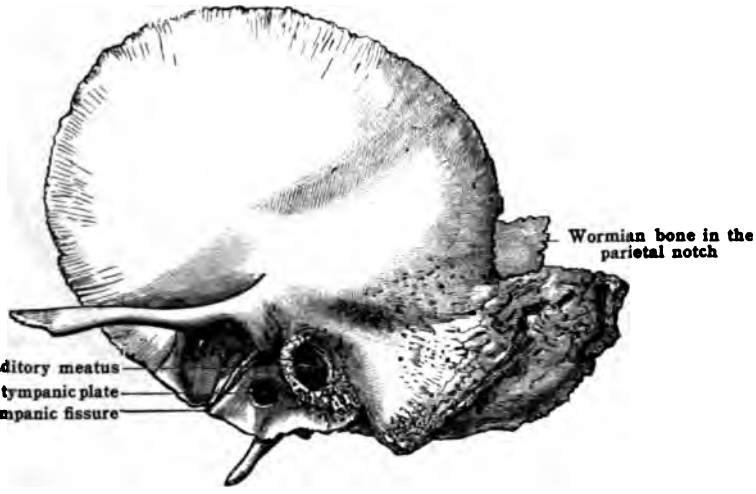
Ossification.—Of the three parts which constitute the temporal bone at birth, the squaosal and tympanic develop in membrane and the petrosal in cartilage. The squamosal is ormed from one center, which appears as early as the eighth week, and ossification extends nto the zygomatic process, which grows concurrently with the squamosal. At first the tymanic border is nearly straight, but soon assumes its characteristic horsesboe shape. At birth he postglenoid tubercle is conspicuous, and at the hinder end of the squamosal there is a procss which comes into relation with the mastoid antrum. The center for the tympanic elenent appears about the twelfth week. At birth it forms an incomplete ring, open above, and ightly ankylosed to the lower border of the squamosal. The anterior extremity terminates n a small irregular process, and the medial aspect presents, in the lower half of its circumfernce, a groove for the reception of the tympanic membrane.

Up to the middle of the fifth month the periotic capsule is cartilaginous; it then ossifies rapidly that by the end of the sixth month its chief portion is converted into porous bone. he ossific material is deposited in four centers, or groups of centers, named according to eir relation to the ear-capsule in its embryonic position.

The nuclei are deposited in the following order:

1. The opisthotic appears at the end of the fifth month. The osseous material is seen first n the promontory, and it quickly surrounds the fenestra cochleæ from above downward, and rms the floor of the vestibule, the lower part of the fenestra vestibuli, and the internal audiry meatus; it also invests the cochlea. Subsequently a plate of bone arises from it to surund the internal carotid artery and form the floor of the tympanum.

FIG. 159.—TEMPORAL BONE AT THE SIXTH YEAR.


Wormian bone in the parietal notch
External auditory meatus
Non-ossified area of the tympanic plate
Petrotympanic fissure

2. The pro-otic nucleus is deposited behind the internal auditory meatus near the medial mb of the superior semicircular canal. It covers in a part of the cochlea, the vestibule, and he internal auditory meatus, completes the fenestra vestibuli, and invests the superior semiircular canal.

3. The pterotic nucleus ossifies the tegmen tympani and covers in the lateral semicircular anal; the ossific matter is first deposited over the lateral limb of this canal.

4. The epiotic, often double, is the last to appear, and is first seen at the most posterior art of the posterior semicircular canal.

At birth (figs. 151–153) the bone is of loose and open texture, thus offering a striking conrast to the dense and ivory-like petrosal of the adult. It also differs from the adult bone in everal other particulars. The floccular fossa is widely open and conspicuous. Voltolini has ointed out that a small canal leads from the floor of the floccular fossa and opens posteriorly n the mastoid surface of the bone; it may open in the mastoid antrum. The hiatus canalis acialis is unclosed and the tympanum is filled with gelatinous connective tissue. The mastoid rocess is not developed, and the jugular fossa is a shallow depression.

After birth the parts grow rapidly. The tympanum becomes permeated with air, the varius elements fuse, and the tympanic annulus grows rapidly and forms the tympanic plate. Development of the tympanic plate takes place by an outgrowth of bone from the lateral spect of the tympanic annulus. This outgrowth preceeds most rapidly from the tubercles or pines at its upper extremities, and in consequence of the slow growth of the lower segment a eep notch is formed; gradually the tubercles coalesce, lateral to the notch, so as to enclose a oramen which persists until puberty, and sometimes even in the adult. In most skulls a cleft tympanomastoid fissure) remains between the tympanic element and the mastoid process. he anterior portion of the tympanic plate forms with the inferior border of the squamosal a left known as the petrotympanic fissure, which is subsequently encroached upon by the growth f the petrosal. As the tympanic plate increases in size it joins the lateral wall of the carotid anal and presents a prominent lower edge, known as the vaginal process (sheath of the styloid).

The **mastoid process** becomes distinct about the first year, coincident with the obliteration of the petrosquamous suture, and increases in thickness by deposit from the periosteum. According to most writers, the process becomes pneumatic about the time of puberty, but it has been shown by Young and Milligan that the mastoid air-cells develop at a much earlier period than is usually supposed. Air-cells were present, as small pit-like diverticula from the mastoid antrum, in a nine months' fetus and in an infant one year old. In old skulls the air-cells may extend into the jugular process of the occipital bone.

At birth the mastoid antrum is relatively large and bounded laterally by a thin plate of bone belonging to the squamosal (postauditory process). As the mastoid increases in thickness the antrum comes to lie at a greater depth from the surface and becomes relatively smaller.

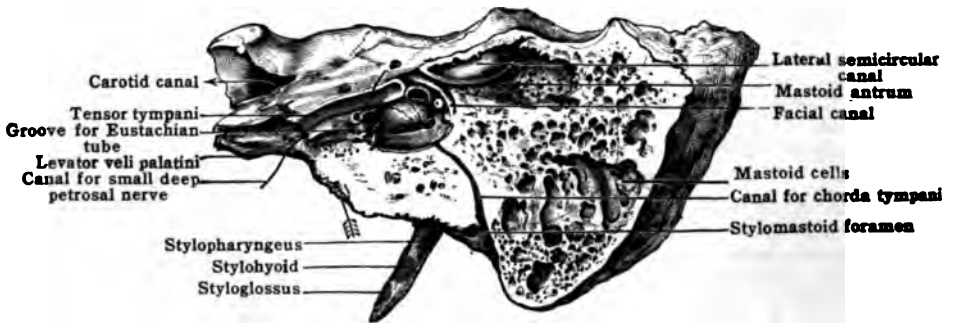
The styloid process is ossified in cartilage from two centers, one of which appears at the base in the tympanohyal before birth. This soon joins with the temporal bone, and in the second year a center appears for the stylohyal, which, however, remains very small until puberty. In the adult it usually becomes firmly united with the tympanohyal, but it may remain permanently separate.

Variations.—A bar of bone in the dura over the trigeminal nerve has been interpreted as a vestige of the primitive cranial wall as presented in the reptilia. The petrosquamous suture may persist. In the heritable defect, known as *cleidocranial dysostosis*, the temporal squama is rudimentary and the zygomatic arch is incomplete. The mastoid cells vary greatly in extent, and may even invade the squamous part.

THE TYMPANUM

The **tympanum** (middle ear) includes a cavity [cavum tympani] of irregular form in the temporal bone, situated over the jugular fossa, between the petrous portion medially and the tympanic and squamous portions laterally. When fully developed, it is completely surrounded by bone except where it communicates

FIG. 160.—THE MEDIAL WALL OF THE TYMPANUM.



with the external auditory meatus, and presents six walls—lateral, medial, posterior, anterior, superior (roof), and inferior (floor). The lateral and medial walls are flat, but the remainder are curved, so that they run into adjoining surfaces, without their limits being sharply indicated.

The **roof** or **tegmen tympani** [paries tegmentalis] is a translucent plate of bone, forming part of the superior surface of the petrous portion and separating the tympanum from the middle fossa of the skull. The **floor** [paries jugularis] is the plate of bone which forms the roof of the jugular fossa. The **medial wall** [paries labyrinthica] (figs. 160, 1075) is formed by the tympanic surface of the petrous portion. In the angle between it and the roof is a horizontal ridge which extends backward as far as the posterior wall and then turns downward in the angle between the medial and posterior walls. This is the **facial (Fallopian) canal, and is** occupied by the facial nerve. The other features of this surface—viz., the **fenestra vestibuli,** the **fenestra cochleæ,** and the **promontory**—have been previously described with the tympanic surface of the petrous portion of the temporal bone. The **posterior wall** [paries mastoidea] of the tympanum is also formed by the anterior surface of the petrous portion. At the superior and lateral angle of this wall an opening leads into the **mastoid antrum.** Immediately below this opening there is a small hollow cone, the **pyramidal eminence,** the cavity of which is continuous with the descending limb of the facial canal. The cavity is occupied by the *stapedius* and the tendon of the muscle emerges at the apex. One or more bony spicules often connect the apex of the pyramid with the promontory.

The roof and floor converge toward the **anterior extremity** (wall) of the tympanum, which is, in consequence, very low; it is occupied by two semicanals, the lower for the Eustachian tube, the upper for the *tensor tympani* muscle. These channels are sometimes described together as the **canalis musculotubarius.** In carefully prepared bones the upper semicanal is a small horizontal hollow cone (anterior pyramid), 12 mm. in length; the apex is just in front of the fenestra vestibuli, and is perforated to permit the passage of the tendon of the muscle. As a rule, the thin walls of the canal are damaged, and represented merely by a thin ridge of bone. The posterior portion of this ridge projects into the tympanum, and is known as the **processus**

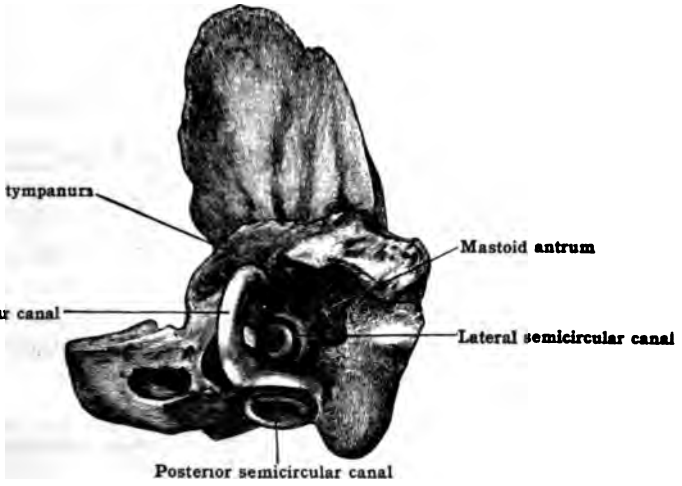
cochleariformis. The thin septum between the semicanal for the tensor tympani and the tube is pierced by a minute opening which transmits the small deep petrosal nerve.

The lateral wall [paries membranacea] is occupied mainly by the external auditory meatus. This opening is closed in the recent state by the tympanic membrane. The rim of bone to which the membrane is attached is incomplete above, and the defect is known as the **tympanic notch (notch of Rivinus).** Anterior to this notch, in the angle between the squamous portion and the tympanic plate, is the **petrotympanic (Glaserian) fissure,** and the small passage which transmits the chorda tympani nerve, known as the **canal of Huguier.**

Up to this point the description of the middle ear conforms to that in general usage. But **Young** and **Milligan** have laid stress on the fact that the middle ear is really a cleft, named by them the '*middle-ear cleft*,' which intervenes between the periotic capsule, on the one hand, and the squamozygomatic and tympanic elements of the temporal bone on the other. This cleft, as development proceeds, gives rise to three cavities:—(1) the mastoid antrum; (2) tympanum; and (3) the Eustachian tube. They point out that 'the cleft is primarily continuous, and however much it may be altered in shape and modified in parts to form these three cavities, that continuity is never lost.' It will be clear that the mastoid antrum, according to this view, is not an outgrowth from the tympanum, but is simply the lateral end of the middle-ear cleft.

The tympanic cavity may be divided into three parts. The part below the level of the superior margin of the external auditory meatus is the **tympanum proper;** the portion above this level is the **epitympanic recess** or **attic;** it receives the head of the malleus, the body of the incus, and leads posteriorly into the

FIG. 161.—TEMPORAL BONE AT BIRTH DISSECTED FROM ABOVE AND BEHIND TO SHOW THE SEMICIRCULAR CANALS AND THE MASTOID ANTRUM. (Enlarged ½.)



recess known as the **mastoid antrum.** The third part is the downward extension known as the **hypotympanic recess.** (For additional details and figures of the tympanic cavity, see p. 1121.)

The tympanic or mastoid antrum.—The air-cells which in the adult are found in the interior of the mastoid portion of the temporal bone open into a small cavity termed the **mastoid antrum (figs. 160, 161, 1075).** This is an air-chamber, communicating with the attic of the tympanum, and separated from the middle cranial fossa by the posterior portion of the tegmen tympani. The floor is formed by the mastoid portion of the petrosal, and the lateral wall by the squamosal, below the temporal ridge. In children the outer wall is exceedingly thin, but in the adult it is of considerable thickness. The **lateral semicircular canal** projects into the antrum on its medial wall, and is very conspicuous in the fetus. Immediately below and in front of the canal is the facial nerve, contained in the facial canal.

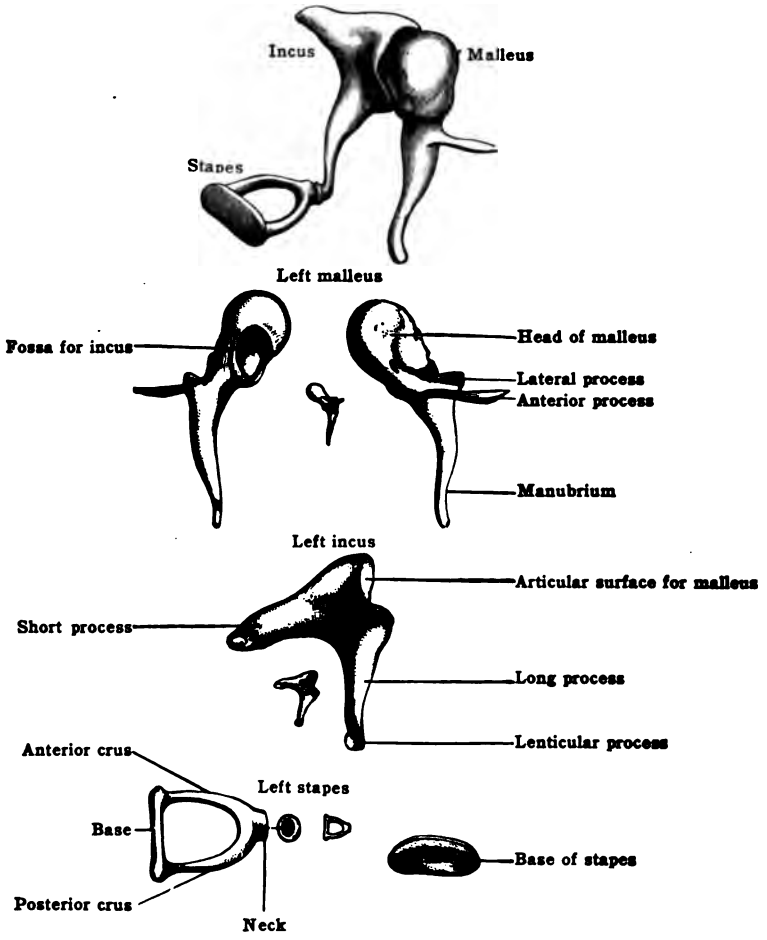
The mastoid antrum has somewhat the form of the bulb of a retort (Thane and Godlee) compressed laterally, and opening by its narrowed neck into the attic or epitympanic recess. Its dimensions vary at different periods of life. It is well developed at birth, attains its maximum size about the third year, and diminishes somewhat up to adult life. In the adult the plate of bone which forms the lateral wall of the antrum is 12 to 18 mm. (½ to ¾ in.) in thickness, whereas at birth it is about 1.8 mm. or less. The deposition of bone laterally occurs, therefore, at average rate of nearly 1 mm. a year in thickness. In the adult the antrum is about 12 mm. from front to back, 9 mm. from above downward, and 4.5 mm. from side to side. A canal occasionally leads from the mastoid antrum through the petrous bone to open in the recess which indicates the position of the floccular fossa; it is termed the petromastoid canal. (Gruber.)

The facial (Fallopian) canal.—This canal begins at the anterior angle of the superior fossa of the internal auditory meatus, and passes forward and laterally above the vestibular portion

of the internal ear for a distance of 1.5–2.0 mm. At the lateral end of this portion of its course it becomes dilated to accommodate the geniculate ganglion, and then turns abruptly backward and runs in a horizontal ridge on the medial wall of the tympanum, lying in the angle between it and the tegmen tympani, immediately above the fenestra vestibuli, and extending as far backward as the entrance to the mastoid antrum. Here it comes into contact with the inferior aspect of the projection formed by the lateral semicircular canal, and then turns vertically downward, running in the angle between the medial and posterior walls of the tympanum to terminate at the stylomastoid foramen.

The canal is traversed by the facial nerve. Numerous openings exist in the walls of this passage. At its abrupt bend, or **genu**, the greater and smaller superficial petrosal nerves escape from, and a branch from the middle meningeal artery enters, the canal, and in the vertical part of its course the cavity of the pyramid opens into it. There is also a small orifice by which the auricular branch of the vagus joins the facial, and near its termination the **iter chordæ posterius** for the chorda tympani nerve leads from it into the tympanum.

FIG. 162.—THE BONES OF THE MIDDLE EAR. (Modified from Henle.)



The small bones of the tympanum.—These bones [ossicula auditus], the malleus, incus and stapes, are contained in the upper part of the tympanic cavity. Together they form a jointed column of bone connecting the membrana tympani with the fenestra vestibuli (fig. 162).

The malleus.—This is the most external of the auditory ossicles, and lies in relation with the tympanic membrane. Its upper portion, or **head**, is lodged in the epitympanic recess. It is of rounded shape, and presents posteriorly an elliptical depression for articulation with the incus. Below the head is a constricted portion or **neck**, from which three processes diverge. The largest is the **handle** or **manubrium**, which is slightly twisted and flattened. It forms an obtuse angle with the head of the bone, and lies between the membrana tympani and the mucous membrane covering its inner surface. The *tensor tympani* tendon is inserted into the manubrium near its junction with the neck on the medial side.

The **anterior process** (processus gracilis or Folii) is a long, slender, delicate spiculum of bone [illegible]rely seen of full length except in the fetus), projecting nearly at right angles to the anterior of the neck, and extending obliquely downward. It lies in the petrotympanic fissure,

and in the adult usually becomes converted into connective tissue, except a small basal stump. The **lateral process** is a conical projection from the lateral aspect of the base of the manubrium. Its apex is connected to the upper part of the tympanic membrane, and its base receives the lateral ligament of the malleus. The malleus also gives attachment to a superior and an anterior ligament, the latter of which was formerly described as the *laxator tympani* muscle.

The incus.—This bone is situated between the malleus externally and the stapes internally. It presents for examination a body and two processes. The **body** is deeply excavated anteriorly for the reception of the head of the malleus. The **short process** projects backward, and is connected by means of ligamentous fibers to the posterior wall of the tympanum, near the entrance to the mastoid antrum. The **long process** is slender, and directed downward and inward, and lies parallel with the manubrium of the malleus. On the medial aspect of the distal extremity of this process is the **lenticular process** (orbicular tubercle), separate in early life, but subsequently joined to the process by a narrow neck. Its free surface articulates with the head of the stapes.

The **stapes** is the innermost ossicle. It has a **head** directed horizontally outward, capped at its outer extremity by a disk resembling the head of the radius. The cup-shaped depression receives the lenticular process of the incus. The **base** occupies the fenestra vestibuli, and like this opening, the inferior border is straight, and the superior curved. The base is connected with the head by means of two **crura**, and a narrow piece of bone called the neck. Of the two crura, the anterior is the shorter and straighter. The crura with the base form a stirrup-shaped arch, of which the inner margin presents a groove for the reception of the membrane stretched across the hollow of the stapes. In the early embryo this hollow is traversed by the stapedial artery. The **neck** is very short, and receives on its posterior border the tendon of the *stapedius*.

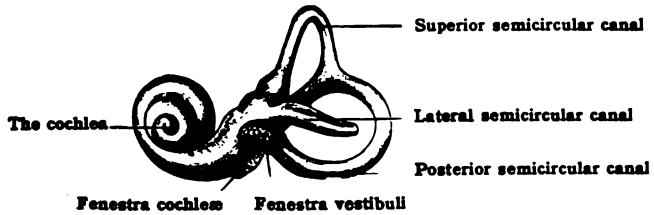
Development.—For the early development of the auditory tube and tympanic cavity from the first branchial pouch, see p. 17. The auditory ossicles are formed from the upper extremities of the axial skeletons of the first and second branchial arches, the malleus and incus belonging to the first arch and the stapes to the second (Reichert). The ossicles consequently lie originally in the walls of the cavity, but they are surrounded by a loose spongy tissue, which, on the entrance of air into the cavity, becomes compressed, allowing the cavity to enfold the ossicles. These therefore are enclosed within an epithelium which is continuous with that lining the tympanic cavity.

The mastoid cells are outgrowths of the cavity into the adjacent bone, and are therefore lined with an epithelium continuous with that of the cavity.

THE OSSEOUS LABYRINTH

The **osseous labyrinth** [labyrinthus osseus] (figs. 163, 865–867) is a complex cavity hollowed out of the petrous portion of the temporal bone and containing

FIG. 163.—THE LEFT OSSEOUS LABYRINTH. (After Henle. From a cast.)



the membranous labyrinth, the essential part of the organ of hearing. The osseous labyrinth is incompletely divided into three parts, named the vestibule, the semicircular canals, and the cochlea.

The vestibule.—This is an oval chamber situated between the base of the internal auditory meatus and the medial wall of the tympanum, with which it communicates by way of the fenestra vestibuli. Anteriorly, the vestibule leads into the cochlea, and posteriorly it receives the extremities of the semicircular canals. It measures about 3 mm. transversely, and is somewhat longer anteroposteriorly.

Its medial wall presents at the anterior part a circular depression, the **spherical recess** (fovea hemispherica), which is perforated for the passage of nerve-twigs. This recess is separated by a vertical ridge (the **crista vestibuli**) from the vestibular orifice of the **aqueductus vestibuli**, which passes obliquely backward to open on the posterior surface of the petrosal. The roof contains an oval depression—the **elliptical recess** (fovea hemielliptica).

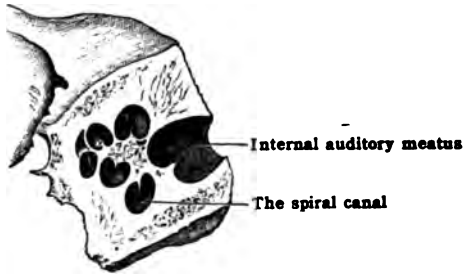
The **semicircular canals** are three in number. Arranged in different planes, each forms about two-thirds of a circle. One extremity of each canal is dilated to form an **ampulla**.

The **superior canal** lies transversely to the long axis of the petrosal, and is nearly vertical; its highest limb makes a projection on the superior surface of the bone. The ampulla is at the lateral end; the medial end opens into the vestibule conjointly with the superior limb of the posterior canal. The **posterior canal** is nearly vertical and lies in a plane nearly parallel to the posterior surface of the petrosal. It is the longest of the three; its upper extremity joins the medial limb of the superior canal, and opens in common with it into the vestibule. The lower is the ampullated end. The **lateral canal** is placed horizontally and arches laterally; its lateral limb forms a prominence in the mastoid antrum. This canal is the shortest; its ampulla is at the lateral end near the fenestra vestibuli.

The cochlea.—This is a cone-shaped cavity lying with its base upon the internal auditory meatus, and the apex directed forward and laterally. It measures about five mm. in length, and the diameter of its base is about the same. The center of this cavity is occupied by a column of bone—the **modiolus**—around which a canal is wound in a spiral manner, making about two and a half turns. This is the **spiral canal** of the cochlea; its first turn is the largest and forms a bulging, the **promontory**, on the medial wall of the tympanum. Projecting into the canal throughout its entire length there is a horizontal, shelf-like lamella, the **lamina spiralis**, which terminates at the apex of the cochlea in a hook-like process, the **hamulus**. The free edge of the lamina spiralis gives attachment to the membranous cochlea, a canal having in section the form of a triangle whose base is attached to the lateral wall of the spiral canal. By this the spiral canal is divided into a portion above the lamina spiralis, termed the **scala vestibuli**, which communicates at its lower end with the osseous vestibule, and a portion below, termed the **scala tympani**, which abuts at its lower end upon the fenestra cochleæ. The two scalæ communicate at the apex of the cochlea by the **helicotrema**. Near the commencement of the scala tympani, and close to the fenestra rotunda, is the cochlear orifice of the **canaliculus cochleæ** (ductus perilymphaticus). In the adult this opens below, near the middle of the posterior border of the petrous bone, and transmits a small vein from the cochlea to the jugular fossa.

Measurements of the principal parts connected with the auditory organs:—
Internal auditory meatus: Length of anterior wall, 13–14 mm.; of posterior wall, 6.7 mm.
External auditory meatus: 14–16 mm. (Gruber.)
Tympanum: Length, 13 mm.; height in center of cavity, 15 mm.; width opposite the membrana tympani, 2 mm.; width opposite the tubal orifice, 3–4 mm. (Von Tröltsch.)
The capsule of the osseous labyrinth is in length 22 mm. (Schwalbe.)
The superior semicircular canal measures along its convexity 20 mm.
The posterior semicircular canal measures along its convexity 22 mm.
The lateral semicircular canal measures along its convexity 15 mm.
The canal is in diameter 1.5 mm. (Huschke.) The ampulla of the canal, 2.5 mm.

FIG. 164.—THE COCHLEA IN SAGITTAL SECTION. (After Henle.)



Development.—For the origin of the otocyst from the surface ectoderm, see p. 38. The mesodermal tissue which surrounds the otocyst becomes later the petrous portion of the temporal bone, the perilymph and the internal periosteal layer; the osseous labyrinth is therefore merely the portions of the petrous which enclose the cavity occupied by the membranous internal ear.

THE ETHMOID

The **ethmoid** [os ethmoidale] is a bone of delicate texture, situated at the anterior part of the base of the cranium (figs. 165–167). Projecting downward from between the orbital plates of the frontal, it enters into the formation of the orbital and nasal fossæ. It is cubical in form, and its extreme lightness and delicacy are due to an arrangement of very thin plates of bone surrounding irregular spaces known as air-cells. The ethmoid consists of four parts: the horizontal or cribriform plate, the ethmoidal labyrinth on each side, and a perpendicular plate.

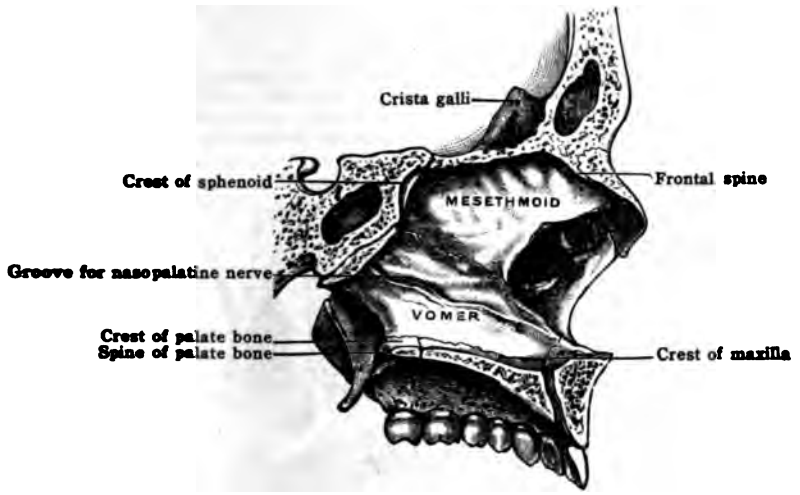
The **cribriform plate** [lamina cribrosa] forms part of the anterior cranial fossa, and is received into the ethmoidal notch of the frontal bone. It presents on its upper surface, in the median line, the intracranial portion of the perpendicular plate, known as the **crista galli**, a thick, vertical, triangular process with the highest point in front, and a sloping border behind which gives attachment to the falx cerebri. The anterior border is short and in its lower part broadens out to form two **alar processes** which articulate with the frontal bone and complete the **foramen cecum**. The crista galli is continuous behind with a median ridge, and on each side of the midline is a groove which lodges the olfactory bulb.

The cribriform plate is pierced, on each side, by numerous foramina, arranged in two or three rows, which transmit the filaments of the olfactory nerves ascending to the bulb. Those in the middle of the groove are few and are simple perforations, through which pass the nerves from the roof of the nose; the medial and lateral series are more numerous and constitute the

upper ends of small canals, which subdivide as they course downward to the upper parts of the septum and the lateral wall of the nasal fossa. At the front part of the cribriform plate is a narrow longitudinal slit, on each side of the crista galli, which transmits the anterior ethmoidal (nasal) branch of the ophthalmic division of the trigeminal nerve. The posterior border articulates with the ethmoidal spine of the sphenoid.

The **perpendicular plate** [lamina perpendicularis] (mesethmoid) is directly continuous with the crista galli on the under aspect of the cribiform plate, so

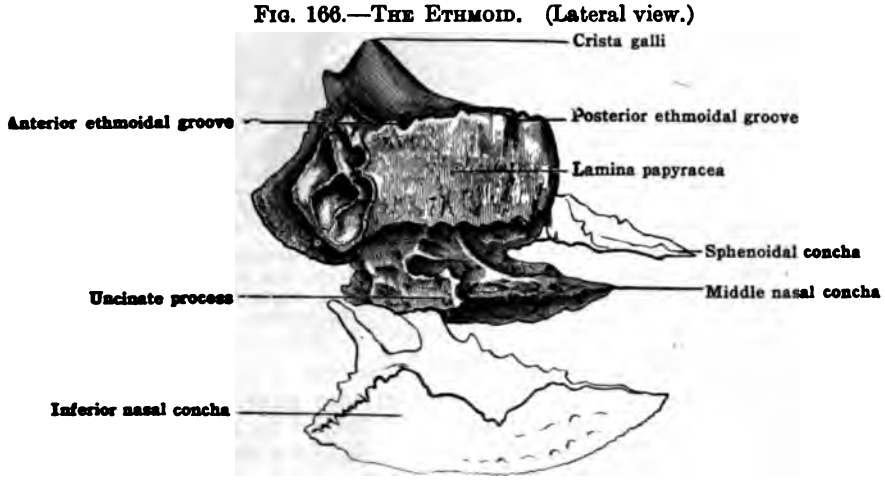
FIG. 165.—SECTION THROUGH THE NASAL FOSSA TO SHOW THE MESETHMOID. (LAMINA PERPENDICULARIS).



that the two plates cross each other at right angles. The larger part of the perpendicular plate is below the point of intersection and forms the upper third of the septum of the nose. It is quadrangular in form with unequal sides.

The **anterior border** articulates with the spine of the frontal and the crest of the nasal bones. The **inferior border** articulates in front with the septal cartilage of the nose and behind with the anterior margin of the vomer. The **posterior border** is very thin and articulates with the

FIG. 166.—THE ETHMOID. (Lateral view.)



crest of the sphenoid. This plate, which is generally deflected a little to one side, presents above a number of grooves and minute canals which lead from the inner set of foramina in the cribriform plate and transmit the olfactory nerves from the septum.

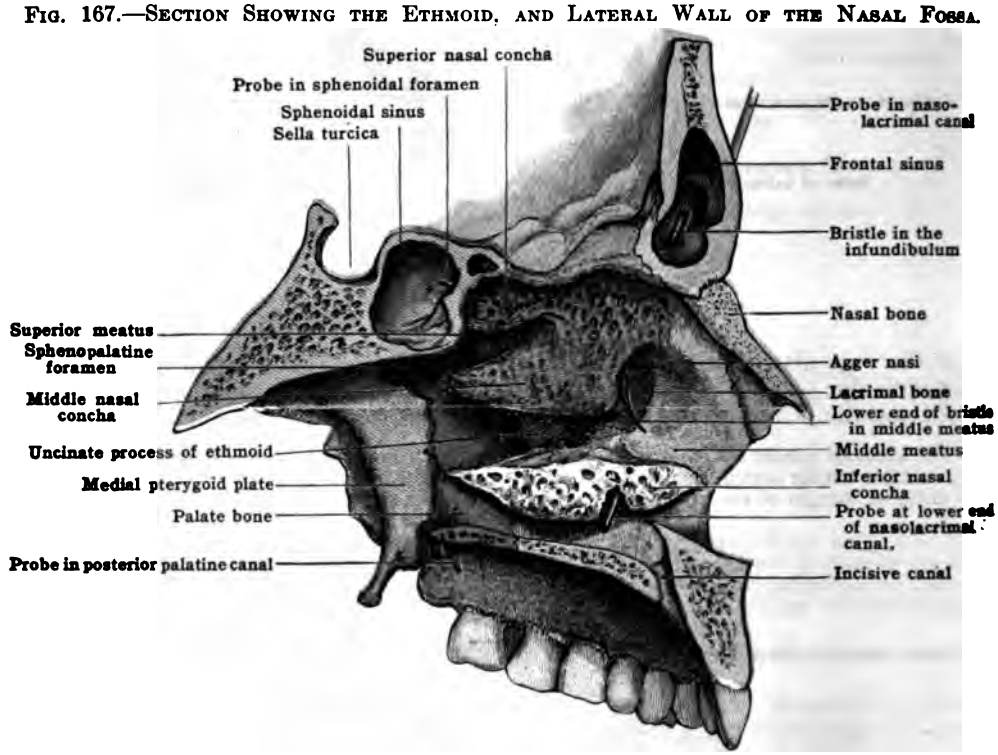
The **ethmoidal labyrinth** (lateral mass) is oblong in shape and suspended from the under aspect of the lateral part of the cribriform plate. It includes two scroll-like pieces of bone, the **superior** and **middle nasal conchæ** (turbinate bones), and encloses numerous irregularly shaped air-spaces, known as the **ethmoidal cells.** These are arranged in two main sets—anterior and posterior ethmoidal cells

—and, in the recent state, are lined with prolongations of the nasal mucous membrane. Laterally the labyrinth presents a thin, smooth, quadrilateral plate of bone—the **lamina papyracea** (os planum)—which closes in the ethmoidal cells and forms a large part of the medial wall of the orbit (figs. 123, 975).

By its anterior border the lamina articulates with the lacrimal, and by its posterior border with the sphenoid; the inferior border articulates with the medial margin of the orbital plate of the maxilla and the orbital process of the palate bone, whilst the superior border articulates with the horizontal plate of the frontal. Two notches in the superior border lead into grooves running horizontally across the lateral mass to the cribriform plate, which complete, with the frontal bone, the **ethmoidal canals**. The anterior canal transmits the anterior ethmoidal vessels and nerve; the posterior transmits the posterior ethmoidal vessels and nerve.

At the lower part of the lateral surface is a deep groove, which belongs to the middle meatus of the nose, and is bounded below by the thick curved margin of the inferior nasal concha. Anteriorly the middle meatus forms the **infundibulum**, a sinuous passage often communicating with the frontal sinus through the anterior part of the labyrinth. The anterior ethmoidal cells in part open into the lower portion of the infundibulum, and in this way communicate with the nose; some (the middle ethmoidal cells) open directly into the meatus. In front of

FIG. 167.—SECTION SHOWING THE ETHMOID, AND LATERAL WALL OF THE NASAL FOSSA.



the lamina papyracea are seen a few broken cells, which extend under, and are completed by, the lacrimal bone and the frontal process of the maxilla; from this part of the labyrinth an irregular lamina, known as the **uncinate process**, projects downward and backward. The uncinate process articulates with the ethmoidal process of the inferior nasal concha and forms a small part of the medial wall of the maxillary sinus.

Medially the labyrinth takes part in the formation of the **lateral wall** of the nasal fossa, and presents the **superior** and **middle nasal conchæ** (turbinate processes), continuous anteriorly, but separated behind by a space directed forward from the posterior margin (fig. 167). This channel is the **superior meatus** of the nose and communicates with the posterior ethmoidal cells.

The conchæ are covered in the recent state with mucous membrane and present numerous foramina for blood-vessels and, above, grooves for twigs of the olfactory nerves. Each concha has an attached upper border and a free, slightly convoluted, lower border, and in the case of the middle concha, the lower margin has already been noticed on the outer aspect, where it overhangs the middle meatus of the nose. The posterior extremity of the labyrinth articulates with the anterior surface of the body of the sphenoid and is commonly united with the sphenoidal concha.

A rounded prominence on the lateral wall of the middle meatus, inclosing an air cell, is known as the **bulla ethmoidalis**. Anteroinferior to the bulla is a large semilunar depression [hiatus semilunaris] which communicates with the infundibulum.

Many of the ethmoidal cells are imperfect and are completed by adjacent bones. Those along the superior edge of the lateral mass are the frontoethmoidal; those at the anterior border, usually two in number, are known as lacrimoethmoidal. Those along the lower edge of the lamina papyracea are the maxilloethmoidal; and posteriorly, are the sphenoethmoidal, completed by the sphenoidal concha, and a palatoethmoidal cell. The anterior extremity presents one or two incomplete cells closed by the nasal process of the maxilla. For further details concerning the ethmoidal cells, see p. 1236.

Blood-supply.—The ethmoid receives its blood-supply from the anterior and posterior ethmoidal arteries and from the sphenopalatine branch of the internal maxillary.

Articulations.—With the frontal, sphenoid, two palate bones, two nasals, vomer, two inferior nasal conchæ, two sphenoidal conchæ, two maxillæ, and two lacrimal bones. The posterior surface of each labyrinth is in relation with the sphenoid on each side of the crest and rostrum, and helps to close in the sphenoidal sinus.

Ossification.—The ethmoid has three centers of ossification. Of these, a nucleus appears in the fourth month of intrauterine life in each labyrinth, first in the lamina papyracea and afterward extending into the middle concha. At birth each lateral portion is represented by two scroll-like bones, very delicate and covered with irregular depressions, which give it a worm-eaten appearance. Six months after birth a nucleus appears in the ethmovomerine cartilage for the vertical plate which gradually extends into the crista galli, and the cribriform plate is formed by ossification extending laterally from this center, and medially from the labyrinth. The three parts coalesce to form one piece in the fifth or sixth year.

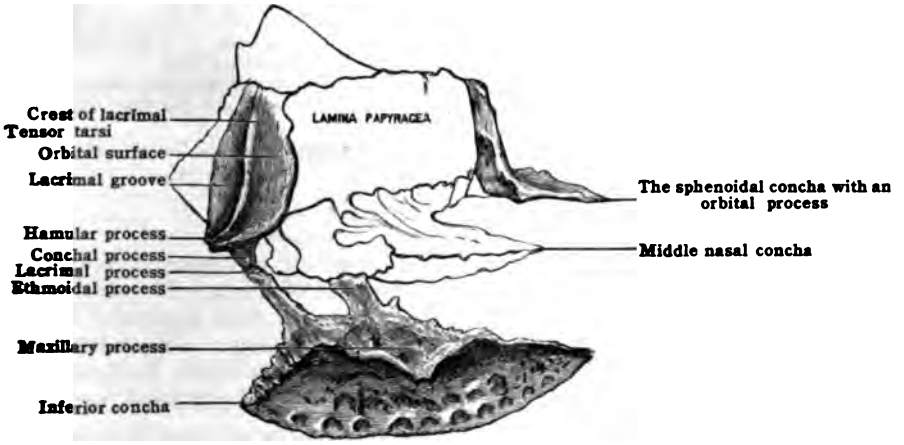
The ethmoidal cells arise before birth and become more prominent about the third year gradually invading the labyrinths. In many places there is so much absorption of bone that the cells perforate the ethmoid. Along the lower border, near its articulation with the maxilla the absorption leads to the partial detachment of a narrow strip known as the uncinate process. Sometimes a second but smaller hook-like process is formed, above and anterior to this, so fragile that it is difficult to preserve it in disarticulated bones. The relations of the uncinate process are best studied by removing the lateral wall of the maxillary sinus.

Variations.—Secondary foramina of the lamina papyracea are not infrequent in the aged. Reduction of this plate is met with where either the maxilla or the frontal or both send processes to participate in forming the medial wall of the orbit. Increase in the number of conchæ is common.

THE INFERIOR NASAL CONCHA

The **inferior nasal concha** (inferior turbinate) (fig. 168) is a slender, scroll-like lamina, attached by its upper margin to the lateral wall of the nasal fossa, and hanging into the cavity in such a way as to separate the middle from the inferior

FIG. 168.—THE INFERIOR CONCHA, ADULT SPHENOIDAL TURBINATE, AND LACRIMAL BONES.



meatus of the nose. It may be regarded as a dismemberment of the ethmoidal labyrinth, with which it is closely related. It presents two surfaces, two borders, and two extremities.

The lateral surface is concave, looks toward the lateral wall of the nasal fossa, and is overhung by the maxillary process. The medial surface is convex, pitted with depressions, and grooved for vessels, which, for the most part, run longitudinally. The superior or attached border articulates in front with the conchal crest of the maxilla, then ascends to form the lacrimal process, which articulates with the lacrimal bone and forms part of the wall of the lacrimal canal. Behind this, it is turned downward to form the maxillary process, already mentioned, which overhangs the orifice of the maxillary sinus and serves to fix the bone firmly to the lateral wall of the nasal fossa. The projection behind the maxillary process is the ethmoidal process, joined in the articulated skull with the uncinate process of the ethmoid across the opening of the maxillary sinus. Posteriorly the upper border articulates with the conchal

crest of the palate. The **inferior border** is free, rounded, and somewhat thickened. The **anterior extremity** is blunt and flattened, and broader than the **posterior extremity,** which is elongated, narrow, and pointed.

Articulations.—With the maxilla, lacrimal, palate, and ethmoid.

Ossification.—The inferior nasal concha is ossified in cartilage from a single nucleus which appears in the fifth month of intrauterine life. At birth it is a relatively large bone and fills up the lower part of the nasal fossa.

Variation.—A more or less prominent line, running the length of the medial surface, may be elevated to form a ridge or give rise to an additional scroll. It is probable that this is a persistence of the maxilloturbinal of the chondrocranium, from the base of which the inferior concha is derived.

THE LACRIMAL

The **lacrimal bone** [os lacrimale] (figs. 123, 168) is extremely thin and delicate quadrilateral in shape, and situated at the anterior part of the medial wall of the orbit. It is the smallest of the facial bones.

The **orbital surface** is divided by a vertical ridge, the **posterior lacrimal crest,** into two unequal portions. The anterior, smaller portion is deeply grooved to form the **lacrimal groove,** which lodges the lacrimal sac and forms the commencement of the canal for the nasolacrimal duct. The portion behind the ridge is smooth, and forms part of the medial wall of the orbit. The ridge gives origin to the *orbicularis oculi* (*pars lacrimalis*) muscle and ends below in a hook-like process, the **lacrimal hamulus,** which curves forward to articulate with the lacrimal tubercle of the maxilla and completes the superior orifice of the nasolacrimal canal. The **medial surface** is in relation with the two anterior cells of the ethmoid (lacrimoethmoidal), forms part of the infundibulum, and inferiorly looks into the middle meatus of the nose.

The **superior border** is short, and articulates with the medial angular process of the frontal. The **inferior border** posterior to the crest joins the medial edge of the orbital plate of the maxilla. The narrow piece, anterior to the ridge, is prolonged downward as the **descending process** to join the lacrimal process of the inferior nasal concha. The **anterior border articulates** with the posterior border of the frontal process of the maxilla and the **posterior border** with the lamina papyracea of the ethmoid.

The vessels of the lacrimal bone are derived from the infraorbital, dorsal nasal branch of the ophthalmic, and anterior ethmoidal arteries.

Articulations.—The lacrimal articulates with the ethmoid, maxilla, frontal, and inferior nasal concha.

Ossification.—This bone arises in the membrane overlying the cartilage of the frontonasal plate, and in its mode of ossification is very variable. As a rule, it is formed from a single nucleus which appears in the third or fourth month of intrauterine life.

Variations.—Division into two or more parts; fusion with neighboring bones; absence and extensive development of the hamulus to project out of the orbit are the chief variations of the lacrimal.

The hamular process is regarded as representing the remains of the facial part of the lacrimal seen in lower animals.

THE VOMER

The **vomer** (figs. 165, 169) (ploughshare bone) is an unpaired flat bone, which lies in the median plane and forms the lower part of the nasal septum. It is thin and irregularly quadrilateral in form, and is usually bent somewhat to one side, though the deflection rarely involves the posterior margin. Each **lateral surface** is covered in the recent state by the nasal mucous membrane, and is traversed by a narrow but well-marked groove, which lodges the nasopalatine nerve.

The **superior border,** by far the thickest part of the bone, is expanded laterally into two **alæ.** The groove between them receives the rostrum of the sphenoid, and the margin of each ala comes into contact with the sphenoidal process of the palate and the vaginal process of the medial pterygoid plate. The **inferior border** is uneven and lies in the groove formed by the crests of the maxillary and palate bones of the two sides. The **anterior border slopes downward** and forward and is grooved below for the septal cartilage of the nose; above it is united with the perpendicular plate of the ethmoid. The **posterior border,** smooth, rounded, and covered by mucus membrane, separates the choanæ (posterior nares). The anterior and inferior borders meet at the anterior extremity of the bone which forms a short vertical ridge behind the incisor crest of the maxillæ. From near the anterior extremity, a small projection passes downward between the incisive foramina.

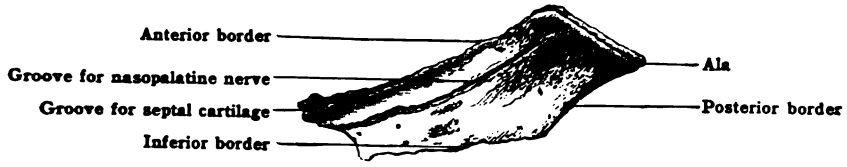
Blood-supply.—The arterial supply of the vomer is derived from the anterior and posterior ethmoidal and the sphenopalatine arteries. Branches are also derived from the posterior palatine through the foramen incisivum.

Ossification.—The vomer is ossified from two centers which appear about the eighth week in the membrane investing the ethmovomerine cartilage. The two lamellæ unite below during

the third month and form a shallow bony trough in which the cartilage lies. In the process of growth the lamellæ extend upward and gradully fuse to form a rectangular plate of bone, the cartilage enclosed between them undergoing absorption at the same time. The alæ on the superior margin and the groove in front are evidence of the original bilaminar condition. However, a bilateral origin of the vomer is not the general rule among mammals. (Terry, Anat. Rec., 1909, 3 : 525.)

Variation.—The inferior margin of the vomer has been observed in the intermaxillary suture participating with the palatal processes in the formation of the hard palate.

FIG. 169.—THE VOMER. (Side view.)



THE NASAL BONES

The **nasal** (figs. 170, 171) are two small oblong bones situated at the upper part of the face and forming the bridge of the nose. Each bone is thicker and narrower above, thinner and broader below, and presents two surfaces and four borders.

The **facial surface** is concave from above downward, convex from side to side, and near the center is perforated by a small foramen, which transmits a small tributary to the anterior facial vein. The posterior or **nasal surface,** covered in the recent state by mucous membrane, is concave laterally, and traversed by a longitudinal groove [sulcus ethmoidalis] for the anterior ethmoidal branch of the ophthalmic division of the trigeminal nerve.

FIG. 170.—THE LEFT NASAL BONE, FACIAL SURFACE.

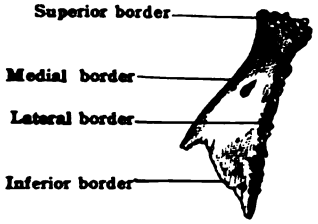
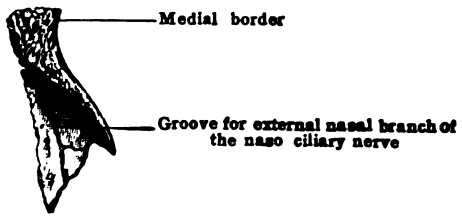


FIG. 171.—THE LEFT NASAL BONE, NASAL SURFACE.



The short **superior border** is thick and serrated for articulation with the medial part of the nasal notch of the frontal. The **inferior border** is thin, and serves for the attachment of the lateral nasal cartilage. It is notched for the external nasal branch of the anterior ethmoidal nerve. The nasal bones of the two sides are united by their **medial borders,** forming the internasal suture. The contiguous borders are prolonged backward to form a crest which rests on the frontal spine and the anterior border of the perpendicular plate of the ethmoid. The **lateral border** articulates with the frontal process of the maxilla.

Blood-supply.—Arteries are supplied to this bone by the nasal branch of the ophthalmic the frontal, the angular, and the anterior ethmoidal arteries.

Articulations.—With the frontal, maxilla, ethmoid, and its fellow of the opposite side.

Ossification.—Each nasal bone is developed from a single center which appears about the eighth week in the membrane overlying the frontonasal cartilage. The cartilage, which is continuous with the ethmoid cartilage above and the lateral cartilage of the nose below, subsequently undergoes absorption. At birth the nasal bones are nearly as wide as they are long, whereas in the adult the length is three times greater than the width.

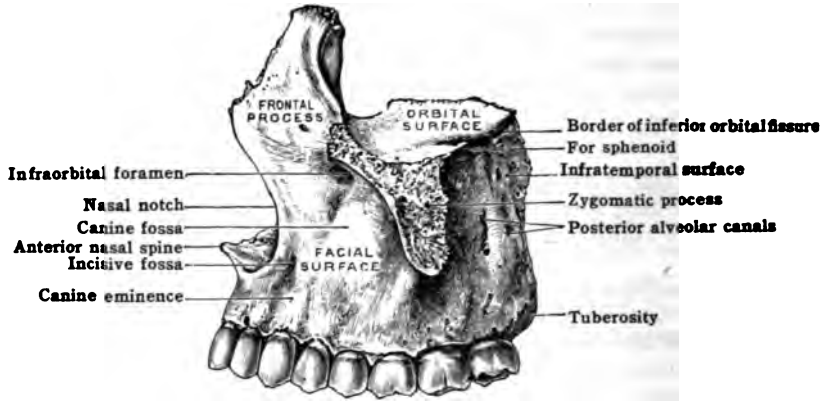
Variations.—Reduction of the nasal bones with concavity of the lateral margins and accompanied by expansion of the frontal process of the maxilla is not uncommon. Rarely the nasal bones are absent.

THE MAXILLA

The **maxilla** or upper jaw-bone (figs. 172–174) is one of the largest and most important of the bones of the face. It supports the maxillary teeth and takes part in the formation of the orbit, the hard palate, and the nasal fossa. It is divisible into a **body** and four processes, of which two—the **frontal** and **zygomatic** —belong to the upper part, and the **palatine** and **alveolar** to the lower part of the bone.

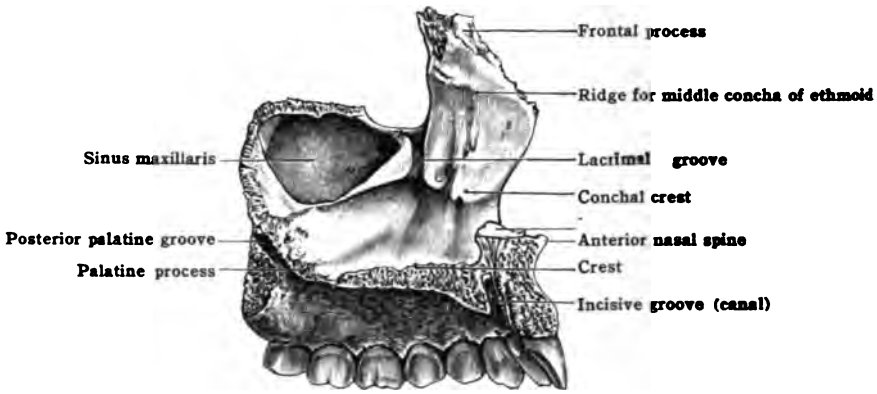
The **body** is somewhat pyramidal in shape and hollowed by a large cavity known as the **sinus maxillaris** (antrum of Highmore), lined by mucous membrane in the recent state, and opening at the base of the pyramid into the **nasal cavity**, the zygomatic process forming the apex. The **anterior** (or facial) **surface** looks forward and outward and is marked at its lower part by a series of eminences which indicate the positions of the roots of the teeth. The eminence produced by the fang of the canine tooth is very prominent and separates two fossæ. That on the medial side is the **incisive fossa**, and gives origin to the *alar* and *transverse portions* of the *nasalis*, and just above the socket of the lateral incisor tooth, to a

FIG. 172.—THE LEFT MAXILLA. (Lateral view.)



slip of the *orbicularis oris;* on the lateral side is the **canine fossa**, from which the *caninus* (*levator anguli oris*) arises. Above the canine fossa, and close to the margin of the orbit, is the **infraorbital foramen**, through which the terminal branches of the infraorbital nerve and vessels emerge, and from the ridge immediately above the foramen the *quadratus labii superioris* takes origin. The medial margin of the anterior surface is deeply concave, forming the **nasal notch**, the lateral boundary of the **piriform aperture** (fig. 122), and is prolonged below into the **anterior nasal spine**.

FIG. 173.—THE LEFT MAXILLA. (Medial view.)

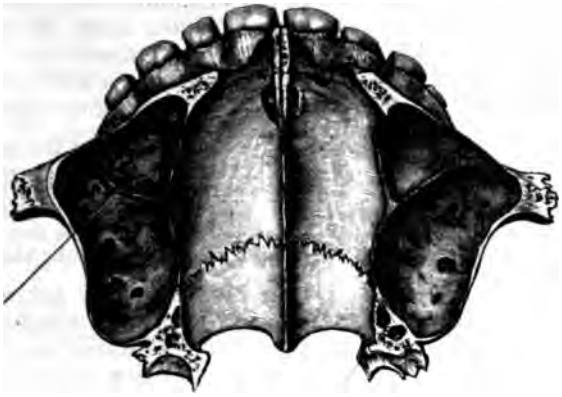


A ridge of bone extending upward from the socket of the **first molar tooth** separates the anterior from the **infratemporal** (zygomatic) **surface**. This latter surface is convex and presents near the middle the orifices of the **posterior alveolar canals**, transmitting the posterior alveolar vessels and nerves. The posterior inferior angle, known as the **tuberosity** [tuber maxillare], is rough and is most prominent after eruption of the wisdom tooth. It gives origin to a few fibers of the *internal pterygoid* muscle and articulates with the tuberosity of the palate.

The **orbital surface** [planum orbitale] is smooth, irregularly **triangular**, and forms the greater part of the floor of the orbit.

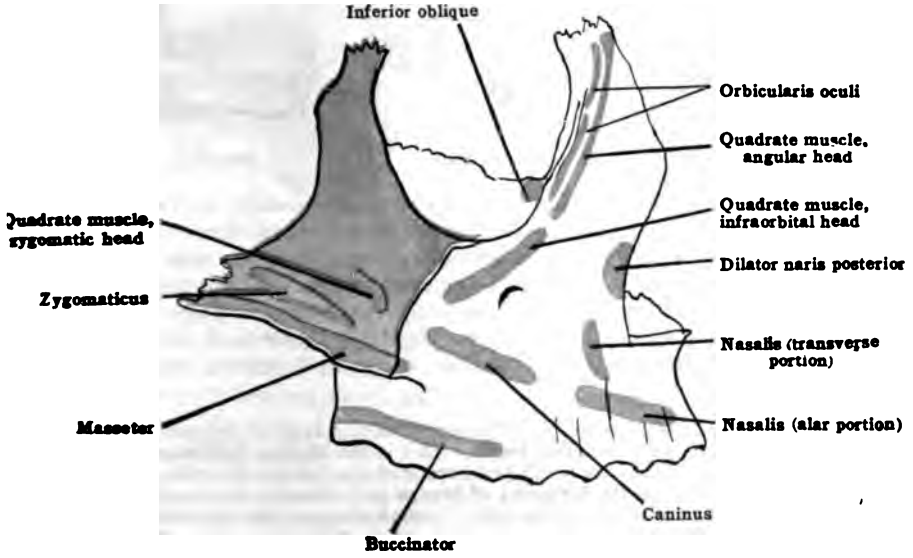
Anteriorly, it is rounded and reaches the orbital circumference for a short distance at the ot of the nasal process; laterally is the rough surface for the zygomatic bone. The posterior order, smooth and rounded, forms the inferior boundary of the inferior orbital fissure. The edial border is nearly straight and presents, behind the frontal process, a smooth rounded ngle forming part of the circumference of the orbital orifice of the nasolacrimal canal, and a otch which receives the lacrimal bone. The rest of the medial border is rough for articulation ith the lamina papyracea of the ethmoid and orbital process of the palate bone.

FIG. 174.—SECTION OF MAXILLÆ TO SHOW THE FLOOR OF THE MAXILLARY ANTRUM. (Reduced ¼.)



The orbital surface is traversed by the **infraorbital groove**, which, commencing at the posterior border, deepens as it passes forward and finally becomes closed in to form the **infraorbital canal**. It transmits the second division of the trigeminal nerve and the infraorbital vessels and terminates on the anterior surface immediately below the margin of the orbit. From the infraorbital, other canals—the **anterior** and **middle alveolar**—run downward in the wall of the

FIG. 175.—MAXILLA AND ZYGOMATIC BONE, TO SHOW MUSCULAR ATTACHMENTS. (Poirier.



antrum and transmit the anterior and middle alveolar vessels and nerves. Lateral to the commencement of the lacrimal canal is a shallow depression for the origin of the *inferior oblique* muscle of the eye.

The **nasal surface** takes part in the formation of the lateral wall of the nasal ossa. It presents a large irregular aperture which leads into the antrum and, immediately in front of this, the **lacrimal groove**, directed downward, backward, and laterally into the inferior meatus of the nose. The groove is converted into a canal by the lacrimal and inferior nasal concha and transmits the nasolacrimal duct.

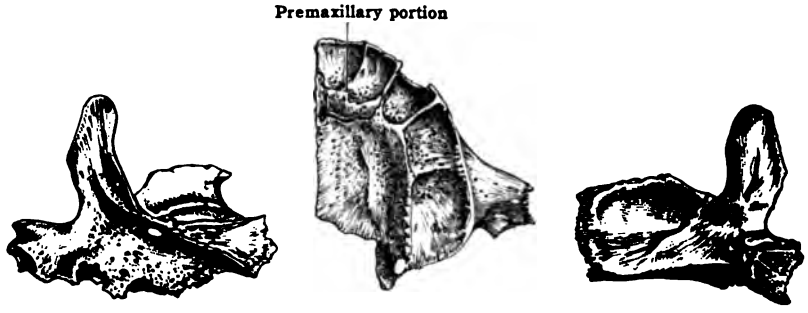
In front of the groove is a smooth surface crossed obliquely by a ridge, the **conchal crest**, for articulation with the inferior nasal concha. The surface below the crest is smooth, concave, and belongs to the inferior meatus; the surface above the crest extends on to the lower part of the frontal process and forms the wall of the atrium of the middle meatus. Behind the opening of the antrum the surface is rough for articulation with the vertical plate of the palate bone and crossing it obliquely is a smooth groove converted by the palate into the **pterygopalatine canal** for the passage of the (descending) palatine nerves and the descending palatine artery.

The **frontal process,** somewhat triangular in shape, rises vertically from the **angle** of the maxilla. Its lateral surface is continuous with the anterior surface of the body, and gives attachment to the *orbicularis oculi,* the medial palpebral ligament and the *quadratus labii superioris* (*caput angulare*). The medial surface forms part of the lateral boundary of the nasal fossa and is crossed obliquely by a low ridge, known as the **agger nasi,** limiting the atrium of the middle meatus.

The hinder part of this surface rests on the anterior extremity of the labyrinth of the ethmoid and completes the maxilloethmoidal cells. The superior border articulates with the frontal; the anterior border articulates with the nasal bone; the posterior border is thick and vertically grooved, in continuation with the lacrimal groove, and lodges the lacrimal sac. The medial margin of the groove articulates with the lacrimal bone, and the junction of its lateral margin with the orbital surface is indicated by the **lacrimal tubercle.**

The **zygomatic process,** rough and triangular, forms the summit of the prominent ridge of bone separating the anterior and infratemporal surfaces. It articulates above with the zygomatic, and from its inferior angle a few fibers of the *masseter* take origin. The anterior and posterior surfaces are continuous with the anterior and infratemporal surfaces of the body.

FIG. 176.—THE MAXILLA AT BIRTH.



The **palatine process** projects horizontally from the medial surface and with the corresponding process of the opposite side, forms about three-fourths of the hard palate. The superior surface is smooth, concave from side to side, and constitutes the larger part of the floor of the nasal fossa. The inferior surface is vaulted, rough, and perforated with foramina for nutrient vessels. Near its lateral margin is a longitudinal groove for the transmission of the vessels and nerves which issue at the posterior palatine canal and course along the lower aspect of the palate.

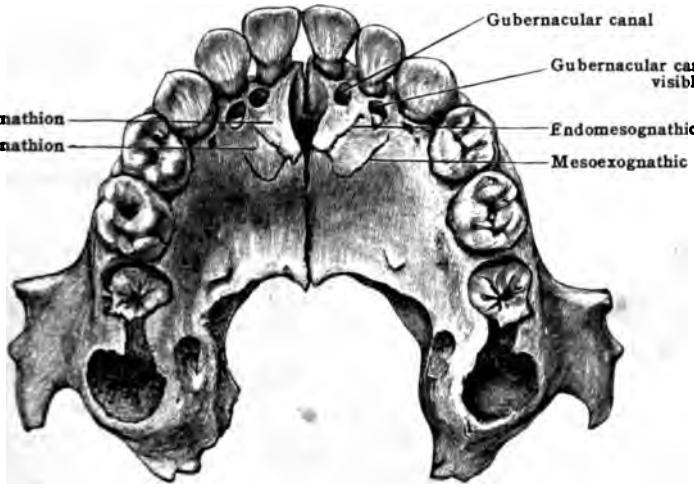
When the bones of the two sides are placed in apposition, a large orifice may be seen in the middle line immediately behind the incisor teeth. This is the **incisive foramen,** at the bottom of which are four foramina. Two are small and arranged one behind the other exactly in the **mesopalatine suture.** These are the **foramina of Scarpa** and transmit the nasopalatine nerves, the left passing through the anterior and the right through the posterior aperture. The lateral and larger orifices are the **foramina of Stenson,** representing the lower apertures of the incisive canals by which the nose communicates with the mouth; they transmit some terminal branches of the descending palatine artery to the nasal fossæ, and may contain recesses or remnants of the nasal mucous membrane.

Running laterally from the incisive foramen to the space between the second incisor and canine tooth, an indistinct suture may sometimes be seen, indicating the line of junction of the maxillary and premaxillary portions of the bone. The **premaxilla** or **incisive bone** is the part which bears the incisor teeth and in some animals exists throughout life as an independent element. The posterior border of the palate process is rough and serrated for articulation with the horizontal plate of the palate bone which completes the hard palate. The **medial border** joins with its fellow to form the **nasal crest** upon which the vomer is received. The more elevated anterior portion of this border is known as the **incisor crest,** and is continued forward into the **anterior nasal spine.** The septal cartilage of the nose rests on its summit and the an-

tremity of the vomer lies immediately behind it. At the side of the incisor crest is upper aperture of a canal leading from the nose to the mouth, which in its course d becomes a groove by a deficiency of its medial wall. Thus when the two bones are ıd the incisive canal is formed, communicating above with the nasal fossa on either side.

alveolar process is crescentic in shape, spongy in texture, and presents [alveoli dentales] in which the upper teeth are lodged. When complete e eight sockets (alveoli), with wide mouths, gradually narrowing as they o the substance of the bone, and forming exact impressions of the cor- ing fangs of the teeth. The pit for the canine tooth is the deepest; r the molars are the widest and subdivided. Along the lateral aspect of olar process the *buccinator* arises as far forward as the first molar tooth. **maxillary sinus** or antrum of Highmore (figs. 128, 174), the air-chamber ng the body of the bone, is somewhat pyramidal in shape, the **base** being ıted by the nasal or medial surface, and the **apex** corresponding to the tic process. In addition it has four walls: the superior is formed by the plate, and the inferior by the alveolar ridge. The anterior wall corre- to the anterior surface of the maxilla, and the posterior is formed by the ıporal surface. The medial boundary or base presents a very irregular ıt its posterior part; this is partially filled in by the vertical plate of the

.—MAXILLÆ AT THE END OF THE FIRST DENTITION IN BOTH OF WHICH THE SUTURES VEEN MAXILLA AND PREMAXILLA, AND BETWEEN THE TWO PARTS OF THE PREMAXILLA, SEEN.



one, the uncinate process of the ethmoid, the maxillary process of the nasal concha, and a small portion of the lacrimal bone. Even when these re in their relative positions, the orifice is very irregular in shape, and the mucous membrane to form the definite rounded aperture (or aper- or they are often multiple) known as the **opening of the sinus** through he cavity communicates with the middle meatus of the nose.

cavity of the sinus varies considerably in size and shape. In the young, it is small walls are thick: as life advances it enlarges at the expense of its walls, and in old age often extremely thin, so that occasionally the cavity extends even into the substance gomatic bone. The floor of the sinus is usually very uneven, due to prominences cor- ng to the roots of the molar teeth. In most cases the bone separating the teeth from is very thin, and occasionally the roots project into it. The teeth which come into lationship with the sinus are the first and second molars, but the sockets of any of the lged in the maxilla may, under diseased conditions, communicate with it. As a rule, y of the sinus is single, but occasionally specimens are seen in which it is divided by ta into chambers, and it is not uncommon to find recesses separated by bony processes. of the sinus presents near its anterior aspect what appears to be a thick rib of bone; llow and corresponds to the infraorbital canal. For further details, see p. 1235.

-supply.—The maxilla is a very vascular bone and its arteries are numerous and large. derived from the infraorbital, alveolar, descending palatine, sphenopalatine, eth- rontal, nasal, and external maxillary vessels.

lations.—With the frontal, nasal, lacrimal, ethmoid, palate, vomer, zygomatic, in- al concha and its fellow of the opposite side. Occasionally it articulates with the great l the pterygoid process, of the sphenoid.

Ossification.—The maxilla is developed from several centers which are deposited in membrane during the second month of intrauterine life. Several pieces are formed which speedily fuse, so that at birth, with the exception of the incisor fissure separating the maxilla from the premaxilla, there is no trace of the composite character of the bone. The centers of ossification comprise—(1) the **malar,** which gives rise to the portion of bone outside the infraorbital canal; (2) the **maxillary,** from which the greater part of the body and the frontal process are developed; (3) the **palatine,** forming the hinder three-fourths of the palatal process and adjoining part of the nasal wall; (4) the **premaxillary,** giving rise to the independent premaxillary bone (os incisivum), which lodges the incisor teeth and completes the anterior fourth of the hard palate. In the early stages of growth the premaxilla may consist of two pieces arising from two centers of ossification which Albrecht has named as follows:—the *endognathion,* or medial division for the central incisor, and the *mesognathion,* or lateral division for the lateral incisor; the rest of the maxilla is named the *exognathion;* (5) the **prepalatine,** corresponding to the infravomerine center of Rambaud and Renault, forms a portion of bone interposed between the premaxillary in front and the palatine process behind. It gives rise to a part of the nasal surface and completes the medial wall of the incisive canal.

At birth the maxillary sinus is narrow from side to side and does not extend laterally to any appreciable extent between the orbit and the alveoli of the teeth. During the early years of life it gradually enlarges, but does not attain its full growth until after the period of the second dentition. For further description of the maxillary sinus, see p. 1235.

Variations.—The walls of the infraorbital canal may be incomplete toward the maxillary sinus, putting the nerve into direct contact with the lining mucosa. The infraorbital foramen may be double. Cleft palate is apparently due to non-union of the embryonic palatine shelves (p. 38). The cleft which occurs to one side of the midline, falls through the incisive bone and germ of the lateral incisor tooth and not as a rule in the plane of the suture between the incisive and maxillary bones.

THE PALATE

The **palate bone** [os palatinum] (figs. 178, 179) forms the posterior part of the hard palate, the medial wall of the nasal fossa between the maxilla and the

FIG. 178.—LEFT PALATE BONE. (Medial view.)

Orbital process (ethmoidal surface)
Sphenoidal process
Sphenopalatine notch (when the foramen is complete in the palate bone, it is due to ankylosis with sphenoidal concha)
Superior meatus
Ethmoidal crest
Middle meatus
Conchal crest
Inferior meatus

medial pterygoid plate, and, by its orbital process, the hinder part of the floor of the orbit. It is somewhat L-shaped and presents for examination a **horizontal** part and a **perpendicular** part; at their point of junction is the **pyramidal process,** and surmounting the top of the vertical plate are the **orbital** and **sphenoidal** processes, separated by the **sphenopalatine notch.**

The **horizontal** part resembles the palatine process of the maxilla, but is much shorter. The **superior surface** is smooth, concave from side to side, and forms the back part of the floor of the nasal fossa; the **inferior surface** completes the hard palate behind and presents near its posterior border a **transverse ridge** which gives attachment to the *tensor veli palatini* muscle.

The anterior border is rough for articulation with the palatine process of the maxilla; the posterior is free, curved, and sharp, giving attachment to the soft palate. Medially it is thick and broad for articulation with its fellow of the opposite side, forming a continuation of the crest of the palatal processes of the maxillæ and supporting the vomer. The posterior extremity of the crest is the **posterior nasal spine,** from which the *azygos uvulæ* arises. Laterally, at its junction with the perpendicular part, it is grooved by the pterygopalatine canal.

The **perpendicular** part is longer and thinner than the horizontal plate. The **lateral surface** is in relation with the maxilla and is divided into two parts by a vertical groove which forms with the maxilla the **pterygopalatine canal** for the transmission of the anterior palatine nerve and the descending palatine

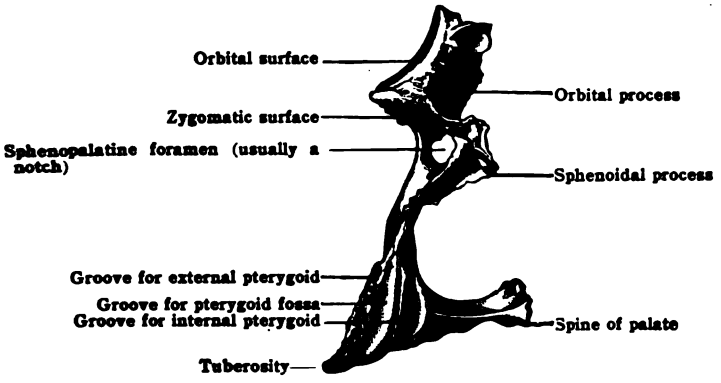
artery. The part of the surface in front of the groove articulates with the nasal surface of the maxilla and overlaps the orifice of the antrum by the **maxillary process,** a variable projection on the anterior border. Behind the groove the surface is rough for articulation with the maxilla below and the medial pterygoid plate above.

The medial or nasal surface presents two nearly horizontal ridges separating three shallow depressions. Of the depressions, the lower forms part of the inferior meatus of the nose, and the limiting ridge or **conchal** (inferior turbinate) **crest** articulates with the inferior nasal concha. Above this is the depression forming part of the middle meatus, and the ridge or **ethmoidal** (superior turbinate) **crest,** constituting its upper boundary, articulates with the middle nasal concha.

The upper groove is narrower and deeper than the other two and forms a large part of the superior meatus of the nose. The anterior border of the vertical plate is thin and bears the **maxillary process,** a tongue-like piece of bone, which extends over the opening of the maxillary sinus from behind. This border is continuous above with the orbital process. The posterior border is rough and articulates with the anterior border of the medial pterygoid plate. It is continuous superiorly with the sphenoidal process.

The pyramidal process or **tuberosity** fits into the notch between the lower extremities of the pterygoid plates and presents posteriorly three grooves. The middle, smooth and concave, completes the pterygoid fossa, and gives origin to a few fibers of the *internal pterygoid;* the medial and lateral grooves are rough for articulation with the anterior border of the corresponding pterygoid plate. Inferiorly, close to its junction with the horizontal plate, are the openings of the **greater palatine** and **smaller palatine canals,** of which the latter are less constant; they

FIG. 179.—PALATE BONE. (Posterior view.)



transmit the palatine nerves. Medially the pyramidal process gives origin to a few fibers of the *superior constrictor* of the pharynx, and laterally a small part appears in the infratemporal fossa between the tuberosity of the maxilla and the pterygoid process of the sphenoid.

The sphenoidal process, the smaller of the two processes surmounting the vertical part, curves upward and medially and presents three surfaces and two borders. **The superior surface** is in contact with the body of the sphenoid, and the top of the medial pterygoid plate, where it completes the **pharyngeal canal.** The **medial** or **inferior surface** forms part of the lateral wall and roof of the nasal fossa, and at its medial end touches the ala of the vomer. The **lateral surface** looks forward and laterally into the pterygopalatine (sphenomaxillary) fossa. Of the two borders, the posterior is thin and articulates with the medial pterygoid plate; the anterior border forms the posterior boundary of the **sphenopalatine** foramen.

The orbital process is somewhat pyramidal in shape, and presents for examination five surfaces, three of which—the posterior, anterior, and medial—are articular and the rest non-articular. **The posterior or sphenoidal surface** is small and joins the anterior surface of the body of the sphenoid; **the medial or ethmoidal** articulates with the labyrinth of the ethmoid; and **the anterior or maxillary,** which is continuous with the lateral surface of the perpendicular part, is joined with the maxilla. Of the two non-articular surfaces, the **superior or orbital,** directed upward and laterally, is slightly concave, and forms the posterior angle of the floor of the orbit; **the lateral or zygomatic,** smooth and directed laterally looks into the pterygopalatine (sphenomaxillary) and infratemporal fossæ, and forms the anterior boundary of the sphenopalatine foramen. The process is usually hollow and the cavity completes one of the posterior ethmoidal cells or communicates with the sphenoidal sinus.

Between the orbital and sphenoidal processes is the **sphenopalatine notch,** converted by the body of the sphenoid, into a complete foramen. It leads from the pterygopalatine fossa into the back part of the nasal cavity close to its roof, and transmits the medial branches from the sphenopalatine ganglion and the sphenopalatine vessels.

Blood-supply.—The palate bone receives branches from the descending palatine and the sphenopalatine arteries.

Articulations.—With the sphenoid, maxilla, vomer, inferior nasal concha, ethmoid, and its fellow of the opposite side.

Ossification.—The palate is ossified in membrane from a single center which appears about the eighth week at the angle between the horizontal and perpendicular parts. At birth the two parts are nearly equal in length, but as the nasal fossæ increase in vertical depth, the perpendicular part is lengthened until it becomes about twice as long as the horizontal part.

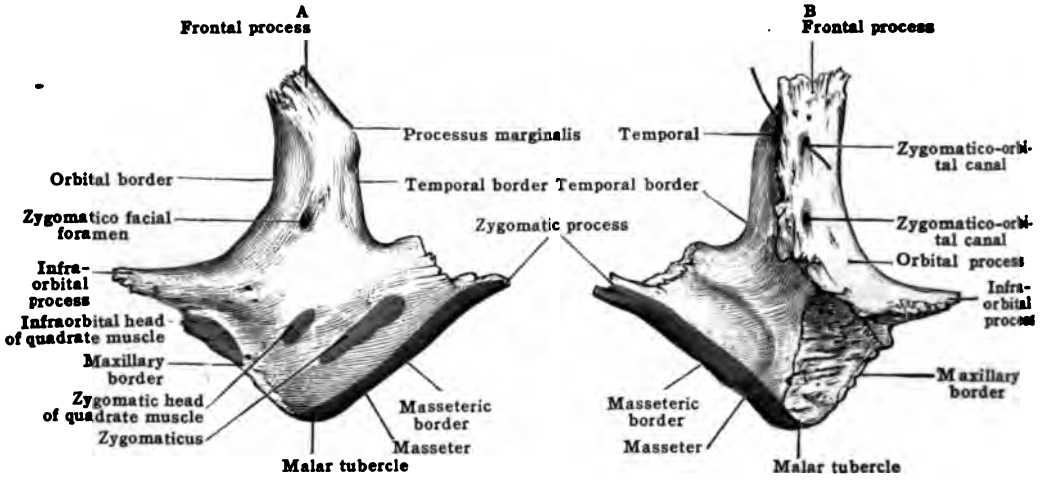
Variations.—Conversion of the sphenopalatine notch into a foramen (fig. 179) is rather frequent. Variation in the size of the orbital process is often observed; by enlargement it may reach the frontal bone in the medial wall of the orbit. The air-cell of this process may communicate with one of the posterior ethmoidal cells. The horizontal plate may be invaded by the maxillary antrum.

THE ZYGOMATIC

The **zygomatic** [os zygomaticum] or **malar bone** (fig. 180) forms the prominence of the cheek and joins the zygomatic process of the temporal with the maxilla. It is quadrangular in form with the angles directed vertically and horizontally. The **malar** (or external) **surface** is convex and presents one or two small orifices for the transmission of the zygomaticofacial nerves and vessels. It is largely covered by the *orbicularis oculi* and near the middle is slightly elevated to form the **malar tuberosity,** which gives origin to the ***zygomaticus*** and zygomatic head of the *quadratus labii superioris* muscle.

The **temporal** (or internal) **surface** is concave and looks into the temporal and infratemporal fossæ; it is excluded from the orbit by a prominent curved plate

FIG. 180.—THE LEFT ZYGOMATIC BONE.
A, the malar surface. B, the temporal and orbital surfaces.



of bone, the **orbital process,** which forms the anterior boundary of the temporal fossa. The upper part gives origin to a few fibers of the *temporal* muscle, while at the lower part is a large rough area for articulation with the zygomatic process of the maxilla.

The **orbital process** is placed at right angles to the remaining part of the bone and forms the anterior portion of the lateral wall of the orbit. On the **orbital surface** of the process are seen the foramina of two **zygomatico-orbital canals,** which transmit the zygomaticofacial and zygomaticotemporal branches of the zygomatic branch of the fifth, together with two small arteries from the lacrimal. In some cases, however, the canal is single at its commencement on the orbital plate and bifurcates as it traverses the bone. The rough free edge of the process articulates above with the zygomatic border of the great wing of the sphenoid, and below with the maxilla. When the orbital process is large, it excludes the great wing of the sphenoid from articulation with the maxilla, and the border then presents near the middle a short, non-serrated portion which closes the anterior extremity of the inferior orbital (sphenomaxillary) fissure.

All the four angles of the zygomatic bone have distinguishing features. **The superior,** forming the **frontosphenoidal process,** is the most prominent, and is serrate for articulation with the zygomatic process of the frontal; the anterior or **infraorbital process,** sharp and pointed, articulates with the maxilla and occasionally forms the superior boundary of the infra-

orbital foramen; the posterior or **temporal process** is blunt and serrated mainly on its medial aspect for articulation with the zygomatic process of the temporal; the inferior angle, blunt and rounded, is known as the **malar tubercle.**

Of the four borders, the **orbital** is the longest and extends from the frontosphenoidal to the **infraorbital process.** It is thick, rounded, and forms more than one-third of the circumference of the orbit; the **temporal border,** extending from the frontosphenoidal to the temporal process, is sinuously curved and gives attachment to the temporal fascia. Near the frontal angle is usually seen a slight elevation, the **processus marginalis,** to which a strong slip of the fascia is attached; the **masseteric** border, thick and rough, completes the lower edge of the zygomatic arch and gives origin to the anterior fibers of the *masseter;* the **maxillary** border, rough and concave, is connected by suture with the maxilla, and near the margin of the orbit gives origin to the infraorbital head of the *quadratus labii superioris.*

Blood-supply.—The arteries of the zygomatic are derived from the infraorbital, lacrimal, transverse facial, and deep temporal arteries.

Articulations.—With the maxilla, frontal, temporal, and sphenoid.

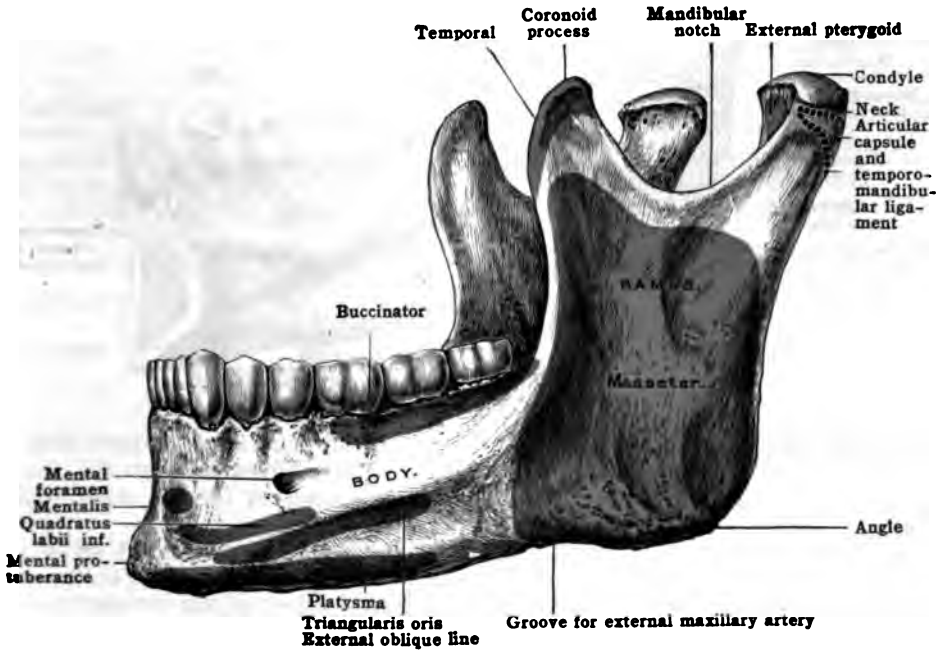
Ossification.—The zygomatic is ossified in membrane from three centers which appear in the eighth week of intrauterine life. The three pieces, which have received the names of *premalar, postmalar,* and *hypomalar,* unite about the fifth month.

Variations.—The canals and foramina, which transmit branches of the zygomatic ramus of the maxillary nerve, are subject to frequent variation in number and position. Occasionally the primary nuclei fail to coalesce, and the bone is then represented in the adult by two or three portions separated by sutures. The bipartite zygomatic has been observed in skulls obtained from at least a dozen different races of mankind, but because of its greater frequency in the crania of the Japanese (seven per cent.), the name of *os Japonicum* has been given to it.

THE MANDIBLE

The **mandible** [mandibula] or lower jaw-bone (figs. 181, 182) is the largest and strongest bone of the face. It supports the lower teeth, and by means of a pair of condyles, moves on the skull at the mandibular fossæ of the temporal

FIG. 181.—THE MANDIBLE. (Lateral view.)



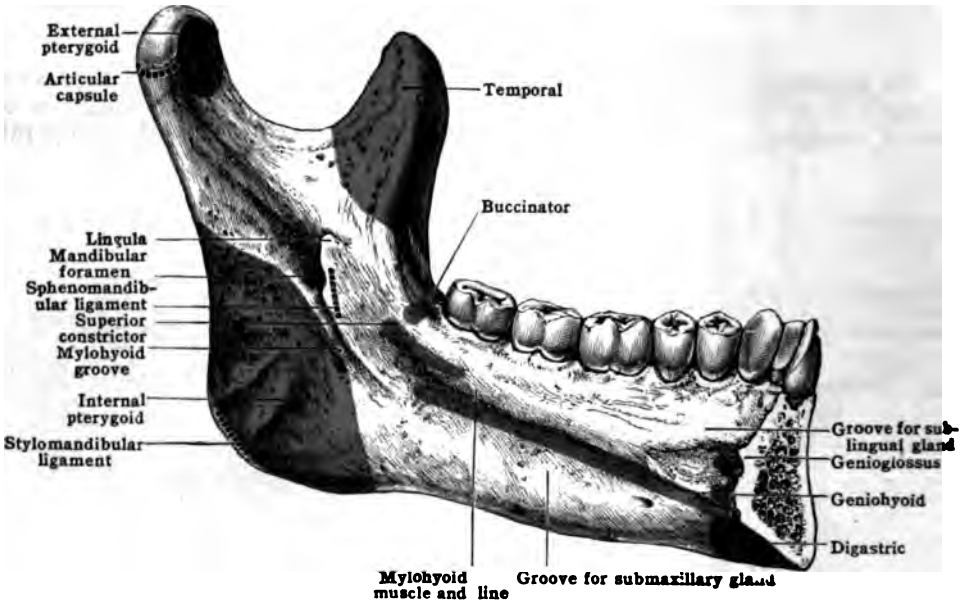
bones. It consists of a horizontal portion—the **body**—strongly curved, so as to somewhat resemble in shape a horseshoe, from the ends of which two branches or **rami** ascend almost at right angles.

The **body** is marked in the middle line in front by a faint groove which indicates the **symphysis** or place of union of the two originally separate halves of the bone. This ends below in the elevation of the chin known as the **mental protuberance,** the lowest part of which is slightly depressed in the center and raised on each side to form the **mental tubercle.** Each half of the mandible presents two surfaces and two borders. On the **lateral surface,** at the side of the symphysis, and below the incisor teeth, is a shallow depression, the **incisor**

fossa, from which the *mentalis* and *the incisivus labii inferioris* muscle arise; and more laterally, opposite the second bicuspid tooth, and midway between the upper and lower margins, is the **mental foramen,** which transmits the mental nerve and vessels. Below the foramen is the **oblique line,** extending backward and upward from the mental tubercle to the anterior border of the ramus; it divides the body into an upper or **alveolar** part and a lower or **basilar** part and affords origin to the *quadratus labii inferioris* and the *triangularis* muscles.

The **medial surface** presents at the back of the symphysis four small projections, forming the **mental spine** (genial tubercles). These are usually arranged in two pairs, one above the other; the upper comprising, a pair of prominent spines, gives origin to the *genioglossi,* and the lower, represented in some bones by a median ridge or only a slight roughness, gives origin to the *geniohyoid* muscles. At the side of the symphysis near the inferior margin is an oval depression, the **digastric fossa,** for the attachment of the anterior belly of the *digastric* muscle. Commencing below the mental spine, and extending upward and backward to the ramus, is the **mylohyoid line,** which becomes more prominent as it approaches the alveolar border; it gives attachment along its whole length to the *mylohyoid* muscle, at its posterior fifth to the *superior constrictor* of the pharynx,

FIG. 182.—THE MANDIBLE. (Medial view.)



and at the posterior extremity to the pterygomandibular raphe. Above this line at the side of the symphysis is a smooth depression [fovea sublingualis] for the sublingual gland, and below it, farther back, is another for the submaxillary gland.

The **alveolar part** or superior border is hollowed out into **eight sockets** or alveoli. These are conical in shape and form an exact counterpart of the roots of the teeth which they contain. From the lateral aspect of the alveolar process, as far forward as the first molar tooth, the *buccinator* muscle takes origin.

The **base** or inferior border is thick and rounded. In the anterior part of its extent it gives attachment to the *platysma,* and near its junction with the ramus is a groove for the external maxillary artery which here turns upward into the face.

The **ramus** is thinner than the body and quadrilateral in shape. The lateral surface is flat, gives insertion to the *masseter,* and at the lower part is marked by several oblique ridges for the attachment of tendinous bundles in the substance of the muscle. The medial surface presents near the middle the **mandibular** (inferior dental) **foramen,** leading into the **mandibular** (inferior dental) **canal.**

The canal traverses the bone and terminates at the mental foramen on the lateral surface of the body. From the canal, which in its posterior two-thirds is nearer to the medial, and in its anterior third nearer to the lateral, surface of the mandible, a series of small channels pass

upward to the sockets of the posterior teeth and transmit branches of the inferior alveolar (dental) vessels and nerve; in front of the mental foramen a continuation of the canal extends forward and conveys the vessels and nerves to the canine and incisor teeth. The mandibular foramen is bounded medially by a sharp margin forming the **lingula** (mandibular spine), which gives attachment to the sphenomandibular ligament. The posterior margin of the lingula is notched. This notch forms the commencement of a groove, the **mylohyoid groove** [sulcus mylohyoideus], which runs obliquely downward and forward and lodges the mylohyoid nerve and artery, and, in the embryo, Meckel's cartilage. Behind the spine is a rough area for the insertion of the *internal pterygoid* muscle.

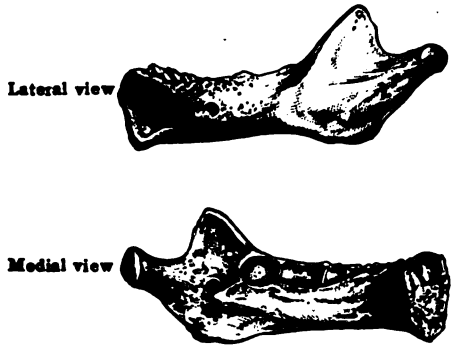
The posterior border of the ramus is thick and rounded, and in meeting the inferior border of the ramus forms the **angle** of the jaw, which is rough, obtuse, usually everted, and about 122° in the adult; the angle gives attachment to the

FIG. 183.—MANDIBLE SHOWING RELATIONS OF MECKEL'S CARTILAGE IN HUMAN FETUS OF 8 CM. CROWN-RUMP LENGTH. (After Kollmann.)

stylomandibular ligament. The inferior border is thick, rounded, and continuous with the base. The anterior border is continuous with the oblique line whilst the upper border presents two processes separated by a deep concavity, the **mandibular** (sigmoid) **notch.** Of the processes, the anterior is the **coronoid;** the posterior, the **condylar.**

The **condylar process** consists of the **condyle** [capitulum mandibulæ] and the narrowed portion by which it is supported, the **neck. The condyle** is oval in shape, with its long axis transverse to the upper border of the ramus, but oblique with regard to the median axis of the skull, so that the lateral extremity, which presents the **condylar tubercle** for the temporomandibular ligament of the

FIG. 184.—THE MANDIBLE AT BIRTH.



mandibular articulation, is a little more forward than the medial extremity. The convex surface of the condyle is covered with cartilage in the recent state, and rests in the mandibular fossa; the **neck** is flattened from before backward, and presents, in front, a depression [fovea pterygoidea] for the insertion of the *external pterygoid* muscle.

The **coronoid process,** flattened and triangular, is continued upward from the anterior part of the ramus. The lateral surface is smooth and gives insertion to the *temporal* and *masseter* muscles; the medial surface is marked by a ridge which descends from the tip and becomes continuous with the posterior part of the mylohyoid line. On the medial surface, as well as on the tip of the coronoid process, the *temporal* muscle is inserted. The **mandibular notch,** the deep semi-

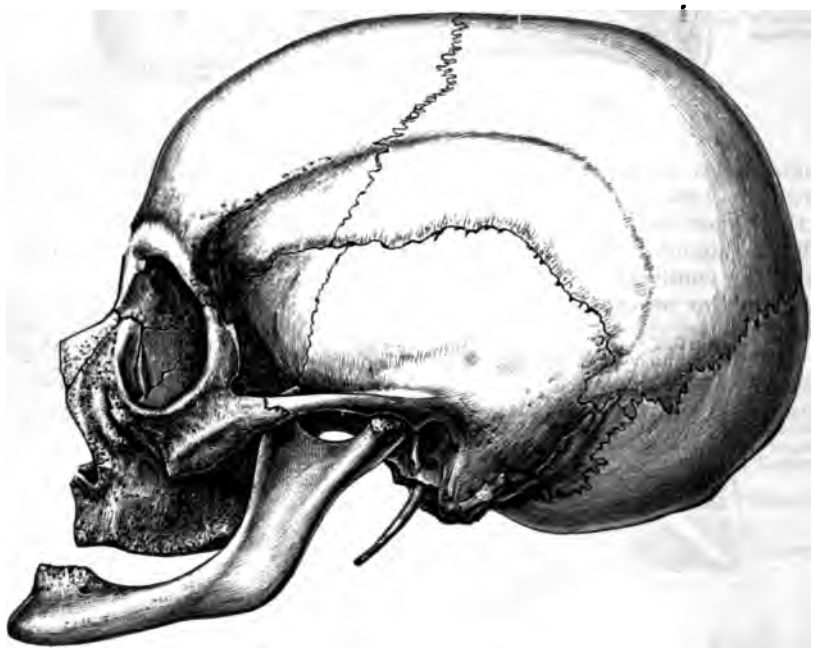
lunar excavation separating the coronoid from the condylar process, is crossed by the masseteric nerve and vessels.

Blood-supply.—Compared with other bones, the superficial parts of the mandible are not so freely supplied with blood. The chief artery is the inferior alveolar which runs in the mandibular canal, and hence, as the bone is exposed to injury and sometimes actually laid bare in its alveolar portion, it often necroses, especially if the artery is involved at the same time.

Ossification.—The mandible is mainly formed by ossification in the fibrous tissue investing the cartilage of the first branchial arch or Meckel's cartilage, although a small portion of the cartilage itself is directly converted into bone.

It is now generally admitted that the lower jaw is developed in membrane as a single skeletal element. The center of ossification appears in the sixth week of intrauterine life in the outer aspect of Meckel's cartilage and gives rise to the bony plate comparable to the *dentale* in lower animals. This plate extends forward right up to the midline in front, and from it a shelf grows upward for the support of the tooth-germs. Meckel's cartilage lies below and medial to the dentary plate, and the inferior alveolar nerve passes forward between the two structures. Meckel's cartilage itself takes some small part in the formation of the lower jaw. Ossification from the primary nucleus invades the cartilage at a point opposite the interval between the first and second tooth-germs, and the resulting bone contributes to the formation of the alveolar margin opposite these two teeth. Behind this point the cartilage atrophies except in so far as it helps to form the sphenomandibular ligament and the malleus and incus. Behind the symphysis the anterior extremity of the cartilage does not enter into the formation of the jaw, but it usually persists throughout fetal life as one or two small, rounded, cartilaginous masses. Occasionally they become ossified and give rise to accessory ossicles in this situation. The lamella of bone situated on the medial side of Meckel's cartilage, corresponding to the distinct splenial element in some animals, arises in man as an extension from the dentary element.

FIG. 185.—THE SKULL OF A WOMAN EIGHTY-THREE YEARS OLD, TO SHOW THE CHANGES IN THE MANDIBLE AND MAXILLA.



In connection with the condylar and coronoid processes, cartilaginous masses are developed. These do not, however, indicate separate elements, but are adaptations to the growth of the lower jaw. They are ossified by an extension from the surrounding membrane bone.

The process of ossification of the lower jaw commences as early as the thirty-ninth day (Mall), and proceeds rapidly, so that by the fourth month the various parts are formed.

Age-changes.—At birth the mandible is represented by two nearly horizontal troughs of bone, lodging unerupted teeth, and joined at the symphysis by fibrous tissue. The body is mainly alveolar, the basal part being but little developed; the condyle and the upper edge of the symphysis are nearly on a level; the mental foramen is nearer the lower than the upper margin, and the angle is about 175°. The inferior alveolar nerve lies in a shallow groove between the splenial and dentary plates.

During the first year osseous union of the two halves takes place from below upward, but is not complete until the second year. After the first dentition, the ramus forms with the body of the mandible an angle of about 140°, and the mental foramen is situated midway between the upper an lower borders of the bone opposite the second milk-molar. In the adult, the angle formed by the ramus and body is nearer to a right angle, and the mental foramen is opposite the second bicuspid, so that its relative position remains unaltered after the first dentition.

In old age, after the fall of the teeth, the alveolar margin is absorbed, the angle formed by the ramus and body is again increased, and the mental foramen approaches the alveolar margin. In a young and vigorous adult the mandible is, with the exception of the petrous portion of the temporal, the densest bone in the skeleton; in old age it becomes exceedingly porous, and often so soft that it may easily be broken.

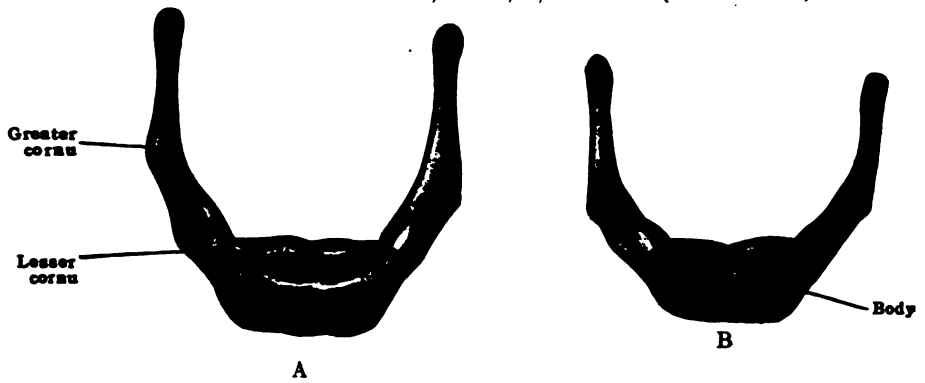
Variations.—Besides the extensive changes in weight and form to which the mandible is normally subjected in the life cycle many sorts of variation may occur. The chin may be protruding or receding. There may be but one eminence instead of a pair of mental tubercles. A median foramen is rarely present at the symphysis, comparable with an arterial canal normally present in certain apes. The coronoid and condylar processes vary considerably in form and size. They are rarely united with the rest of the ramus by sutures. A process of the inferior margin near the angle is often observed and has been compared with a similar spur in the jaws of carnivora.

THE HYOID BONE

The **hyoid bone** [os hyoideum] or os linguæ (fig. 186), situated in the anterior part of the neck between the chin and the thyroid cartilage, supports the tongue and gives attachment to numerous muscles. It is suspended from the lower extremities of the styloid processes of the temporal bones by two slender bands known as the **stylohyoid ligaments,** and is divisible into a **body** and two pairs of processes, the **greater** and **lesser cornua.**

The **body,** constituting the central portion of the bone, is transversely placed and quadrilateral in form. It is compressed from before backward and lies obliquely so that the anterior surface looks upward and forward and the posterior surface in the opposite direction.

FIG. 186.—THE HYOID BONE. A, MALE; B, FEMALE. (Natural Size.)



The **anterior surface** is convex and divided by a horizontal ridge into a superior and an inferior portion. Frequently it also presents a vertical ridge crossing the former at right angles, and just above the point of intersection is the **glossohyal** process, the vestige of a well-developed process is to be found in this situation in the hyoid bone of some of the lower animals. In this way four spaces or depressions for muscular attachments are marked off, two on either side of the middle line. The **posterior surface** is deeply concave and separated from the epiglottis by the thyrohyoid membrane, and by some loose areolar tissue. The membrane passes upward from the thyroid cartilage to be attached to the **superior border,** and interposed between it and the concavity on the back of the body is a small synovial bursa. The **inferior border,** thicker than the upper, gives insertion to muscles. The **lateral borders** are partly in relation with the greater cornua, with which they are connected, up to middle life, by synchrondrosis, but after this period, usually by bone.

The **greater cornua** projects upward and backward from the sides of the body. They are flattened from above downward, thicker near their origin, and terminate posteriorly in a rounded tubercle to which the thyrohyoid ligament is attached.

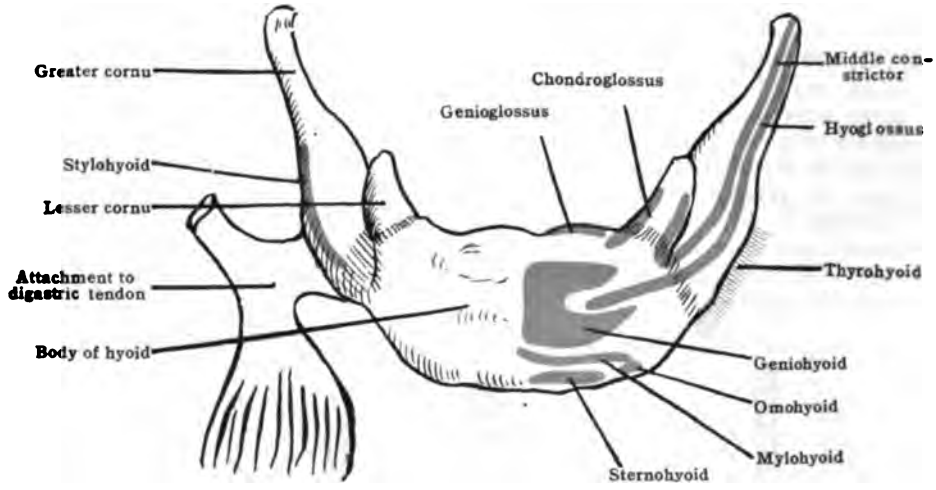
The **lesser cornua** are small conical processes projecting upward and backward opposite the lines of junction between the body and the greater cornua, and by their apices give attachment to the stylohyoid ligaments; they are connected to the body by fibrous tissue. Professor Parsons has shown that a joint with a synovial cavity is common between the smaller and greater cornua. The lesser cornua are sometimes partly or completely cartilaginous in the adult.

The **muscles** attached to each half of the hyoid bone may be enumerated as follows:—

Body.....Geniohyoid, genioglossus, mylohyoid, sternohyoid, omohyoid, stylohyoid, thyrohyoid and hyoglossus.
Greater cornu.....Thyrohyoid, middle constrictor, hyoglossus, and digastric.
Lesser cornu.....Chondroglossus, and middle constrictor.

Ossification.—In the early months of intrauterine life the hyoid bone is composed of hyaline cartilage and is directly continuous with the styloid processes of the temporal bones. Ossification takes place from six centers, of which two appear in the central piece of cartilage, one on either side of the middle line, either just before or just after birth; soon after their appearance, however, they coalesce to form the body of the bone (basihyal). The center for each of the greater cornua (thyreohyals) appears just about the time of birth, and for each of the lesser cornua (ceratohyals) some years after birth, even as late as puberty. (F. G. Parsons.) The greater cornua and the body unite in middle life; the lesser cornua rarely ankylose with the body and only in advanced age. Parsons has shown, however, that the lesser cornua more frequently unite with the greater cornua.

FIG. 187.—HYOID BONE ENLARGED TO SHOW MUSCULAR ATTACHMENTS. (After F. G. Parsons.)



THE MORPHOLOGY OF THE SKULL

In man the skull during development passes through three stages. At first the brain vesicles are enclosed in a sac of indifferent tissue which ultimately becomes tough and fibrous to form the **membranous cranium.** This, in turn, is partly converted into the membrane or roof bones of the cranium, whilst the remainder is represented in the adult by the dura mater. At the sides and base of the membranous cranium, however, cartilage is deposited, **chondrocranium,** in which as well as in the membranous tracts, osseous tissue appears in due course. Eventually, an **osseous box** is formed, consisting of membrane bones and cartilage bones intricately interwoven. For early stages and figure of the chondrocranium, see p. 28.

A study of the skull in the chondral stage is very instructive. It consists of two parts: (1) The skull proper and (2) the appendicular elements.

(1) The **skull proper** consists of three regions:—

(*a*) The **notochordal** region, which ultimately gives rise to the chief parts of the occipital bone and a part of the sphenoid. It is named notochordal because the notochord runs in it as far as the anterior extremity, i.e., the level of the fossa hypophyseos (sella turcica).

(*b*) Anterior to the notochordal is the **trabecular region,** from which the remainder of the sphenoid is developed.

(*c*) The most anterior part of the prechordal portion of the base is the **ethmovomerine region,** from which the nasal septum and its cartilages arise. These three parts continue forward the line of the vertebral axis, and constitute a *craniofacial axis* terminating, in front, in the premaxillæ. Finally, wedged in on each side, between the notochordal and trabecular regions, is the complicated **periotic** (auditory) capsule.

(2) The **appendicular elements** of the skull are a number of cartilaginous rods surrounding the visceral cavity—i. e., nose, mouth, and pharynx—which undergo a remarkable metamorphosis, and are represented in the adult by the *ear-bones*, the *styloid process*, and the *hyoid bone*. These rods of cartilage are named, from before backward, the **mandibular, hyoid,** and **thyroid** bars. They may with care be easily dissected in the fetus between the third and fourth months. For description of their metamorphosis, see p. 29.

In addition to these structures ossifications occur in the connective tissue of the maxillary process, a structure which may be regarded as forming the anterior part of the first branchial arch, and in the medial nasal process. The ossifications in the maxillary process give rise to the pterygoid (medial pterygoid process of the sphenoid), the palate, the maxilla, and the zygomatic, while that in the medial nasal process forms the premaxilla.

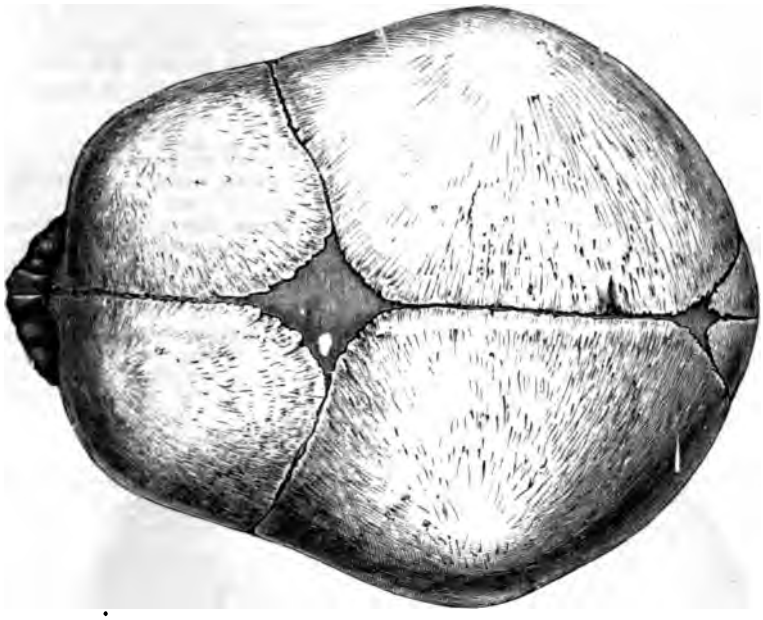
The Skull at Birth

The skull at birth presents, when compared with the adult skull, several important and interesting features. Its peculiarities may be considered under three headings:—The peculiarities of the fetal skull as a whole; the construction of the individual bones; the remnants of the chondral skull.

(1) *The General Characters of the Fetal Skull* (Figs. 188–190)

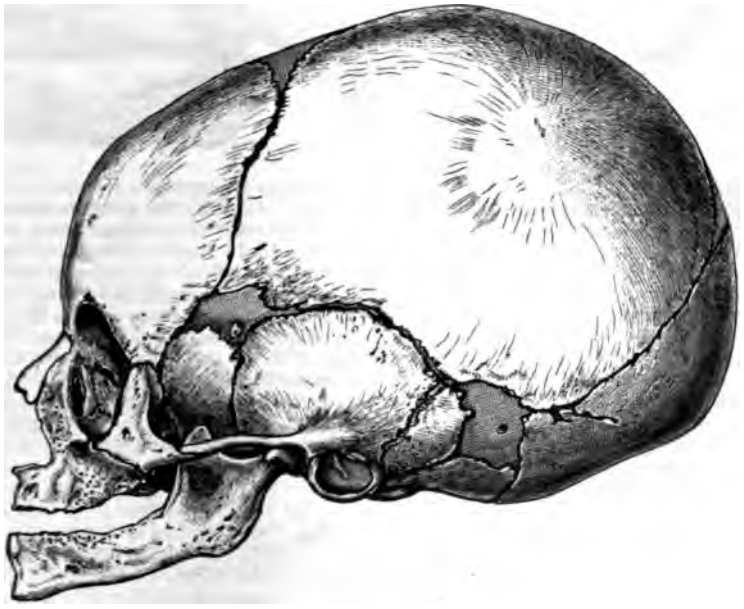
The most striking features of the skull at birth are, its relatively large size in comparison with the body, and the predominance of the cranial over the facial portion of the skull (8 to 1). The frontal and parietal eminences are large and conspicuous; the sutures are absent; the adjacent margins of the bones of the vault are separated by septa of fibrous tissue continuous

FIG. 188.—THE CRANIUM AT BIRTH. (Viewed from above.)



with the dura mater internally and the pericranium externally; hence it is difficult to separate the roof bones from the underlying dura mater, each being lodged, as it were, in a dense membranous sac. The bones of the vault consist of a single layer without any diploë, and their cranial surfaces present no digital impressions. Six membranous spaces exist, named fonta-

FIG. 189.—THE CRANIUM AT BIRTH. (Lateral view.)



nelles: two are median, the frontal [fonticulus frontalis; major] being anterior and the occipital [fonticulus occipitalis; minor] posterior. Two exist on each side, termed anterior [fonticulus sphenoidalis] and posterior [fonticulus mastoideus] lateral fontanelles. Each angle of the parietal bones is in relation with a fontanelle. The anterior fontanelle is lozenge-shaped, the poste-

rior triangular. The lateral fontanelles are irregular in outline. The lateral fontanelles close soon after birth; the occipital fontanelle closes in the first year, and the frontal during the second year. For further details on the fontanelles, see p. 29.

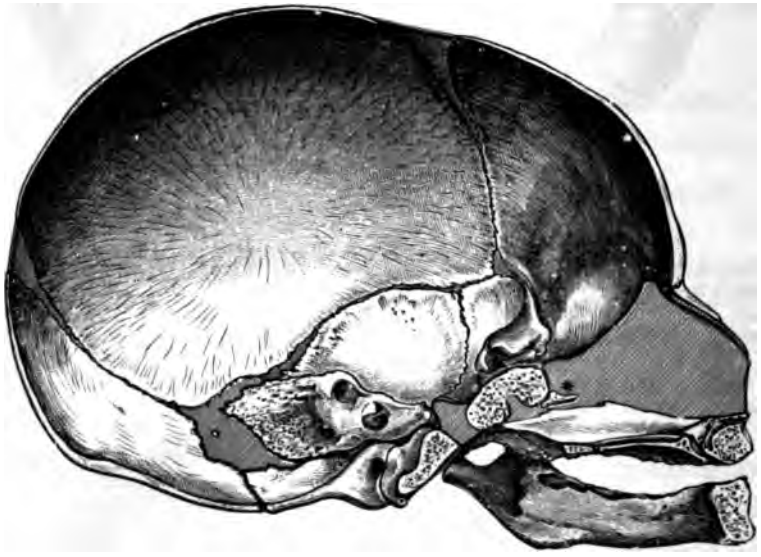
Turning to the base of the skull, the most striking points are the absence of the mastoid processes, and the large angle which the pterygoid plates form with the skull-base, whereas in the adult it is almost a right angle. The base of the skull is relatively short, and the lower border of the mental symphysis is on a level with the occipital condyles.

The **facial skeleton** is relatively small in consequence of the small size of the nasal fossæ, the small size of the maxillary sinus, and the rudimentary condition of the alveolar borders of the maxillæ and mandible; the nasal fossæ are as wide as they are high, and are almost filled with the conchæ. Growth takes place rapidly in the first seven years after birth. There is a second period of rapid growth at puberty, when the air-sinuses develop, and this affects especially the face and frontal portion of the cranium. For further details on the growth of the skull, see p. 29.

(2) *The Peculiarity of Individual Bones at Birth*

The **occipital bone** (fig. 134) consists of four distinct parts, which have already been described. Compared with the adult bone, the following are the most important points of distinction:—There is no **pharyngeal tubercle** or **jugular process**; the squamous portion presents two deep fissures separating the interparietal from the supraoccipital portion and extending medially as far as the occipital protuberance. The grooves for the transverse (lateral) sinuses are absent.

FIG. 190.—THE CRANIUM AT BIRTH IN SAGITTAL SECTION. (Sphenoidal concha indicated by a *.)



The **sphenoid** (see fig. 146) in a macerated fetal skull falls into three pieces: (1) united pre- and post-sphenoids, orbitosphenoids, and linguläe, and (2 and 3) the **alisphenoids**. The presphenoid is quite solid and connected with the ethmovomerine cartilage, and presents but traces of the air-sinus which occupy this part in the adult skull. The presphenoid by its upper surface forms part of the anterior cranial fossa, from which it is subsequently excluded by the growth of the orbitosphenoids. The optic foramina are large and triangular in shape. The **linguläe** stand out from the basisphenoid as two lateral buttresses, and at the tuberculum sellæ is the **basipharyngeal canal**, which in the recent bone is occupied by fibrous tissue. The **dorsum sellæ** is still cartilaginous. The **alisphenoids** with the pterygoid processes are separated from the rest of the bone by cartilage. The foramen rotundum is complete, but the future foramen ovale is merely a deep notch in the posterior border of the great wing, and there is no foramen spinosum. The pterygoid processes are short, and each medial pterygoid plate presents a broad surface for articulation with the lingula. The **pterygoid canal** is a groove between the medial pterygoid plate, the lingula, and great wing.

The **temporal bone** at birth (figs. 151–153, 161) consists of three elements, the **petrosal**, **squamosal**, and **tympanic**. The **petrosal** presents a large and conspicuous floccular (subarcuate) fossa; the hiatus canalis facialis (Fallopii) is a shallow bay lodging the geniculate ganglion of the facial nerve. There is a relatively large mastoid antrum, but no mastoid process. The styloid process is unossified, but the **tympanohyal** may be detected as a minute rounded nodule of bone near the stylomastoid foramen.

The **squamosal** has a very shallow mandibular fossa and a relatively large postglenoid tubercle. The posterior part of the inferior border is prolonged downward into an uncinate process (*postauditory process*) which closes the mastoid antrum laterally.

The **tympanic** bone or annulus is a delicate, horseshoe-shaped ossicle, attached by its anterior and posterior extremities to the inferior border of the squamosal.

The **ear-bones** are chiefly of interest from their size, for they are as large at birth as in the adult. The anterior (Folian) process may be 2 cm. in length.

The **frontal** (fig. 140) consists of two bones separated by a median vertical (metopic) suture. The frontal eminence is very pronounced, but the superciliary arches and frontal sinuses are wanting. The frontal spine, which later becomes one of the most conspicuous features of this bone, is absent. There is no temporal line.

The **parietal** (figs. 188–189) is simply a quadrilateral lamina of bone, concave on its inner and convex on the outer surface. The parietal eminence, which indicates the point at which the ossification of the bone commenced, is large and prominent. The grooves for blood-sinuses, as in other cranial bones, are absent. Each angle of the parietal is in relation with a fontanelle. As in the adult, the anterior inferior angle of the bone is prolonged downward toward the alisphenoid.

The **ethmoid** consists of two lateral portions separated by the still cartilaginous ethmovomerine plate. The ethmoid cells are represented by shallow depressions, and the uncinate process is undeveloped.

The **sphenoidal conchæ** are two small triangular pieces of bone lying in the perichondrium on each side of the ethmovomerine plate near its junction with the presphenoid. (Indicated by the * in fig. 190.)

The **maxilla** (fig. 176) presents the following characters:—The incisive suture is visible on the palatine aspect of the bone. The alveolar border presents five sockets for teeth. The infraorbital foramen communicates with the floor of the orbit by a deep fissure; this fissure sometimes persists in the adult. The sinus is a shallow depression.

The **mandible** at birth (figs. 184, 189, 190) consists of two halves united by fibrous tissue in the line of the future symphysis. Each half is a bony trough lodging teeth. The trough is divided by thin osseous partitions into five compartments: of these, the fifth is the largest, and is often subdivided by a ridge of bone. The floor is traversed by a furrow as far forward as the fourth socket (that for the first milk molar), where it turns outward at the mental foramen. This furrow lodges the inferior alveolar nerve and artery, which enter by the large mandibular foramen. The condyle is on a level with the upper border of the anterior extremity of the bone.

The **palate bones** differ mainly from those in the adult in that the vertical and horizontal plates are of the same length; thus the nasal fossæ in the fetus are as wide as they are high, whereas in the adult the height of each nasal fossa greatly exceeds the width.

Concerning the remaining bones little need be said. The **vomer** (fig. 190) is a delicate trough of bone for the reception of the inferior border of the ethmovomerine plate; its inferior border, which rests upon the hard palate, is broad, and the bone presents quite a different appearance from that in the adult. The **nasal bones** are short and broad; the **zygomatics** and **inferior conchæ** are relatively very large; and the **lacrimals** are thin, frail, and delicate lamellæ.

The **hyoid** consists of five parts. There is a median nucleus for the basihyal, and one on each side for the greater cornua (thyrohyals). The lesser cornua are cartilaginous.

(3) *Remnants of the Cartilaginous Cranium*

It has already been pointed out that at an early date the base of the skull and the face are represented by hyaline cartilage, which for the most part is replaced by bone before birth. Even at birth remnants of this primitive chondral skull are abundant. In the cranium, cartilaginous tracts exist between the various portions of the occipital bone, as well as at the line of junction of the occipital with the petrosal and sphenoid. The dorsum sellæ is entirely cartilaginous at birth, and the last portion of this cartilage disappears with the ankylosis of the basioccipital and basisphenoid about the twentieth year. A strip of cartilage unites the alisphenoids with the lingulæ, and for at least a year after birth this cartilage is continuous with that which throughout life occupies the foramen lacerum. A strip of cartilage exists along the posterior border of the orbitosphenoid, and not infrequently extends lateralward to the pterion. In the adult skull it is replaced by ligamentous tissue.

The **ethmovomerine plate** (fig. 190 is entirely cartilaginous, and near the end of the nose supports the lateral nasal cartilages, remnants of the frontonasal plate. The fate of the ethmovomerine pla e is instructive. The upper part is ossified to form the mesethmoid; the lower part atrophies from the pressure exerted by the vomer; the anterior end remains as the septal cartilage. The lateral snout-like extremities of the frontonasal plate persist as the lateral cartilages of the nose. Among the appendicular elements of the skull, the styloid process and a large portion of the hyoid are cartilaginous at birth.

The Nerve-foramina of the Skull

The various foramina and canals in the skull which give passage to nerves may be arranged in two groups, **primary** and **secondary**. **Primary** foramina indicate the places where the nerves leave the general cavity of the dura mater, and as this membrane indicates the limit of the primitive cranium, a cranial nerve, in a morphological sense, becomes extracranial at the point where it pierces this membrane. The primary foramina are the formen magnum, the hypoglossal, jugular, auditory, trigeminal, petrosphenoidal and optic foramina. In consequence of the complicated and extraordinary modifications the vertebrate skull has undergone, many nerves traverse, in the adult skull, bony tunnels and canals which are not represented in the less complex skulls of low vertebrates, such as sharks and rays. To such foramina and canals the terms **secondary** or **adventitious** may be applied. These include the superior orbital fissure, foramen rotundum, foramen ovale, ethmoidal canals, infraorbital canal, zygomaticotemporal foramen, zygomaticofacial canals, sphenopalatine foramen, Scarpa's foramen, pharyngeal foramen, pterygoid (Vidian) canal, posterior palatine canal, mandibular (inferior dental) canal, stylomastoid foramen, iter chordæ posterius, iter chordæ anterius, petrotympanic fissure, and inferior orbital fissure.

CRANIOMETRY

Among normal human individuals of all races the **capacity of the cranial cavity**, which is used in calculating the size of the brain, is between 1000 and 1800 c.c. with an average of 1400 c.c. Crania having a capacity below 1350 are *microcephalic;* those exceeding 1450, *megacephalic;* ranging between these figures, *mesocephalic.* The capacity is found by carefully filling the cranial cavity with shot and then measuring the latter.

The greatest **length of the cranium** is measured between the glabella and the point in the midline of the occiput furthest removed—the *occipital point.* The **breadth of the cranium** is the greatest transverse diameter above the level of the supramastoid ridges. The **cephalic index** is obtained by finding the proportion between the maximum length and breadth. $\frac{100 \times \text{breadth}}{\text{length}}$. Skulls having a cephalic index between 75 and 80 are *mesaticephalic;* above 80, *brachycephalic;* below 75, *dolichocephalic.*

The horizontal **circumference of the cranium** is measured passing around the skull through the glabella and occipital point.

The *basibregmatic height* (from basion to bregma) is used in determinations of the **height of the cranium**: $\frac{100 \times \text{length}}{\text{height}}$ = *index of height:* 70–75, *metriocephalic;* below 70, *tapeinocephalic* above 75, *akrocephalic.*

The degree of facial prominence is indicated by the **facial angle**, made with the horizontal by a line from the frontal prominence to the anterior nasal spine. Since the prominence of the face is almost purely prominence of the jaws, the modern method of measuring is by a **gnathic (jaw) index;** that proposed by Flower is a comparison of the basialveolar (basion to alveolar point) with the basinasal length (basion to nasion). When the gnathic index is below 98, the skull is *orthognathous;* above 103, *prognathous;* between 98 and 103, *mesognathous.*

The **form of the face** is determined by comparing the height and breadth (nasio-mental height and bizygomatic breadth); the face is *leptoprosopic* when the index is 90.1 or above; *chameprosopic,* below 90.1.

The **orbital index** is obtained by comparing the vertical height of the aditus orbitæ to its transverse breadth: index between 89–84 is *mesoseme;* below 84, *microseme;* above 89, *megaseme.*

The **nasal index** is derived by comparing the height of the nose (nasion to subnasal point) with the maximum width of the pyriform aperture. A skull having a nasal index under 48 is *leptorhine;* above 53, *platyrhine;* between 48 and 53, *mesorhine.*

Size of the teeth varies considerably among the races, with tendency to be larger in savage peoples. The **dental index** of Flower is; dental length (distance between anterior surface of first premolar and posterior surface of third molar), compared with the basinasal length. Teeth are *mesodont* when the index is between 42 and 44; *microdont,* below 42; *megodont,* above 44.

C. THE THORAX

The **thorax** is a bony cage (figs. 203, 204) formed by the thoracic vertebræ already described, the ribs with their costal cartilages, and the sternum. It serves to protect and support the thoracic viscera and in connection with the musculature of the ribs performs important respiratory functions. The red marrow of the cancellous tissue of the ribs and sternum is one of the chief seats of the red blood-corpuscle formation.

THE RIBS

The **ribs** [costæ] (figs. 191, 192) twelve in number on each side, constitute a series of narrow, flattened bones, extending from the sides of the thoracic vertebræ toward the median line on the anterior aspect of the trunk. The anterior ends of the first seven pairs are connected, by means of their costal cartilages, with the sides of the sternum, and on this account the first seven ribs on each side are termed **true** or sternal ribs. The remaining five pairs, known as **false** or asternal ribs, may be arranged in two sets:—one, including the eighth, ninth, and tenth ribs, in which the cartilages of the anterior extremities are connected together, and the other, including the eleventh and twelfth, in which the anterior extremities, tipped with cartilage, are free. The eleventh and twelfth are known, in consequence, as the **floating** ribs. Thus, the first seven are **vertebrosternal;** the eighth, ninth, and tenth, **vertebrochondral;** the eleventh and twelfth, **vertebral** ribs.

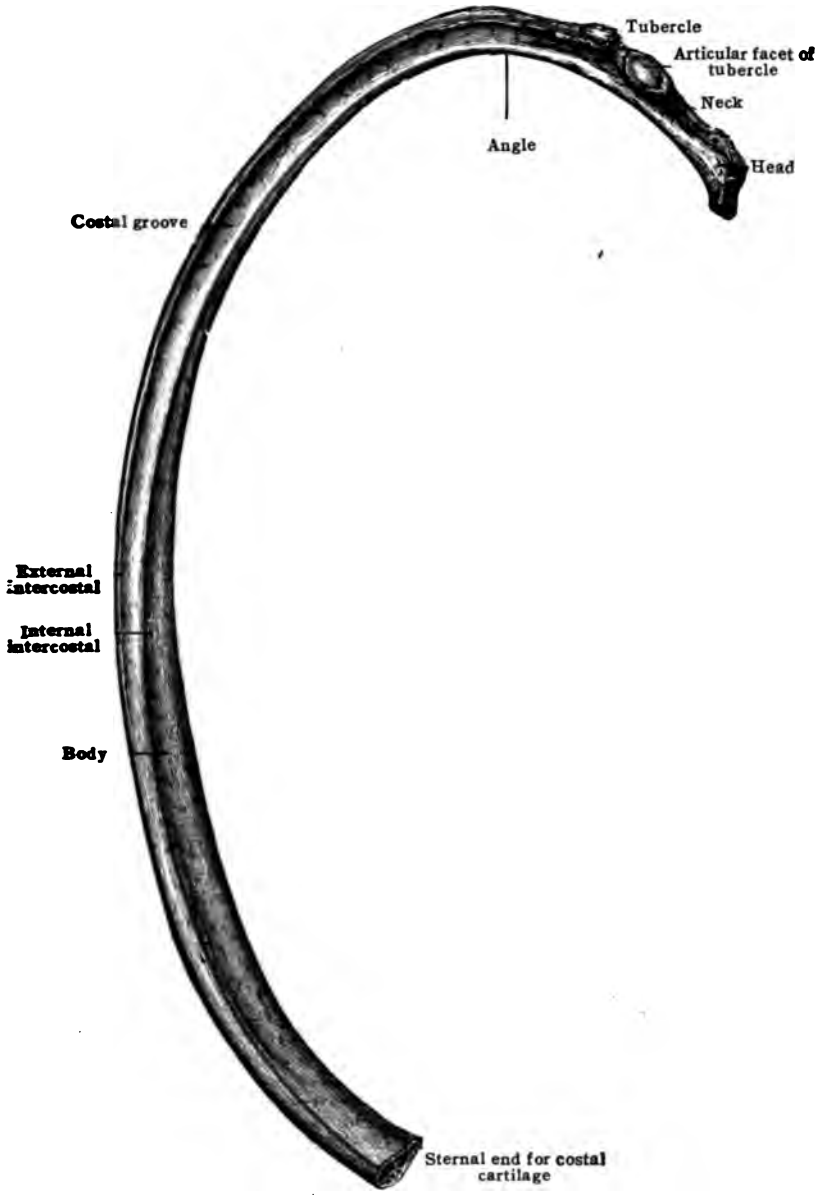
The ribs increase in length from the first to the seventh, and decrease from the seventh to the twelfth. They also vary in their direction, the upper ones being less oblique than the lower. The obliquity is greatest at the ninth rib and gradually decreases from the ninth to the twelfth.

Typical characters of a rib (fig. 191).—The seventh is regarded as the most typical rib. It presents a vertebral extremity or **head**; a narrow portion or **neck**; a **sternal** extremity; and an intermediate portion, the **body** or **shaft.**

The **head** [capitulum costæ] presents an **articular surface** made up of two articular facets separated by a horizontal **crest** [crista capituli].

The crest is connected by an interarticular ligament with an intervertebral disk, and the facets articulate with the costal pits on the sides of the bodies of two vertebræ (sixth and

FIG. 191.—THE SEVENTH RIB OF THE LEFT SIDE. (Seen from below.)



seventh). As a rule, the lower facet is the larger, and articulates with the thoracic vertebra, to which the rib corresponds in number. This is the p imary facet, and is the one represented in those ribs which possess only a single facet on the rib-head. The anterior margin is lipped for the attachment of the radiate ligament.

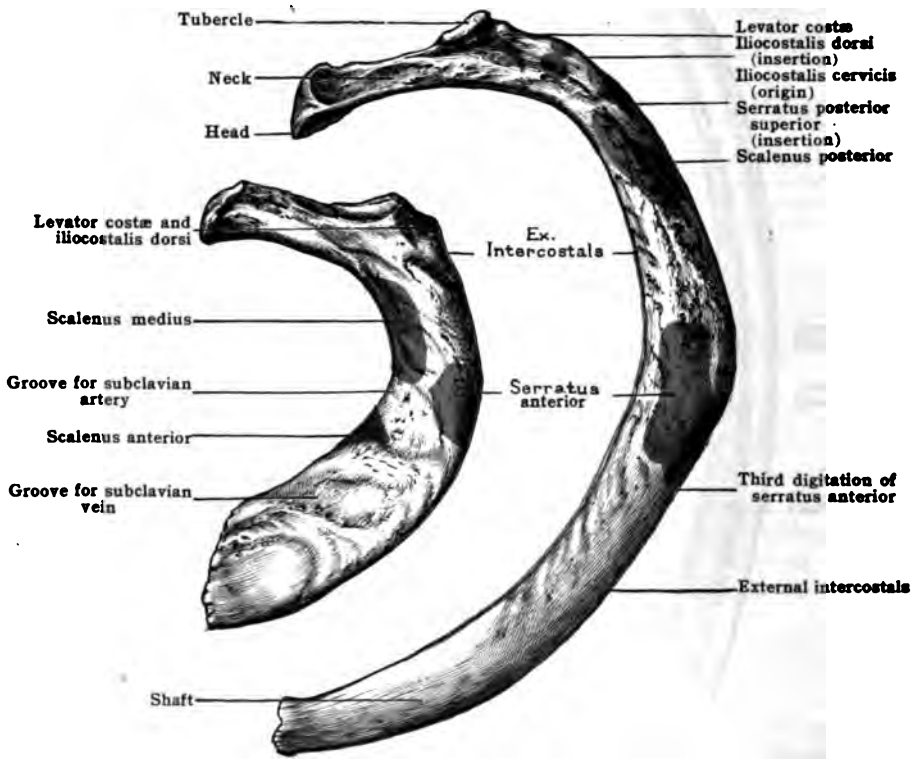
The **neck** [collum costæ] is that portion of the rib extending from the head to the **tubercle.** It is flattened from before backward and is in relation posteriorly with the transverse process of the lower of the two vertebræ with which the head articulates; it forms the anterior boundary of the **costotransverse foramen.**

It is rough where it is attached to the neck ligament [lig. colli costæ]. The anterior surface is flat and smooth. The superior border of the neck, continuous with the corresponding border of the shaft, presents a rough crest [crista colli] for the anterior costotransverse ligament. The inferior border of the neck is rounded and continuous with the ridge of the **costal groove.**

The **tubercle,** situated behind at the junction of the neck with the shaft, consists of an upper and lateral part, rough for the attachment of the posterior costotransverse ligament, and a lower and medial part, bearing a facet for articulation with a pit near the tip of the transverse process. The tubercle projects below the lower edge of the rib to form a crest, marking the beginning of the costal groove.

The **body** is strongly curved and presents two surfaces and two borders. At first the curve is in the same plane as the neck, but it quickly turns forward at a point on the posterior surface of the shaft known as the **angle,** where it gives attachment to the *iliocostalis* muscle and some of its subdivisions. The rib has also a second or upward curve, beginning at the angle. These curves are expressed by describing the main curve as disposed around a vertical, and the second or upward curve around a second transverse axis.

FIG. 192.—FIRST AND SECOND RIBS. (Viewed from above.)



Besides the two curves now described, the rib is slightly twisted on itself, so that the surfaces which look medially and laterally behind are placed obliquely in front and look downward as well as medially, and upward as well as laterally.

The **external surface** of the rib is convex, and gives attachment to muscles. Near its anterior extremity it forms a somewhat abrupt curve, indicated by a ridge on the bone, which gives attachment to the *serratus anterior* (*magnus*) muscle, and is sometimes called the **anterior angle**

The **internal surface** is concave and presents near its inferior border the **costal groove** [sulcus costæ]. The groove is best marked near the angle, and gradually becomes shallower toward the anterior extremity of the rib, where it is finally lost; it lodges the intercostal vessels and nerve. The ridge limiting the groove above is continuous with the inferior border of the neck of the rib, and gives attachment to the *internal intercostal* muscle.

The **superior border** is rounded, and affords attachment to the *internal* and ***external intercostal*** muscles. The **inferior border** commences abruptly near the angle, and gives attachment to the *external intercostal* muscle.

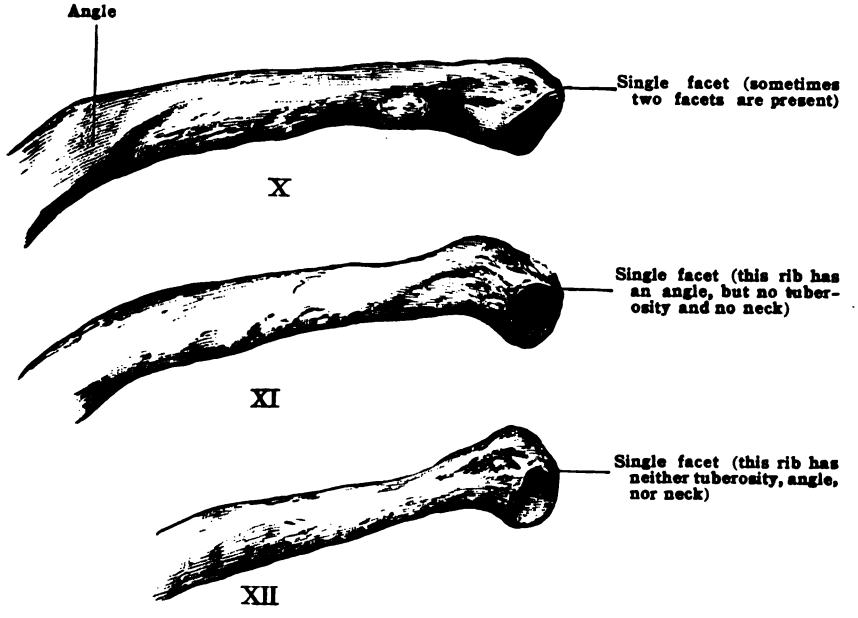
The **sternal** end of the shaft is cupped for the reception of the costal cartilage.

Blood-supply.—The ribs are very vascular and derive numerous branches from the intercostal arteries. The branches in the shaft run toward the vertebral end, whilst those in the head and neck run, as a rule, toward the shaft. In the neighborhood of the tuberosity the vessels do not seem to have any constant arrangement.

Peculiar ribs (figs. 192, 193).—Several ribs present certain peculiarities and differ in many particulars from the general description given above. These are the first, second, tenth, eleventh and twelfth.

The **first rib** (fig. 192) is the broadest, shortest, and most curved of all the series. It is not twisted, and is so placed that its superior surface looks forward as well as upward, and its inferior surface backward as well as downward. The head is small, and as a rule is furnished with only one articular facet. The neck, longer than that of most of the ribs, is slender and rounded. The tubercle is large and prominent. The shaft lies for its whole extent nearly in one plane, has no angle, and is curved in one direction only, i. e., around a vertical axis. The superior surface presents two shallow grooves, separated near the inner border by a rough surface (**scalene tubercle** or tubercle of Lisfranc) for the *scalenus anterior* muscle. The groove in front of this surface is for the subclavian vein and the groove behind it is for the subclavian artery and a nerve trunk passing to the brachial plexus. Between the groove for the artery and the tubercle is a rough surface for the insertion of the *scalenus medius*, and between the groove and the outer margin is an area for the origin of the *serratus anterior* (*magnus*). The inferior surface is uniformly flat and lacks a subcostal groove. By the lateral portion, which is rough,

FIG. 193.—THE VERTEBRAL ENDS OF TENTH, ELEVENTH, AND TWELFTH RIBS.


Angle
Single facet (sometimes two facets are present)
X
Single facet (this rib has an angle, but no tuberosity and no neck)
XI
Single facet (this rib has neither tuberosity, angle, nor neck)
XII

it gives attachment to the internal intercostal muscle; the remainder of the inferior surface is in relation to pleura and lung. The lateral border is thick and rounded, and gives attachment to the *external intercostal* muscle, whilst the medial border, thin, sharp, and concave, receives the attachment of the fascia (Sibson's) covering the dome of the pleura. The anterior extremity is thick and broad, and its upper margin, as well as the cartilage to which it is joined, afford attachment to the costoclavicular ligament and the *subclavius* muscle. The costal cartilage of this rib is directly united to the manubrium sterni, and occasionally the cartilage and the adjoining part of the anterior extremity of the rib are replaced by fibrous tissue. The rib derives its nutrition mainly from the superior intercostal branch of the subclavian artery.

The **second rib** (fig. 192) is much longer than the first, and although like it in being strongly curved round a vertical axis, in its form and general character there is a closer resemblance to the ribs lower down in the series. The head is round and present two facets, the costal groove is present, though faintly marked, and an angle is situated near the tubercle. The specially distinguishing feature of the rib, however, is a well-marked tuberosity on its outer surface somewhat near the middle, for the origin of a part of the first digitation, and the whole of the second digitation of the *serratus anterior* (*magnus*). Between the tuberosity and the tubercle the outer surface is smooth and rounded and gives attach ent to the *scalenus posterior*, the *serratus posterior superior*, the *iliocostalis cervicis* (*cervicalis ascendens*), and the *liocostalis dorsi* (*accessorius*). The internal surface is smooth and in relation to the pleura. The borders give attachment to the *intercostal* muscles, the upper, to those of the first space, the lower, to those of the second. The shaft of the second rib is not twisted on its own axis, so that both ends can lie flat on the table. The second rib receives vessels from the superior intercostal branch of the subclavian artery and the first aortic intercostal.

The **tenth rib** (fig. 193) is distinguished by a single facet on the head for articulation with

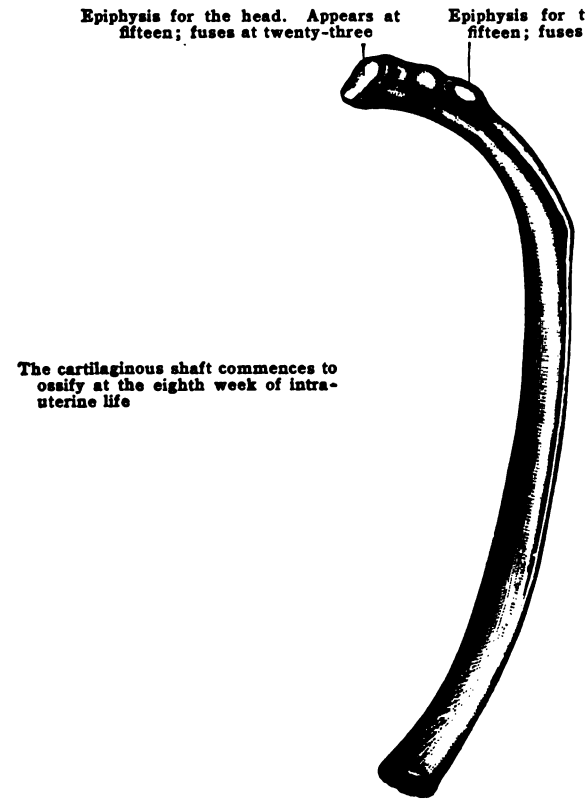
the body of the tenth thoracic vertebra. Occasionally there are two facets, in which case the rib articulates also with the ninth thoracic vertebra. The tenth rib, like the ribs immediately above, is long, curved, presents a deep costal groove, a well-marked tuberosity and an angle. It may be noted, however, that the distance between the tubercle and the angle in this rib is greater than in the ribs above. Speaking generally, the distance between these points increases from above downward.

The **eleventh rib** is peculiar in that it has a single facet on the head, a feebly marked angle some distance from the head, a shallow costal groove, no tubercle, and no neck. The tubercle is sometimes represented by a slight elevation or roughness without any articular facet. The anterior extremity is pointed.

The **twelfth rib** has a large head furnished with one facet for articulation with the root (pedicle) of the twelfth thoracic vertebra. The shaft is narrow and extremely variable in length (3 to 20 cm.). It is usually somewhat longer than the first rib, but it may be shorter. There is no tubercle, no angle, no neck, no costal groove. The anterior extremity is pointed. Posteriorly, the upper border is smooth and rounded; the lower border is sharp and rough.

The **costal cartilages** are bars of hyaline cartilage attached to the anterior extermities of the ribs. Like the shaft of a rib, each cartilage has an outer and inner surface. The outer surfaces give origin and insertion to large muscles, and the inner surfaces, from the second to the

FIG. 194.—RIB AT PUBERTY.


Epiphysis for the head. Appears at fifteen; fuses at twenty-three
Epiphysis for tubercle. Appears at fifteen; fuses at twenty-three
The cartilaginous shaft commences to ossify at the eighth week of intrauterine life

sixth inclusive, are in relation with the *transversus thoracis* (*triangularis sterni*). The upper and lower borders serve for the attachment of the *internal intercostal* muscles. The upper seven cartilages, and occasionally the eighth, are connected with the sternum. Of these, the first fuses with the manubrium sterni and the remaining six are received into small articular concavities, and retained by means of ligaments. The cartilages of the vertebrochondral ribs are united to one another and to the seventh costal cartilage by ligaments (sometimes by short vertical bars of cartilage), while those of the vertebral ribs form no such attachment, but lie between the abdominal muscles. The inner surfaces of the lower six costal cartilages afford attachment to the *diaphragm* and the *transversalis* muscle.

Each of the second, third, fourth, and fifth costal cartilages articulates with the side of the sternum, at a point corresponding to the junction of two sternebræ. The sixth and seventh (and eighth when this reaches the sternum) are arranged irregularly. As a rule, the sixth lies in a recess at the side of the fifth sternebra; the seventh corresponds to the line of junction of the meso- and metasternum; and the eighth articulates with the metasternum (fig. 195).

Blood-supply.—The costal cartilages derive their blood-supply from the terminal twigs of the aortic intercostals and from the internal mammary arteries. They are distributed to the perichondrium. (Blood supply of ribs noted above.)

Ossification.—At the eighth week of intrauterine life the ribs are cartilaginous. About this time a nucleus appears near the angle of each rib, and spreads with great rapidity along the

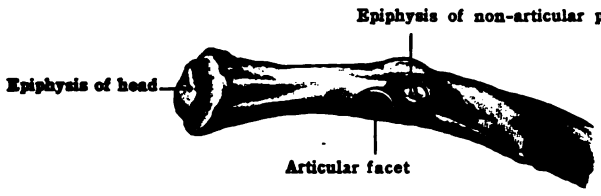
shaft, and by the fourth month reaches as far as the costal cartilage. At this date the length of rib-shaft bears the same proportion to that of the costal cartilage as in adult life. Whilst the ribs are in a cartilaginous condition, the first eight reach to the side of the sternum, and even after ossification has taken place, the costal cartilage of the eighth rib, in many instances, retains its articulation with the sternum up to as late as the eighth month (fig. 195). This relationship may persist through life, but usually the cartilage retrogresses, and is replaced by ligamentous tissue. About the fifteenth year a secondary center appears for the head of each rib, and a little later one makes its appearance for the tubercle, except in the eleventh and twelfth ribs. Frequently epiphyses are developed on both parts of the tubercle (see figs. 196 and 197). The epiphyses fuse with the ribs about the twenty-third year. The rib-shaft increases in length mainly at its line of junction with the costal cartilage.

Variations.—The ribs may be increased in number by addition either at the cervical or lumbar end of the series, but it is extremely rare to find an additional rib or pair of ribs in both the cervical and lumbar regions in the same subject.

FIG. 195.—THE THORAX AT THE EIGHTH FETAL MONTH.
(On the left side eight cartilages reach the sternum.)

Cervical ribs are fairly common; as a rule, they are of small size and rarely extend more than a few mm. beyond the extremity of the transverse process. (For their morphology, see also p. 1365.) Occasionally they exceed such insignificant proportions and reach as far as the sternum; between these two extremes many varieties occur. In one case Turner was able to make a thorough dissection of a specimen in which a complete cervical rib existed. Its head articulated with the body of the seventh cervical vertebra and had a radiate ligament. The tubercle was well developed, and articulated with the transverse process. The costal cartilage blended with that of the first thoracic rib, and gave attachment to the costoclavicular ligament. Between it and the first thoracic rib there was a well-marked intercostal space occupied by intercostal muscles. It received the attachment of the *scalenus anterior* and *medius* muscles, and it was crossed by the subclavian artery and vein. The nerves of the intercostal space were

FIG. 196.—POSTERIOR PORTION OF THE SIXTH RIB IN THE FIFTEENTH YEAR.
(After Toldt.)



supplied by the eighth cervical and first thoracic. The artery of the space was derived from the deep cervical, which, with the superior intercostal, arose from the root of the vertebral. The head of the first thoracic rib in this specimen articulated with the seventh cervical, as well as with the first thoracic vertebra. In this specimen, there was no movable twelfth thoracic rib on the same side as this well-developed cervical rib; the twelfth thoracic vertebra had mammillary and accessory processes, and a strong elongated costal process, and was in linear series with the lumbar transverse processes.

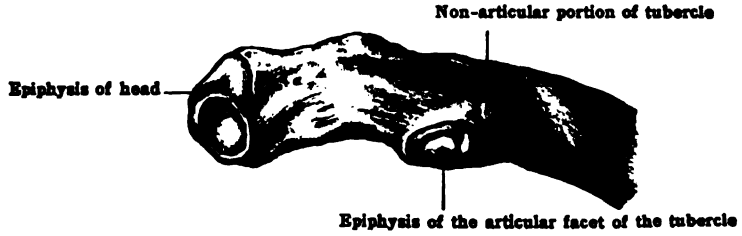
Gruber and Turner, from a careful and elaborate study of this question, summarise the variations in the cervical rib thus:—It may be very short and possess only a head, neck, and tubercle. When it extends beyond the transverse process, its shaft may end freely or join the first thoracic rib: this union may be effected by bone, cartilage, or ligament. In very rare instances it may have a costal cartilage and join the manubrium of the sternum. Not unfrequently a process, or eminence, exists on the first thoracic rib at the spot where it articulates

with a cervical rib. For a recent discussion of the subject of cervical ribs see Todd, Jour. Anat. & Phys., vols. 46 and 47.

Lumbar ribs are of less significance than cervical ribs and rarely attain a great length. Their presence is easily accounted for, as they are the differentiated costal elements of the transverse processes. They are never so complete as the cervical ribs, and articulate only with the transverse processes; the head never reaches as far as the body of the vertebra, and there is no neck or tubercle. An extra *levator costæ* muscle is associated with a lumbar rib.

An interesting variation is that known as the bicipital rib. This condition is seen exclusively in connection with the first thoracic rib. The vertebral end consists of two limbs which lie in different transverse planes. These bicipital ribs have been especially studied in whales and man. This abnormality is due to the fusion of two ribs, either of a cervical rib with the shaft of the first thoracic; or the more common form, the fusion of the first and second true ribs. Among unusual variations of ribs should be mentioned the replacement of the costal cartilage and a portion of the rib-shaft by fibrous tissue, a process which occurs normally in the case of the eighth rib during its development. Sometimes the shafts of two or more ribs may become united by small quadrilateral plates of bone extending across the intercostal spaces.

FIG. 197.—POSTERIOR PORTION OF THE SIXTH RIB IN THE EIGHTEENTH YEAR. (After Toldt.)



THE STERNUM

The **sternum** (figs. 198, 199) is a flat, oblong plate of bone, situated in the anterior wall of the thorax, and divisible into three parts—(1) the **manubrium sterni** (presternum), (2) the **corpus sterni** (mesosternum), constituting the **body** of the bone, and (3) the **xiphoid** (or ensiform) **process** (metasternum). In the young subject it consists of six segments (sternebræ). Of these, the first remains separate throughout life and forms the manubrium; the succeeding four segments fuse together, forming the body; while the lowest segment, also distinct until middle life, is represented by the xiphoid process.

In its natural position the sternum is inclined obliquely from above downward and forward, and corresponds in length to the vertebral column from the third to the ninth thoracic vertebra. It is not of equal width throughout, being broader above at the manubrium and narrow at the junction of this piece with the body. Toward the lower part of the body the sternum again widens, and then suddenly contracts at its junction with the xiphoid process which constitutes the narrowest part.

The **manubrium** or first piece of the sternum forms the broadest and thickest part of the bone, and is of a somewhat triangular form with the base directed upward and the apex downward. It represents two surfaces and four borders. The **anterior surface** [planum sternale] is largely subcutaneous. It is slgihtly convex and directed obliquely upward and forward, is smooth and gives origin on each side to the sternal head of the *sternomastoid* and the *pectoralis major*. The **posterior surface,** almost flat, and directed downward and backward, affords origin near the lateral margins on each side, to the *sternohyoid* muscle above and the *sternothyroid* muscle below. Of the four borders, the **superior** is the longest and much the thickest. In the middle is a curved, non-articular depression, called the **jugular** (interclavicular) **notch,** to which the fibers of the interclavicular ligament are attached, and at either end is an oval **articular surface** [incisura clavicularis], somewhat saddle-shaped and directed upward, backward, and laterâlly for the reception of the medial end of the clavicle. The circumference of the articular surface gives attachment to the sternoclavicular ligaments.

The **lateral borders** of the manubrium slope from above downward and medially and each presents an irregular surface, the **costal notch** [incisura costalis], above the first costal cartilage and a small facet below, which, with an adjoining facet on the body, forms a notch for the second costal cartilage. The two articular surfaces are separated by a narrow curved edge in relation with the *internal intercostal* muscle of the first space. The **lower border is thick**

and short and presents an oval rough surface which articulates with the upper border of the body, forming the **sternal synchondrosis.** The two opposed surfaces are separated by a fibrocartilaginous disk, which may, however, become partially ossified in advanced age, and at the position of the joint there is usually an angle—the **sternal angle** (angulus Ludovici)—which can be felt as a transverse ridge beneath the skin. This is useful in locating the second rib in the living subject.

The **body** [corpus sterni] (gladiolus) or second piece of the sternum is longer, narrower, and thinner than the manubrium. It is widest opposite the notches for the fifth costal cartilages and becomes narrower above and below. The **anterior surface** is flat, directed upward and forward, and marked by three transverse elevations which indicate the lines of junction of its four component parts. It gives attachment on each side to fibers of the *pectoralis major* and is subcutaneous in the midline; it occasionally presents a foramen—the **sternal foramen**—situated at the junction of the third and fourth pieces of the bone. The **posterior surface** is slightly concave, marked by lines corresponding to those on the anterior surface, and below gives attachment on each side to fibers of the *transversus thoracis* (*triangularis sterni*).

The **lateral borders** of the body present four whole costal notches and two half-notches on each side, which articulate with the costal cartilages of the second to the seventh ribs inclusive; the two half-notches are completed by corresponding notches on the manubrium and the xiphoid process. Between the articular depressions the lateral border is curved and in relation to the *internal intercostal* muscles.

In order to appreciate the nature of these articular notches, it is advantageous to study the sternum in a young subject (fig. 202). Each typical **sternebra** presents four angles at each of which is a deminotch. Between every two sternebræ there is an intersternebral disk so that when in position, each notch for a costal cartilage is formed by a sternebra above and below and an intersternebral disk in the middle, thus repeating the relation of the rib-head to the vertebral centrum. Later in life these fuse more or less together, except in the case of the first and second sternebræ, which usually remain separate to the end of life. The first (presternum) is the most modified of all the sternebræ, and differs from them in the fact that the costal cartilage of the first rib is continuous with it, and in fact that it supports the clavicles.

The **superior border** of the sternal body presents an oval facet for articulation (synchondrosis) with the manubrium. The **inferior border** is short and articulated with the xiphoid process, forming the mesometasternal joint, the two opposed surfaces being separated by a layer of cartilage so long as they are not united by bone.

The **xiphoid** (ensiform) **process** is the thin, elongated process projecting downward between the cartilages of the seventh ribs. It is the least developed part of the sternum and is subject to many variations in form, being sometimes pointed, broad and thin, occasionally bifid or perforated by a foramen, and sometimes bent forward, backward, or deflected to one side. In structure it is cartilaginous in early life, partially ossified in the adult, but in old age it tends to become ossified throughout and to fuse with the body.

The **anterior surface** of the xiphoid process gives attachment to a few fibers of the *rectus abdominis* muscle and the chondroxiphoid ligament; the **posterior surface** to the sternal fibers of the *diaphragm*, and the lowest fibers of the *transversus thoracis* (*triangularis sterni*), while the lateral margins receive the aponeuroses of the abdominal muscles. Its tip is directly continuous with the **linea alba.**

Differences according to sex.—The sternum differs somewhat in the two sexes. The female sternum is relatively shorter, the diminution being confined almost to the body. In the male the body is more than twice as long as the manubrium, whereas in the female it is usually less than twice the length of the first piece.

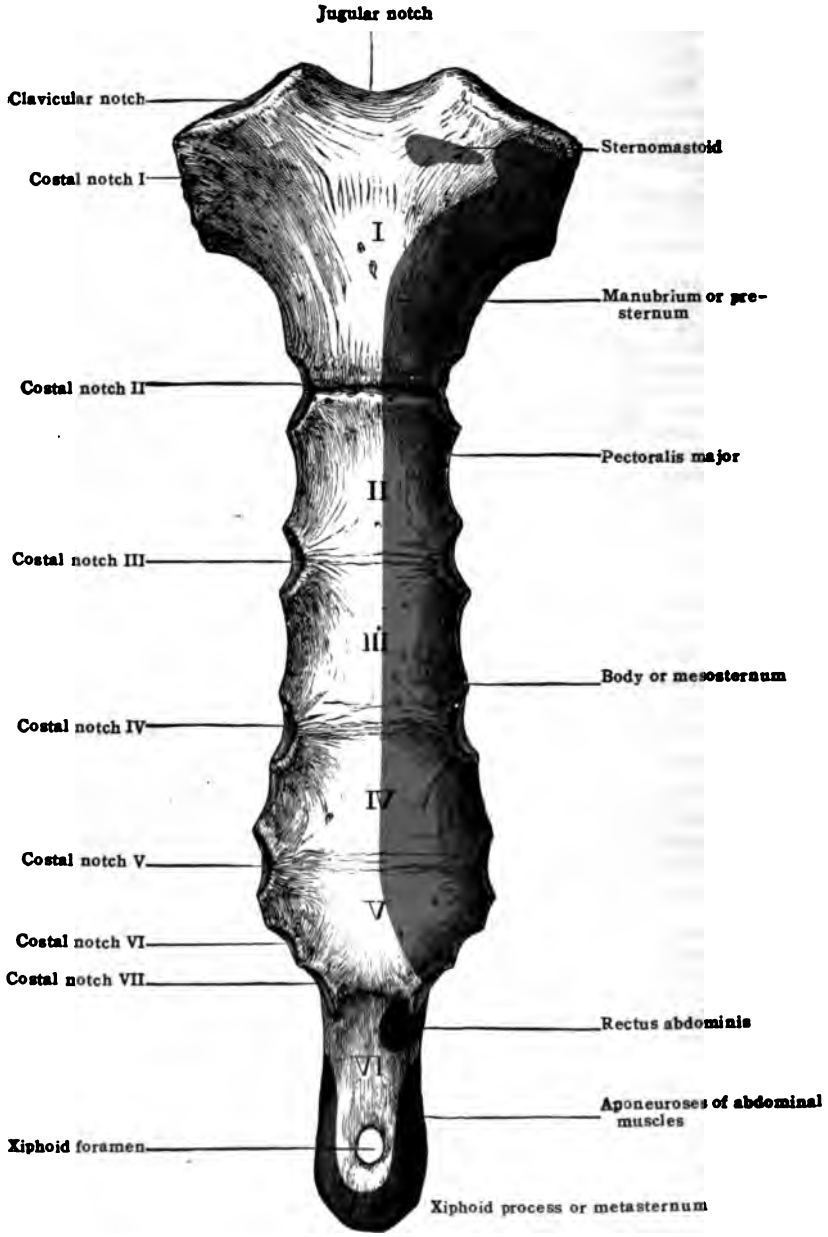
Structurally the sternum is composed of cancellous tissue covered with an outer layer of compact tissue. Its **arterial supply** is derived mainly from the sternal and perforating branches of the internal mammary.

Development of the sternum (figs. 201, 202).—The osseous sternum is preceded by a continuous or non-segmented central sternal cartilage formed in the following way. When the cartilaginous ribs first appear in the embryo, their anterior or ventral ends are united with a tract of mesenchyma, one of a pair of *sternal bands* which are connected with the medial ends of the clavicles and with the mass of tissue between them which has been regarded as the representative of the *episternum.* For some time a median fissure is present, bordered by the two sagittally directed bands which have proceeded to the cartilaginous stage with each of which at first nine ribs are joined. As development proceeds the two bands come into contact in the midline and fuse from before backward to form a median sternal cartilage. The cephalic extremity, *presternum,* is at first connected with the medial ends of the clavicles by mesenchyma in which the sternoclavicular joint and interarticular disk are formed. The latter may be a derivative of the episternum, the remaining part of which is included in the presternum. The eighth costal cartilage generally loses its sternal attachment, although in some cases it remains permanently articulated with the side of the xiphoid process. The ninth costal cartilage be-

comes subdivided, one part remaining attached to the sternum and forming the xiphoid process, while the end still continuous with the rib acquires a new attachment to the eighth cartilage. The ends adherent to the sternum may remain separate and give rise to a bifid xiphoid process, though much more frequently they unite, leaving a small foramen.

At first, therefore, the sternum and costal cartilages are continuous. A joint soon forms between the presternum and mesosternum, and others between the costal cartilages and the

FIG. 198.—THE STERNUM. (Anterior view.)



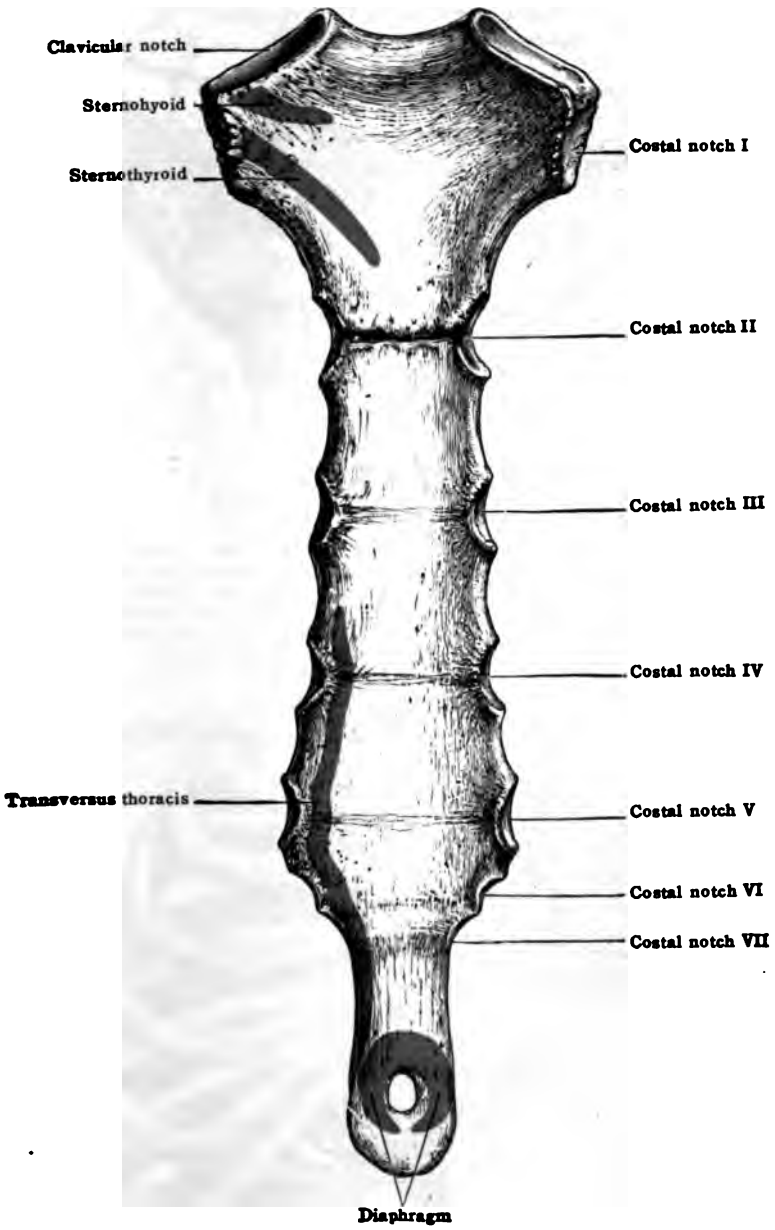
sternum (except in the case of the first) quickly follow. The division of the mesosternum into segments is a still later formation and arises during the process of ossification. On the development of the sternum see Paterson, Jour. Anat. & Phys., vol. 25; Hanson, Am. Jour. Anat., 1919, 26: 41.

Ossification.—The ossification of the sternum is slow and irregular. The process begins in the presternum (manubrium) by a single center about the sixth month of intrauterine life, though occasionally other accessory centers are superadded.

The mesosternum (body) usually ossifies from seven centers. The upper segment ossifies from a single median nucleus about the eighth month, and below this, three pairs of ossific nuclei appear, which may remain for a long time separate. Of these, two pairs for the second and third segments are visible at birth, and those for the lower segment make their appearance

toward the end of the first year. The various lateral centers unite in pairs, so that at the sixth year the sternum consists of six sternebræ, the lowest (metasternum) being cartilaginous. Very often, however, there are only four centers of ossification in the gladiolus, as shown in fig. 202. Gradually the four pieces representing the mesosternum fuse with one another, and at twenty-five they form a single piece, but exhibit, even in advanced life, traces of their original separation. A sternal foramen is usually the result of non-union across the middle line or a defect of ossification.

FIG. 199.—THE STERNUM. (Posterior view.)

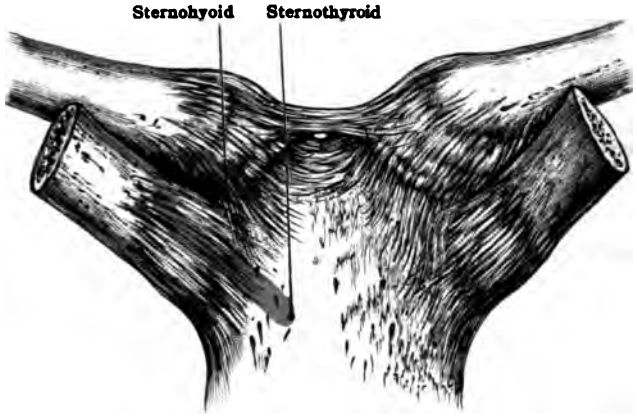


The metasternum is always imperfectly ossified, and does not join with the mesosternum till after middle life. The presternum and mesosternum rarely fuse. The dates given above for the various nuclei, and for the union of the various segments, are merely approximate, hence the sternum affords very uncertain data as to age.

Variations.—The mode of development of the sternum as described above will explain some deviations to which it is occasionally subject. In rare instances the two lateral halves fail to unite, giving rise to the anomaly of a completely cleft sternum (fissura sterni). The union of the two halves may occur in the region of the manubrium and fail below, while in other cases the upper and lower parts have fused but remain separate in the middle. The clefts are in many instances so small as not to be of any moment, and are not even recognised until the skele-

ton is prepared. In a few individuals, however, they have been so extensive as to allow the pulsation of the heart to be perceptible to the hand, and even to the eye, through the skin covering the defect in the bone. A common variation in the sternum is asymmetry of the costal cartilages. Instead of corresponding, the cartilages may articulate with the sternum in an alternating manner. Rarely a pair of cartilaginous nodules or ossicles [ossa suprasternalia] occur at the superior margin of the manubrium; these have been interpreted as vestiges of an *episternum*.

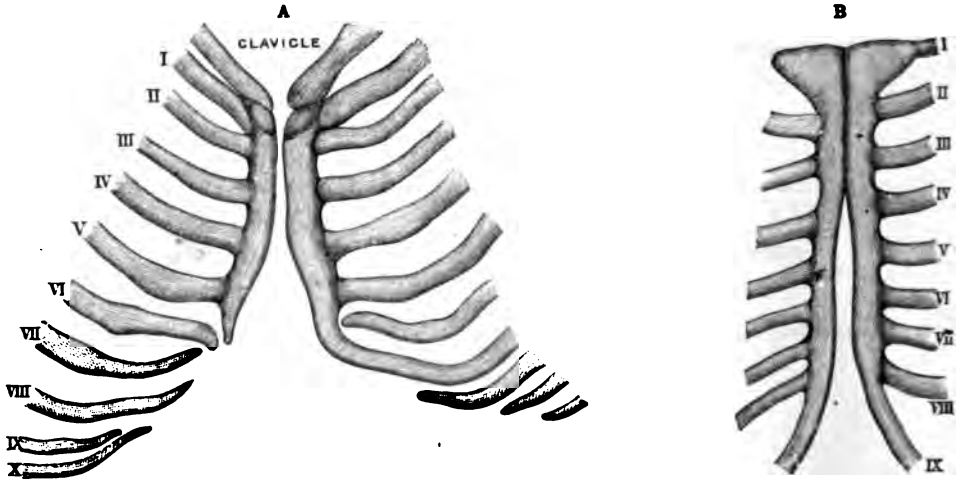
FIG. 200.—POSTERIOR SURFACE OF THE MANUBRIUM, WITH STERNAL ENDS OF CLAVICLES AND THE FIRST COSTAL CARTILAGES.



THE THORAX AS A WHOLE

The bony thorax (figs. 203, 204) is somewhat conical in shape, deeper behind than in front and compressed anteroposteriorly, so that in the adult it measures less in the sagittal than in the transverse axis. The **posterior** wall, formed by the thoracic vertebræ and the ribs as far lateralward as their angles, is convex from above downward, and the backward curve of the ribs produces on each side of the vertebræ a deep furrow, the **costovertebral groove,** in which the *sacrospinalis* (*erector spinæ*) muscle and its subdivisions are lodged. The backward curve of the ribs produces also a deep, broad groove or hollow on each side of the vertebral column

FIG. 201.—TWO STAGES IN THE FORMATION OF THE CARTILAGINOUS STERNUM. (After Ruge.)



within the thorax in which the posterior bulky margin of the lung is contained. **The anterior** wall is formed by the sternum and costal cartilages. It is slightly convex and inclined forward in its lower part, forming an angle of about 20° with the vertical plane. The **lateral** walls are formed by the ribs from the angles to the costal cartilages. The top of the **thorax presents** an elliptical aperture, the **superior thoracic aperture,** which measures on an average 12.5 cm. (5 inches) transversely and 6.2 cm. (2½ inches) in its sagittal axis. It is bounded by the first thoracic vertebra behind, the upper margin of the manubrium sterni in front, and the first rib on each side. As the upper margin of the manubrium sterni is oftenest on a level with the disk between the second and third thoracic vertebræ, it follows that the plane of the opening is directed obliquely upward and forward. The sternal angle is usually opposite the body of

FIG. 202.—OSSIFICATION OF THE STERNUM.
common arrangement of the ossific centers. B, showing accessory center in the manubrium sterni, and bilateral centers in the second, third, and fourth pieces of the body.

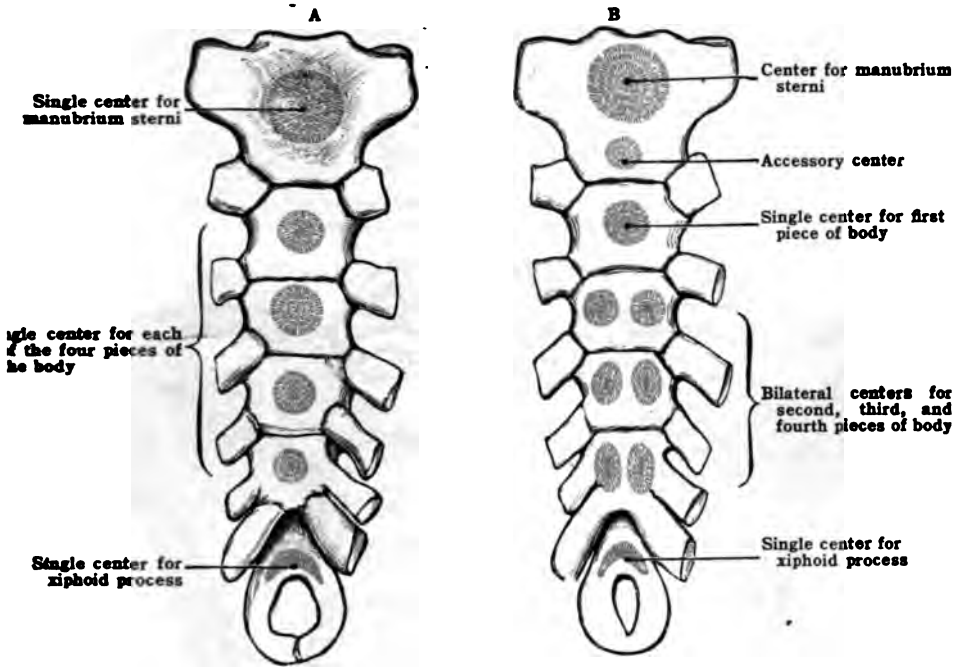
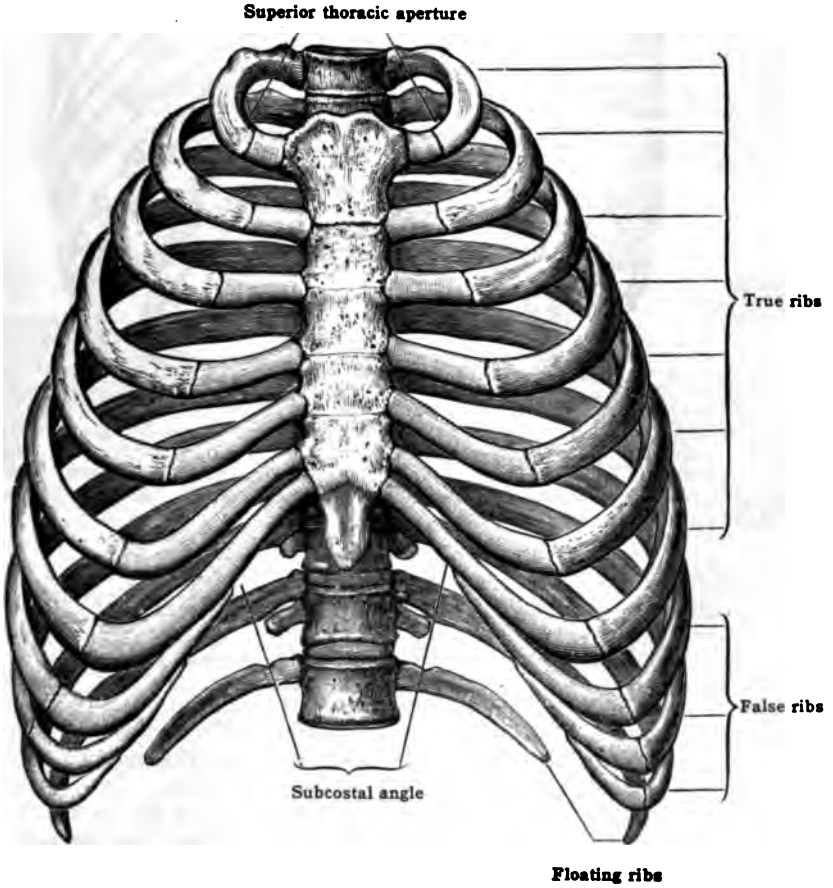

A
B
Single center for manubrium sterni
gle center for each f the four pieces of he body
Single center for xiphoid process
Center for manubrium sterni
Accessory center
Single center for first piece of body
Bilateral centers for second, third, and fourth pieces of body
Single center for xiphoid process

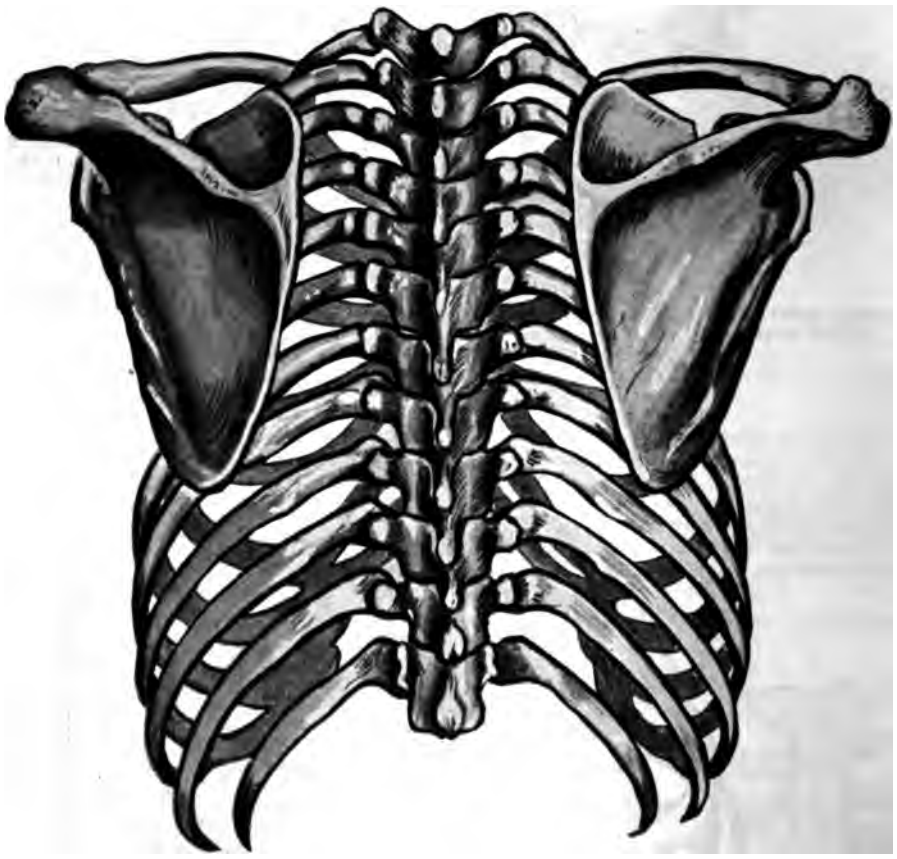
FIG. 203.—THE THORAX. (Front view.)



the fifth thoracic vertebra and the xiphisternal junction corresponds to the disk between the ninth and tenth thoracic vertebræ. The lower aperture of the thorax is very irregular, and is formed by the twelfth thoracic vertebra behind, the twelfth ribs laterally, and in front by two curved lines, ascending one on either side from the last rib, along the costal margin to the lower border of the body. The two borders form the **costal arch**, which in the median line below the sternum forms the **infrasternal angle**. From this angle the xiphoid process projects downward. The intervals between the ribs are the **intercostal spaces**, and are eleven in number on each side.

The ratio of the sagittal and the transverse diameter of the thorax forms the **thoracic index**, which is higher in the female and in children, in whom the thorax is more rounded. In the embryo (p. 17), the index is very much higher, the sagittal diameter being greater than the transverse. In the early embryo, the index is nearly 200; at birth it is about 90. In the adults

FIG. 204.—THE THORAX. (Posterior view.) The scapulæ are drawn from an *X*-ray photograph of a man 33 years old.



it varies from 70 to 75, averaging 2 or 3 per cent. lower in the male than in the female. It is also lower in the negro than in the white race. (Rodes, Zeitschr. f. Morph. u. Anthrop., Bd. 9.) The low thoracic index in man (as compared with quadrupedal mammals) is partly an effect of gravity upon the anterior thoracic wall in the upright posture. Jackson, however, concludes that other factors are predominant.

II. THE APPENDICULAR SKELETON

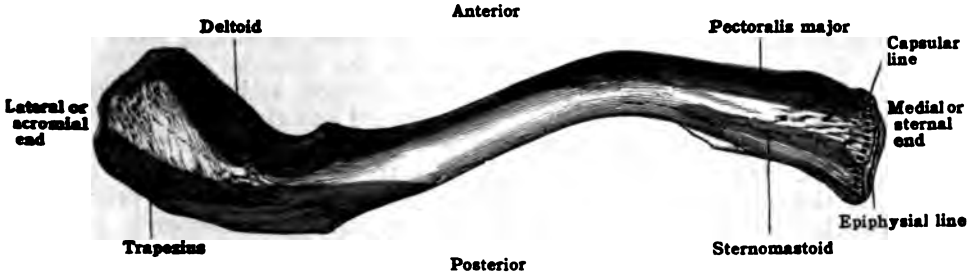
A. BONES OF THE UPPER EXTREMITY

The skeleton of the upper limb is adapted chiefly to the function of prehension which in man is perfected to a high degree. The bones of the upper extremity may be arranged in four groups corresponding to the division of the limb into four segments. In the *shoulder* are the clavicle and the scapula, which together constitute the pectoral or shoulder girdle; in the *arm* is the humerus; in the *forearm* are the radius and ulna; and in the *hand* the carpus, the metacarpus, and the phalanges.

THE CLAVICLE

The **clavicle** [clavicula] or collar bone (figs. 205, 206) is situated immediately above the first rib and extends from the upper border of the manubrium sterni, laterally and backward to the acromion of the scapula. It connects the upper limb with the trunk, and is so situated that while the medial end is securely but flexibly united with the sternum and first costal cartilage, the lateral end is joined with the scapula, supporting it firmly in its various positions and associated with it in all its movements. The clavicle functions chiefly as a prop to the shoulder, putting it away from the side of the body and so establishing conditions for free action of the arm. The clavicle is a long bone, and when

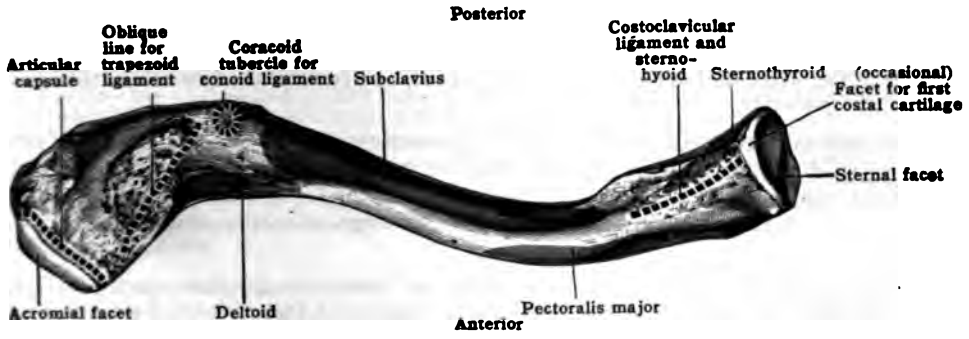
FIG. 205.—THE LEFT CLAVICLE. (Superior surface.)



viewed from above presents a double curvature, so that it somewhat resembles in shape the italic letter *f*, with a medial prismatic portion, convex forward, and a lateral flattened portion, concave forward.

Prismatic portion.—The medial two-thirds of the bone, extending from the sternal extremity to a point opposite the coracoid process of the scapula, has the form of a triangular prism. This portion, however, is subject to considerable variations of form, being more cylindrical in ill-developed specimens and becoming almost quadrangular when associated with great muscular development. In a typical specimen it is marked by three borders separating three surfaces. Of these, the **anterior surface** is convex and divided near the sternal end by a prominent ridge into two parts, a lower, giving origin to the clavicular portion of

FIG. 206.—THE LEFT CLAVICLE. (Inferior surface.)



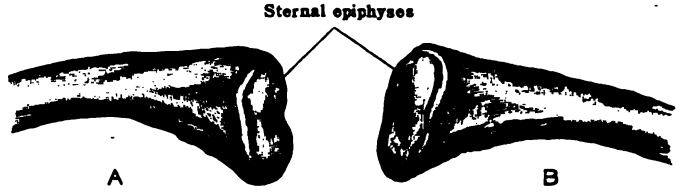
the *pectoralis major;* an upper, for the clavicular portion of the *sternocleidomastoid.* Near the middle of the shaft the ridge disappears, the surface is smooth, and is covered only by the integument, and, the *platysma.* The **posterior surface** is concave, forming an arch over the brachial plexus and the subclavian artery, broadest medially and smooth in its whole extent. It gives origin near the sternal extremity to a part of the *sternohyoid* and occasionally to a few fibers of the *sternothyroid.* Somewhere near the middle of this surface is a small foramen, directed laterally, for the chief nutrient artery of the bone, derived from the transverse scapular (suprascapular) artery. Sometimes the foramen is situated on the inferior surface of the bone, in the subclavian groove. On the **inferior surface** near the sternal end is a rough area, the **costal tuberosity,** about three-quarters of an inch in length, for the attachment of the costoclavic-

ular ligament by which the clavicle is fixed to the cartilage of the first rib. More laterally is a longitudinal groove for the *subclavius*, bordered by two lips, to which the sheath of the muscle is attached. To the posterior of the two lips the layer of deep cervical fascia which binds down the posterior belly of the omohyoid to the clavicle is also attached.

Of the three **borders**, the **superior** separates the anterior and posterior surfaces. Beginning at the sternal end, it is well-marked, becomes rounded and indistinct in the middle, whilst laterally it is continuous with the posterior border of the outer third. The **posterior border** separates the inferior and posterior surfaces and forms the posterior lip of the subclavian groove. It begins at the costal tuberosity and can be traced laterally as far as the coracoid tubercle, an eminence on the under aspect of the bone near the junction of prismatic and flattened portions. The **anterior border** is continuous with the anterior border of the flattened portion and separates the anterior and inferior surface. Medially, it forms the lower boundary of the elliptical area for the origin of the *pectoralis major*, and approaches the posterior border. Near the middle of the bone it coincides with the anterior lip of the subclavian groove.

Flattened portion.—The lateral third of the bone, extending from a point opposite the coracoid process of the scapula to the acromial extremity, is flattened from above downward and presents two surfaces and two borders. The **superior surface** is rough and looks directly upward and gives attachment to the *trapezius* behind and the *deltoid* in front; between the two areas the surface is subcutaneous. On the **inferior surface**, near the posterior border, is a rough elevation, the **coracoid** (conoid) **tubercle**; it overhangs the coracoid process and gives attachment to the conoid ligament. From the coracoid tubercle, a prominent ridge, the **trapezoid** or **oblique line**, runs laterally and forward to near the lateral end of the bone. To it the trapezoid ligament is attached. The conoid and trapezoid ligaments are the two parts of the coracoclavicular ligament which binds the clavicle down to the coracoid process.

FIG. 207.—THE STERNAL ENDS OF TWO CLAVICLES WITH EPIPHYSES.
A, right clavicle from below and behind. B, left clavicle from below and behind.
(From Royal College of Surgeons Museum.)



The **anterior border** is sharp, gives origin to the *deltoid* muscle, and frequently presents near the junction of the flattened and prismatic portions a projection known as the **deltoid tubercle**. The **posterior border** is thick and rounded, and receives the insertion of the upper fibers of the *trapezius*.

The **sternal extremity** of the clavicle presents a triangular articular surface, directed medially, downward, and a little forward, slightly concave from before backward and convex from above downward, which articulates with a facet on the upper border of the manubrium sterni through an interposed interarticular disk.

Of the three angles, one is above and two below. The *posteroinferior angle* is prolonged backward, and so renders this surface considerably larger than that with which it articulates; the *superior angle* receives the attachment of the upper part of the disk. The lower part of the surface is continuous with a facet on the under aspect of the bone, medial to the costal tuberosity, for the first costal cartilage. The circumference of the extremity is rough, and gives attachment to the interclavicular ligament above and the anterior and posterior sternoclavicular ligaments in front and behind.

The **acromial extremity** presents a smooth, oval, articular facet, flattened or convex, directed slightly downward for the acromion; its border is rough, for the attachment of the capsule of the acromioclavicular joint.

Structure.—The clavicle consists externally of a compact layer of bone, much thicker in the middle and thinning out gradually toward the two extremities. There is no true medullary cavity, for the interior is occupied from end to end by cancellous tissue, the amount in the various parts of the bone being in inverse proportion to the thickness of the outer compact shell.

Ossification—From observations made by F. P. Mall, D. C. L. Fitzwilliams, and E. Fawcett it seems almost certain that there are two centers of ossification of the shaft of the clavicle,

at the juncture of the middle and lateral thirds. They appear very early (first ossific center in the body), about the fifth week of embryonic life, and rapidly fuse. The ossific process extends medially and laterally along the shaft toward the medial and lateral extremities, respectively. About the eighteenth year a secondary center appears at the sternal end and forms a small epiphysis which joins the shaft about the twenty-fifth year.

Variations.—Not infrequently the shaft of the clavicle is perforated by a small canal transmitting one of the cutaneous nerves of the cervical plexus. The degree of curvature in the lateral and medial portions of the bone is subject to fluctuation. The most important deviation from the type is a true variation, with a hereditary tendency, namely partial or complete absence of one or both clavicles. This rare condition is the more remarkable because of its constant association with certain defects of the cranium. It has been named *dysostosis cleidocranialis*. For further details, see Hultkranz, Zeitschr. f. Morph. u. Anthropol., 1908, 11: 385.

THE SCAPULA

The **scapula** (figs. 204, 208, 209) is a large flat bone, triangular in shape, situated on the dorsal aspect of the thorax, between the levels of the second and seventh ribs. It is attached to the trunk by means of the clavicle, with which it is articulated, and by various muscles through which a variety of movements are permitted; it articulates with the humerus at the shoulder-joint. The greater part of the scapula consists of a triangular plate known as the *body*, from which two processes are prolonged: one anterior in position, is the *coracoid;* the other, posterior in position, is the *spine*, which is continued laterally into the *acromion*.

The body presents two surfaces, three borders, and three angles. The **costal (anterior) surface,** or venter, looks considerably medialward, is deeply concave, forming the **subscapular fossa.**

The fossa is marked by several oblique lines which commence at the posterior border and pass obliquely upward and laterally; these lines or ridges divide the surface into several shallow grooves, from which the *subscapularis* takes origin, while the ridges give attachment to the tendinous intersections of that muscle. The lateral third of the surface is smooth and overlapped by the subscapularis, while medially are two small flat areas in front of the upper and lower angles respectively, but excluded from the subscapular fossa by fairly definite lines and joined by a ridge which runs close to the vertebral border. The ridge and its terminal areas serve for the insertion of the *serratus anterior (magnus)*.

The **dorsal** (posterior) **surface** is generally convex and divided by a prominent plate of bone—the **spine**—into two unequal parts. The hollow above the spine is the **supraspinous fossa** and lodges the *supraspinatus* muscle. The part below the spine is the **infraspinous fossa;** it is three times as large as the supraspinous fossa, is alternately concave and convex, and gives origin to the *infraspinatus*. The muscle is attached to its medial three-fourths and covers the lateral fourth, without taking origin from it.

The infraspinous fossa does not extend as far as the axillary border, but is limited laterally by a ridge—the oblique line—which runs from the glenoid cavity—the large articular surface for the head of the humerus—downward and backward to join the posterior border a short distance above the inferior angle. This line, which gives attachment to a stout aponeurosis, cuts off an elongated surface, narrow above for the origin of the *teres minor*, and crossed near its middle by a groove for the circumflex (dorsal) artery of the scapula; below, the surface is broader for the origin of the *teres major* and occasionally a few fibers of the *latissimus dorsi*. The two areas are separated by a line which gives attachment to an aponeurotic septum situated between the two teres muscles.

The supra- and infraspinous fossæ communicate through the **great scapular notch** at the lateral border of the spine, and through the notch the suprascapular nerve and transverse scapular artery are transmitted from one fossa to the other.

Borders.—The three borders of the scapula are named superior, vertebral, and axillary. The **superior** is short and thin and extends from the upper angle to the coracoid process. Laterally it presents a deep depression, the **scapular notch,** to the extremities of which the superior transverse ligament is attached.

The notch or foramen transmits the suprascapular nerve, while the transverse scapular artery usually passes over the ligament. From the adjacent margins of the notch and from the ligament the posterior belly of the *omohyoid* takes origin.

The **vertebral border** (sometimes called the base) is the longest, and extends from the upper or medial to the lower angle of the bone.

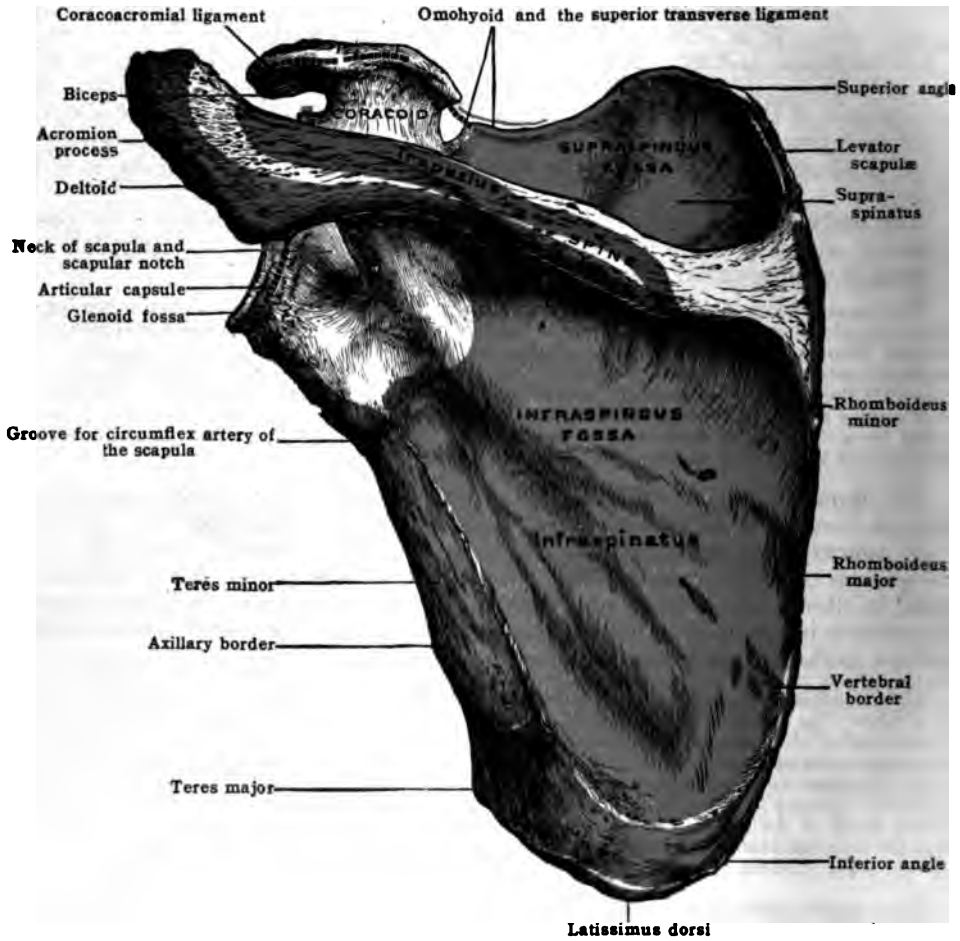
It is divisible into three parts, to each of which a muscle is attached: an upper portion extending from the medial (superior) angle to the spine, for the insertion of the *levator scapulæ;*

a middle portion, opposite the smooth triangular area at the commencement of the spine, for the *rhomboideus minor;* and the lowest and longest portion, extending below this as far as the inferior angle, for the *rhomboideus major*, the attachment of which takes place through the medium of a fibrous arch.

The **axillary border** is the thickest, and extends from the lower margin of the glenoid cavity to the inferior angle of the bone. Near its junction with the glenoid cavity there is a rough surface, about 2.5 cm. (1 in.) in length the **infraglenoid tubercle,** from which the long head of the *triceps* arises, and below the tubercle is the groove for the circumflex (dorsal) artery of the scapula. The upper two-thirds of the border is deeply grooved on the ventral aspect and gives origin to a considerable part of the *subscapularis.*

Angles.—The three angles are named medial, inferior, and lateral.

FIG. 208.—THE LEFT SCAPULA. (Dorsal surface.)



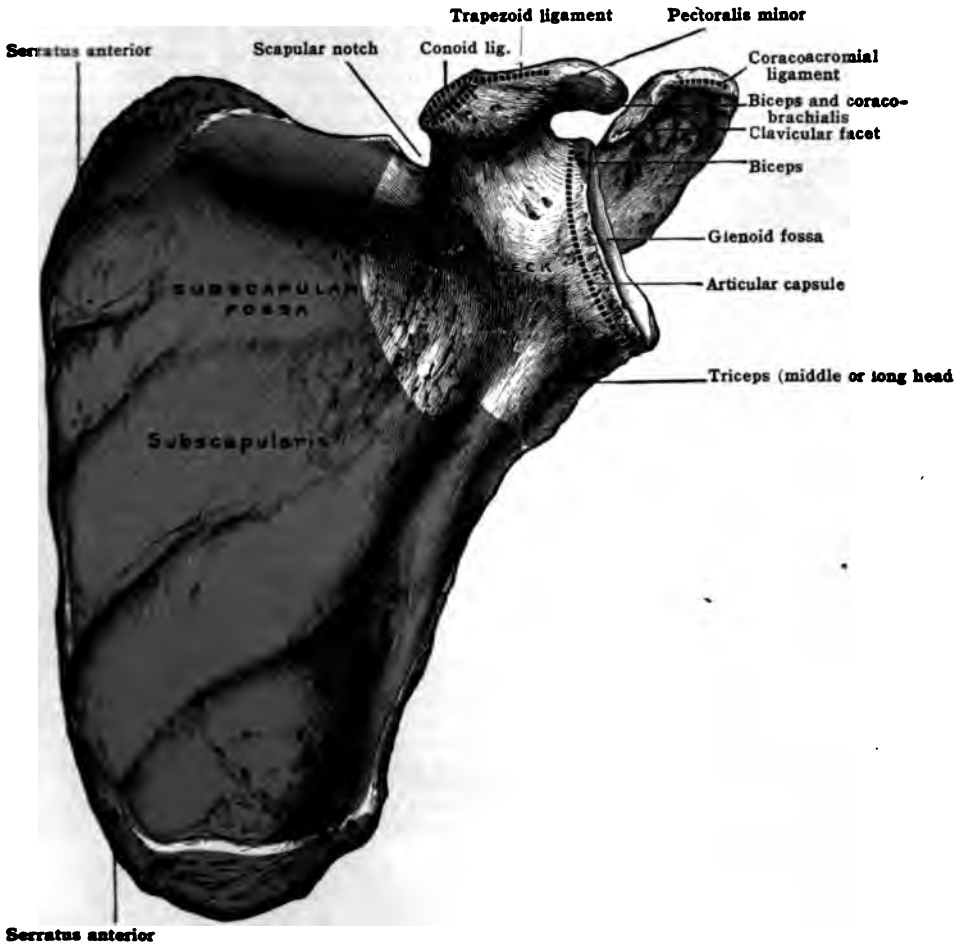
The **medial** (or superior) **angle,** forming the highest part of the body, is thin, smooth, and either rounded or approximating a right angle. It is formed by the junction of the superior and vertebral borders and gives insertion to a few fibers of the *levator scapulæ.* The **inferior angle,** constituting the lowest part of the body, is thick, rounded, and rough. It is formed by the junction of axillary and vertebral borders, gives origin to the *teres major,* and is crossed horizontally by the upper part of the *latissimus dorsi,* the latter occasionally receiving from it a small slip of fleshy fibers.

The **lateral angle** forms the expanded portion of the bone known as the **head,** bearing the **glenoid cavity,** and supported by a somewhat constricted **neck.** The glenoid cavity is a wide, shallow, pyriform, articular surface for the head of the humerus, directed forward and laterally, with the apex above and the broad end below. Its margin is raised, and affords attachment to the glenoid ligament, which deepens its concavity. The margin is not, however, of equal prominence

throughout, being somewhat defective where it is overarched by the acromion, notched anteriorly, and emphasized above to form a small eminence, the **supraglenoid tubercle,** for the origin of the long head of the *biceps*.

The circumference and adjoining part of the neck give attachment to the articular capsule of the shoulder-joint, and the anterior border to the three accessory ligaments of the capsule, known as the superior, middle, and inferior glenohumeral folds. The superior fold (Flood's ligament) is attached above the notch near the upper end; of the two remaining folds, which together constitute Schlemm's ligament, the middle is attached immediately above the notch and the inferior below the notch. In the recent state the glenoid cavity is covered with hyaline cartilage. The neck is more prominent behind than before and below than above, where it supports the coracoid process. It is not separated by any definite boundary from the body.

FIG. 209.—THE LEFT SCAPULA. (Ventral surface.)



Processes.—The **spine** is a strong, triangular plate of bone attached obliquely to the dorsum of the scapula and directed backward and upward. Its apex is situated at the vertebral border; the base, corresponding to the middle of the neck, is free, concave, and gives attachment to the inferior transverse ligament, which arches over the transverse scapular (suprascapular) vessels and suprascapular nerve. Of the two borders, the anterior is joined to the body, while the posterior is free, forming a prominent subcutaneous **crest.** The latter commences at the vertebral border, in a smooth triangular area, over which the tendon of the *trapezius* glides, usually without the intervention of a bursa, as it passes to its insertion into a small tubercle on the crest beyond. Further laterally, this border is rough, and presents two lips—a superior for the insertion of the *trapezius* and an inferior for the origin of the *deltoid*. Laterally the crest is continued into the **acromion.**

The **spine has** two surfaces, the superior, which also looks medialward and

forward, is concave, contributes to the formation of the supraspinous fossa, and gives origin to the *supraspinatus* muscle; the inferior surface, also slightly concave, is directed lateralward and backward, forms part of the infraspinous fossa, and affords origin to the *infraspinatus* muscle. On both surfaces are one or more prominent vascular foramina.

The **acromion,** a process overhanging the glenoid cavity, springs from the angle formed by the junction of the crest with the base of the spine. Somewhat crescentic in shape, it forms the summit of the shoulder and is compressed from above downward so as to present two surfaces, two borders, and two extremities.

The posterior part sometimes terminates laterally in a prominent **acromial angle** (metacromion) and the process then assumes a more or less triangular form. Of the two extremities, the posterior is continuous with the spine, while the anterior forms the free tip. The upper surface, directed upward, backward, and slightly lateralward, is rough and convex, and affords origin at its lateral part to a portion of the *deltoid;* the remaining part of this surface is subcutaneous. The lower surface, directed downward, forward, and slightly medialward, is concave and smooth. The medial border, continuous with the upper lip of the crest, presents, from behind forward, an area for the insertion of the *trapezius;* a small, oval, concave articular facet for the lateral end of the clavicle, the edges of which are rough for the acromioclavicular ligaments; and, beyond this, the anterior extremity or tip, to which is attached the apex of the coracoacromial ligament. The lateral border, continuous with the inferior lip of the crest, is thick, convex, and presents three or four tubercles with intervening depressions; from the tubercles the tendinous septa in the acromial part of the *deltoid* arise, and from the depressions, some fleshy fibers of the same muscle.

Projecting upward from the neck of the scapula is the **coracoid process,** bent finger-like, pointing forward and laterally. It consists of two parts, ascending and horizontal, placed at almost a right angle to each other.

The *ascending part* arises by a wide root, extends upward and medially for a short distance, and is compressed from before backward; it is continuous above with the horizontal part and below with the neck of the scapula; the lateral border lies above the glenoid cavity and gives attachment to the coracohumeral ligament; the medial border, which forms the lateral boundary of the scapular notch, gives attachment to the conoid ligament above and the transverse ligament below. Its anterior and posterior surfaces are in relation with the *subscapularis* and *supraspinatus* respectively. The *horizontal part* of the process runs forward and lateralward; it is compressed from above downward so as to present two borders, two surfaces, and a free extremity. The medial border gives insertion along its anterior half to the *pectoralis minor* and nearer the base to the costocoracoid membrane; the lateral border is rough for the coracoacromial and coracohumeral ligaments; the upper surface is irregular and gives insertion in front to the *pectoralis minor,* and behind to the trapezoid ligament; the inferior surface is smooth and directed toward the glenoid cavity, which it overhangs; the free extremity or apex gives origin to the conjoined *coracobrachialis* and short head of the *biceps.*

Structure and vessels.—The greater part of the body of the scapula and the central parts of the spinous process are thin and transparent. The coracoid and acromion processes, the crest of the spine and inferior angle, the head, neck, and axillary border, are thick and opaque. The young bone consists of two layers of compact tissue with an intervening cancellous layer, but in the transparent parts of the adult bone the middle layer has disappeared. The vascular foramina on the costal surface transmit twigs from the subscapular and transverse scapular (suprascapular) arteries; those in the infraspinous fossa, twigs from the circumflex (dorsal) and transverse scapular (suprascapular) arteries, the latter also giving off vessels which enter the foramina in the supraspinous fossa. The acromion is supplied by branches from the thoracoacromial (acromiothoracic) artery.

The line of attachment of the spinous process to the dorsum of the scapula is known as the **morphological axis,** and the obtuse angle in the subscapular fossa opposite the spine as the *subscapular angle.* From the axis three plates of bone radiate as from a center, the **prescapula** forward, the **mesoscapula** laterally, and the **postscapula** backward, being named in accordance with the long axis of the body in the horizontal position. In the human subject the postscapula is greatly developed, and this is associated with the freedom and versatility of movement possessed by the upper limb.

The **scapular index,** $\frac{100 \times \text{breadth}}{\text{length}}$, is the ratio between the breadth and length of the bone. The index is higher in negroes than in Europeans; it is also higher in infants than in adults.

Ossification.—The scapula is ossified from nine centers. Of these, two (for the body of the scapula and the coracoid) may be considered as primary, and the remainder as secondary. The center for the body appears in a plate of cartilage near the neck of the scapula about the eighth week of intrauterine life, and quickly forms a triangular plate of bone, from which the spine appears as a slight ridge about the middle of the third month. At birth the glenoid fossa and part of the scapular neck, the acromion and coracoid processes, the vertebral border and inferior angle, are cartilaginous. During the first year a nucleus appears for the coracoid, and at the tenth year a second center appears for the base of the coracoid and the upper part of the glenoid cavity (subcoracoid, fig. 210).

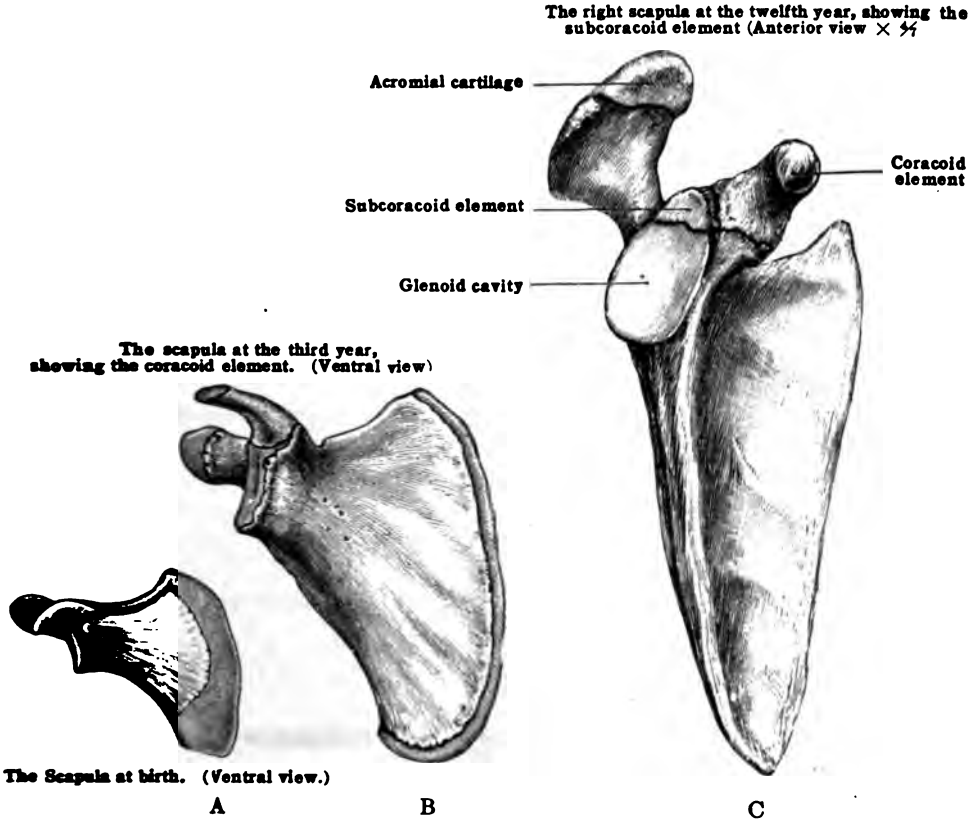
During the fifteenth year the coracoid unites with the scapula, and about this time the other secondary centers appear. Two nuclei are deposited in the acromial cartilage, and fuse to form the acromion, which joins the spine at the twentieth year. The union of spine and acromion

may be fibrous, hence the latter is sometimes found separate in macerated specimens. The cartilage along the vertebral border ossifies from two centers, one in the middle, and another at the inferior angle. A thin lamina is added along the upper surface of the coracoid process and occasionally another at the margin of the glenoid cavity. These epiphyses join by the twenty-fifth year.

The occurrence of a special primary center for the coracoid process is of morphological importance in that the process is the representative of what in the lower vertebrates is a distinct *coracoid bone*. This primarily takes part in the formation of the glenoid cavity and extends medially to articulate with the sternum. In man and all the higher mammals only the lateral portion of the bone persists.

Variations.—The scapular notch is sometimes found bridged over by bone converting it into a foramen (normal in some animals). The whole acromion process may fail to unite or a part of it, representing one of the two or three component centers may be separate. Scapulæ with concave vertebral margins (scaphoid type) have been described by Dr. W. W. Graves as of frequent occurrence, generally poorly ossified and with low scapular index.

FIG. 210.—OSSIFICATION OF THE SCAPULA.


The right scapula at the twelfth year, showing the subcoracoid element (Anterior view × ⅓
Acromial cartilage
Coracoid element
Subcoracoid element
Glenoid cavity
The scapula at the third year, showing the coracoid element. (Ventral view)
The Scapula at birth. (Ventral view.)
A
B
C

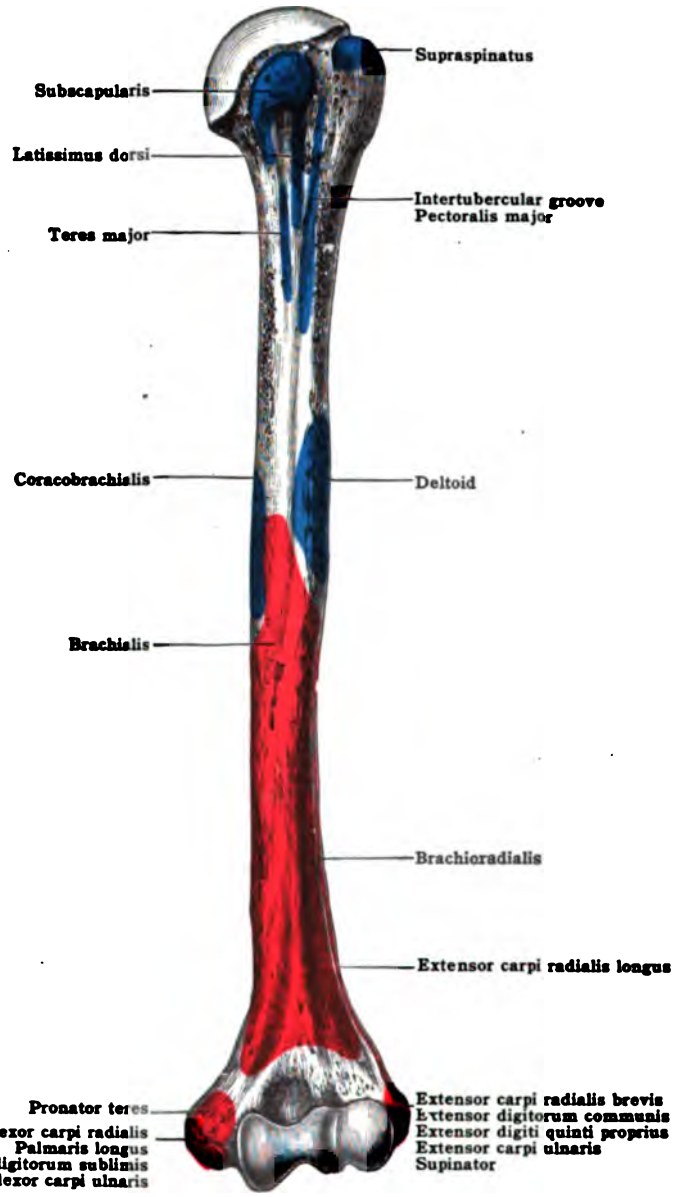
THE HUMERUS

The **humerus** (figs. 211–213) is the longest and largest bone of the upper limb, and extends from the shoulder above, where it articulates with the scapula, to the elbow [cubitus] below, where it articulates with the two bones of the forearm [antibrachium]. It is divisible into a shaft and two extremities; the *upper* extremity includes the head [caput], neck [collum], and two tuberosities—great and small; the *lower* extremity includes the articular surface with the surmounting fossæ in front and behind, and the two epicondyles.

Upper extremity.—The **head** forms a nearly hemispherical articular surface, cartilage-clad in the recent state and directed upward, medially, and backward toward the glenoid cavity. Below the head the bone is rough and somewhat constricted, constituting the **anatomical neck**, best marked superiorly, where it forms a groove separating the articular surface from the two tuberosities. The circumference of the neck gives attachment to the capsule of the shoulder-joint and the glenohumeral ligaments, the upper of which is received into a depression near the top of the intertubercular (bicipital) groove. The lowest part of the

capsule descends upon the humerus some distance from the articular margin. Laterally and in front of the head are the two tuberosities, separated by a deep furrow. The **greater tuberosity** [tuberculum majus], lateral in position and reaching higher than the **lesser tuberosity** [tuberculum minus], is marked by three facets for the insertion of muscles: an upper one for the *supraspinous*, a middle for the *infraspinatus*, and a lower for the *teres minor*. The **lesser tuberosity** is situated in front of the head and is the more prominent of the two; it receives the insertion

FIG. 211.—THE LEFT HUMERUS. (Anterior view.)

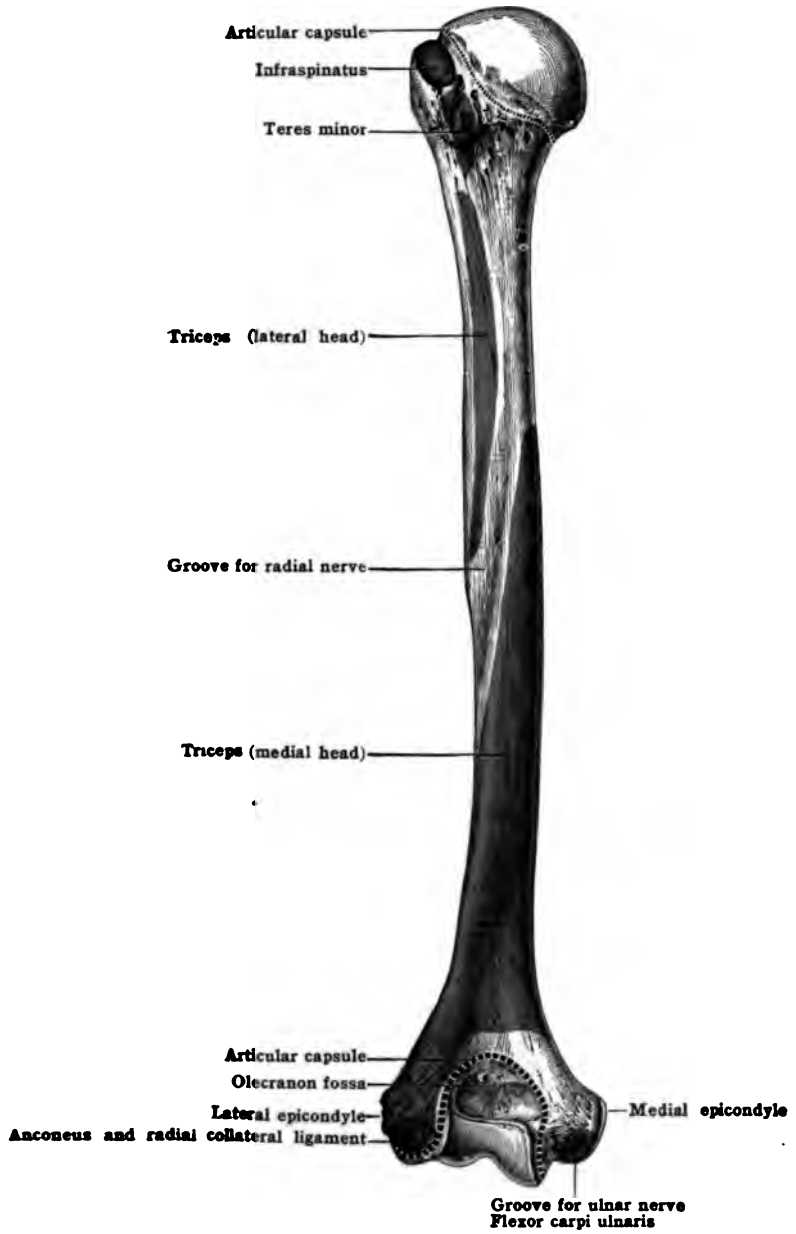


of the *subscapularis*. The furrow between the tuberosities lodges the long tendon of the biceps and forms the commencement of the **intertubercular** (bicipital) **groove,** which extends downward along the shaft of the humerus. Between the tuberosities the transverse humeral ligament converts the upper end of the groove into a canal. In addition to the long tendon of the biceps and its tube of synovial membrane, the groove transmits a branch of the anterior circumflex artery. Immediately below the two tuberosities the bone becomes contracted and forms the **surgical neck.**

The shaft or **body** [corpus humeri] is somewhat cylindrical above, flattened and prismatic below. Three borders and three surfaces may be recognised.

Borders.—The **anterior border** commences above at the greater tuberosity, and its upper part, forming the **crest** of this tuberosity [crista tuberculi majoris] receives the *pectoralis major*. In the middle of the shaft it is rough and prominent and gives insertion to the *deltoid;* below it is smooth and rounded, giving origin

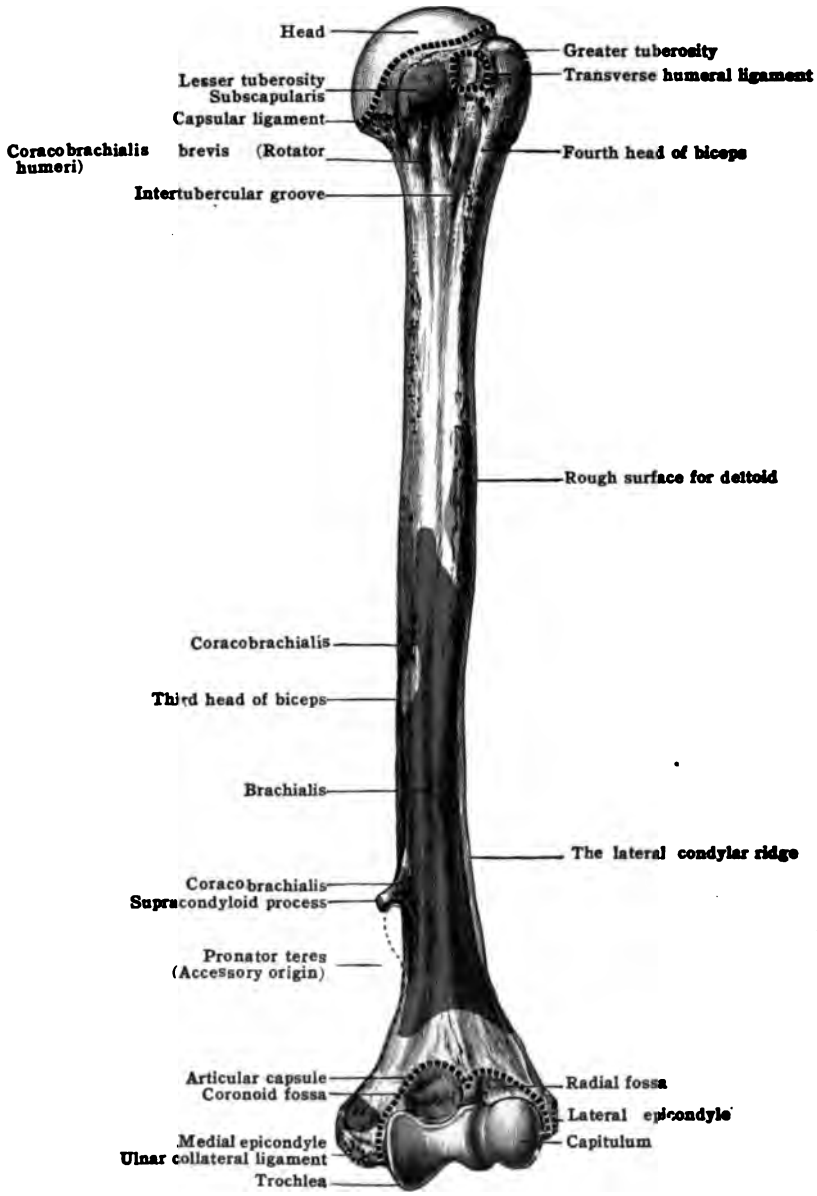
FIG. 212.—THE LEFT HUMERUS. (Posterior view.)



to the *brachialis*, and finally it passes along lateral to the coronoid fossa to become continuous with the ridge separating the capitulum and trochlea. It separates the anteromedial from the anterolateral surface. The **lateral margin** extends from the lower and posterior part of the greater tuberosity to the lateral epicondyle. Smooth and indistinct above, it gives attachment to the *teres minor* and the lateral head of the *triceps;* it is interrupted in the middle by the **groove for the radial nerve** (musculospiral groove), and the lower third becomes prominent and curved

laterally to form the **lateral supracondylar ridge,** which affords origin in front to the *brachioradialis* and the *extensor carpi radialis longus;* behind to the medial head of the *triceps,* and between these muscles in front and behind to the lateral intermuscular septum. It separates the anterolateral from the posterior surface. The **medial border** commences at the lesser tuberosity, forming its **crest** which receives the insertion of the *teres major,* and continuing downward to the medial epicondyle. Near the middle of the shaft it forms a ridge for the insertion of the

FIG. 213.—THE LEFT HUMERUS WITH A SUPRACONDYLOID PROCESS AND SOME IRREGULAR MUSCLE ATTACHMENTS. (Anterior view.)



coracobrachialis and presents a foramen for the nutrient ratery, directed downward toward the elbow-joint. Below it forms a distinct **medial supracondylar ridge,** curved medially, which gives origin to the *brachialis* in front, the medial head of the *triceps* behind, and the medial intermuscular septum in the interval between the muscles. This border separates the anteromedial from the posterior surface.

Surfaces.—The **anterolateral surface** is smooth above, rough in the middle, forming a large impression for the insertion of the *deltoid,* below which is the

termination of the groove for the radial nerve. The lower part of the surface **gives origin** to the lateral part of the *brachialis*. The **anteromedial surface** is **narrow above**, where it forms the floor of the intertubercular (bicipital) groove, **and receives** the insertion of the *latissimus dorsi*. Near the junction of the upper **and middle** thirds of the bone the groove, gradually becoming shallower, widens **out and**, with the exception of a rough impression near the middle of the shaft **for the** *coracobrachialis*, the remaining part of the anteromedial surface is flat **and smooth**, and gives origin to the *brachialis*.

Occasionally, a bony spine of variable size, the **supracondylar process** (fig. 213), projects downward from the medial border about 5 cm. (2 in.) above the medial epicondyle, to which it is joined by a band of fibrous tissue. It occurs in from 1 per cent. (Testut) to 2.7 per cent. (Gruber) of cases; and was found in 8 of 1000 living subjects (Terry). Through the ring thus formed, which corresponds to the supracondylar foramen in many of the lower animals, the median nerve and brachial artery are transmitted, though in some cases it is occupied by the nerve alone. The process gives origin to the *pronator teres*, and may afford insertion to a persistent lower part of the *coracobrachialis*.

The **posterior surface** is obliquely divided by a broad shallow groove, which runs in a spiral direction from behind downward and forward and transmits the radial (musculospiral) nerve and the profunda artery. The lateral part of the surface above the groove gives attachment to the lateral head, and the part below the groove, to the medial head of the *triceps*.

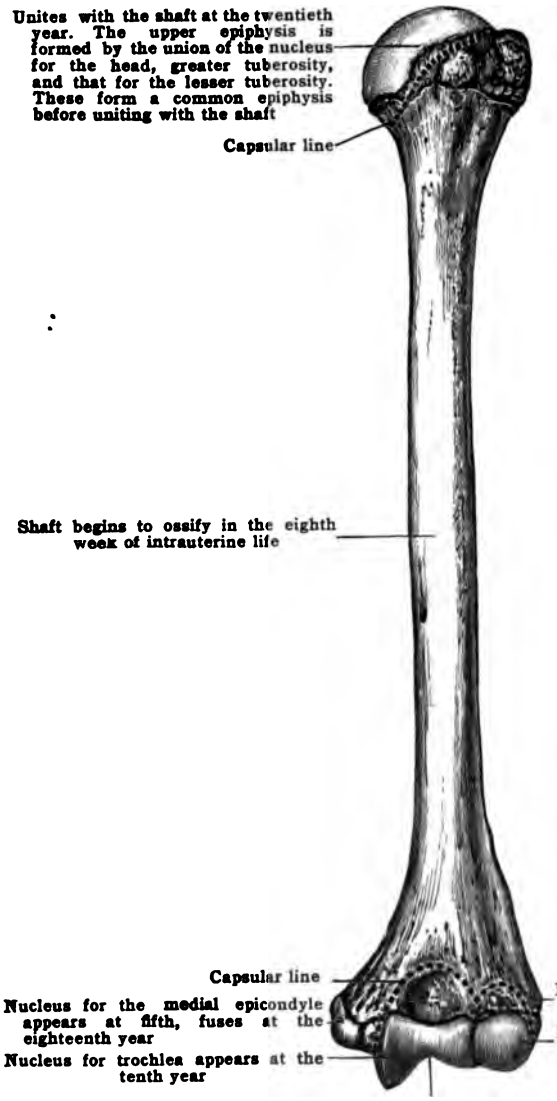
FIG. 214.—A DIAGRAM SHOWING PRESSURE AND TENSION CURVES IN THE HEAD OF THE HUMERUS. (After Wagstaffe.)

The **lower extremity** of the humerus is flattened from before backward, and terminates below in a sloping articular surface, subdivided by a low ridge into the **trochlea and the capitulum.** The **trochlea** is the pulley-like surface which extends over the end of the bone for articulation with the semilunar notch (great sigmoid cavity) of the ulna. It is constricted in the center and expanded laterally to form two prominent edges, the medial of which is thicker, descends lower, and forms a marked projection; the lateral edge is narrow and corresponds to the interval between the ulna and radius. Above the trochlea are two fossæ: on the anterior surface is the **coronoid fossa,** an oval pit which receives the coronoid process of the ulna when the forearm is flexed; on the posterior aspect is the **olecranon fossa,** a deep hollow for the reception of the anterior extremity of the olecranon in extension of the forearm. These fossæ are usually separated by a thin, translucent plate of bone, sometimes merely by fibrous tissue, so that in macerated specimens a perforation, the **supratrochlear foramen,** exists. The **capitulum,** or radial head, is much smaller than the trochlea, somewhat globular in shape, and limited to the anterior and inferior surfaces of the extremity. It articulates with the concavity on the summit of the radius. The **radial fossa** is a slight depression on the front of the bone, immediately above the capitulum, which receives the anterior edge of the head of the radius in complete flexion of the forearm, whilst between the capitulum and the trochlea is a shallow groove occupied by the medial margin of the head of the radius.

In the recent state the inferior articular surface is covered with cartilage, the fossæ are lined by synovial membrane, and their margins give attachment to the capsule of the elbow-joint. Projecting on either side from the lower end of the humerus are the two **epicondyles.** Both epicondyles project beneath the skin and are easily felt in palpating the elbow. The medial

one is large and by far the more prominent of the two, rough in front and below, smooth behind, where there is a shallow groove for the ulnar nerve. The rough area serves for origin of the *pronator teres* above, the common tendon of origin of the *flexor carpi radialis, palmaris longus, flexor digitorum sublimis* and *flexor carpi ulnaris* in the middle, and the ulnar collateral ligament below. The lateral epicondyle is flat and irregular. Above, it gives attachment to a common tendon of origin of the *extensor carpi radialis brevis, extensor digitorum communis, extensor quinti digiti proprius, extensor carpi ulnaris,* and *supinator;* to a depression near the outer margin of the capitulum, the radial collateral ligament is attached, and from an area below and behind, the *anconeus* takes origin.

FIG. 215.—OSSIFICATION OF THE HUMERUS; THE FIGURE ALSO SHOWS THE RELATIONS OF THE EPIPHYSIAL AND CAPSULAR LINES.


Unites with the shaft at the twentieth year. The upper epiphysis is formed by the union of the nucleus for the head, greater tuberosity, and that for the lesser tuberosity. These form a common epiphysis before uniting with the shaft
Capsular line
Shaft begins to ossify in the eighth week of intrauterine life
Capsular line
Nucleus for the medial epicondyle appears at fifth, fuses at the eighteenth year
Nucleus for trochlea appears at the tenth year
Nucleus for lateral epicondyle appears at fourteenth year
Nucleus for capitulum appears in the third year
The centers for the radial epicondyle, trochlea, and capitulum unite together and form an epiphysis which fuses with the shaft at the seventeenth year

The *length* of the humerus is somewhat less than one-fifth the stature of the individual. The principal axes of the upper and lower extremities of the bone lie in planes that cross each other at an angle that varies in size between 12° and 20° in Europeans and is considerably greater in negroes.

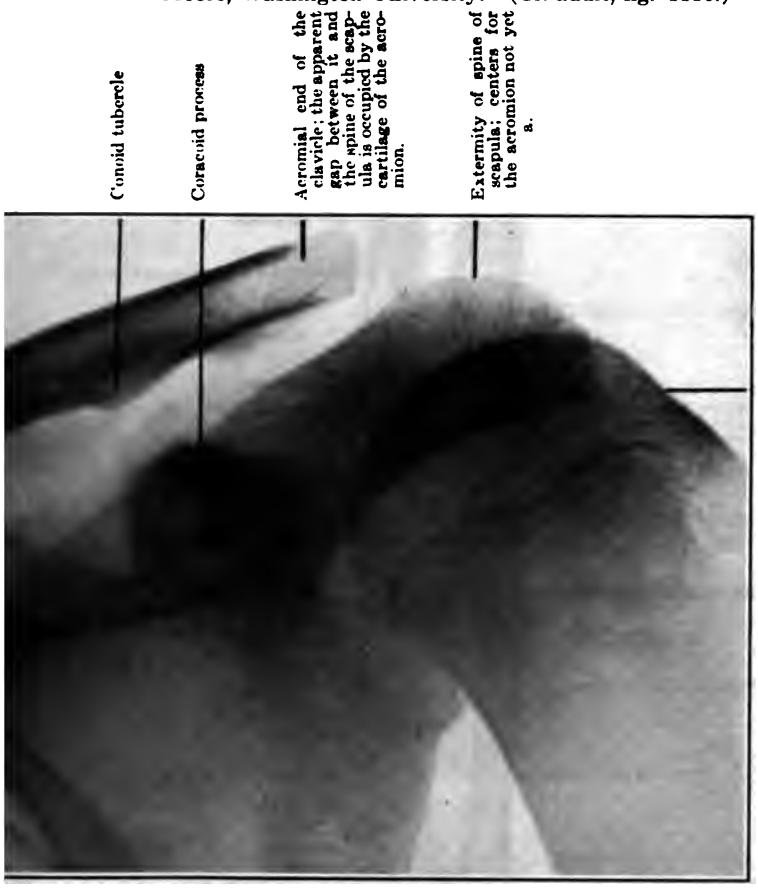
The term neck is applied to three parts of the humerus. The *anatomical* neck is the constriction to which the articular capsule is mainly attached. The upper extremity of the humeral shaft, before its union with the epiphysis, terminates in a low three-sided pyramid, the surfaces of which are separated from one another by ridges. The medial of these three surfaces underlies the head of the bone, and the two lateral surfaces underlie the tuberosities. The part sup-

ng the head constitutes the *morphological* neck of the humerus. The *surgical* neck is the inite area below the tuberosities where the bone is liable to fracture.

rchitecture.—The interior of the shaft of the humerus is hollowed out by a large medullary l, whereas the extremities are composed of cancellated tissue invested by a thin compact . The arrangement of the cancellous tissue at the upper end of the humerus is shown g. 214. The lamellæ converge to the axis of the bone and form a series of superimposed es which reach upward as far as the epiphysial line. In the epiphyses the spongy tissue s a fine network, the lamellæ resulting from pressure being directed at right angles to the ular surface of the head and to the great tuberosity.

lood-supply.—The foramina which cluster round the circumference of the head and tuber- es transmit branches from the transverse scapular (suprascapular) and anterior and pos- r circumflex arteries. At the top of the intertubercular groove is a large nutrient foramen branch of the anterior circumflex artery which supplies the head. The nutrient artery of haft is derived from the brachial, and in many cases, an additional branch, derived from profunda artery, enters the foramen in the groove for the radial nerve (musculospiral

216.—SHOULDER OF A BOY OF SIXTEEN YEARS. From an *X*-ray plate by Dr. Sherwood Moore, Washington University. (Cf. adult, fig. 1116.)


Conoid tubercle
Coracoid process
Acromial end of the clavicle; the apparent gap between it and the spine of the scapula is occupied by the cartilage of the acromion.
Extremity of spine of scapula; centers for the acromion not yet a.

Proximal humeral epiphysis (the originally independent centers for the head and greater and lesser tuberosities have united.)

re). The lower extremity is nourished by branches derived from the profunda (superior nda), the superior and inferior ulnar collateral (inferior profunda and anastomotic), and ecurrent branches of the radial, ulnar, and interosseous arteries.

ssification.—The humerus is ossified from one primary center (diaphysial) and six second- enters (epiphysial). The center for the shaft appears about the seventh week (forty-second according to Mall) of intrauterine life and grows very rapidly. At birth only the two mities are cartilaginous, and these ossify in the following manner: Single centers appear he head in the first year, for the greater tuberosity in the third year, and for the lesser rosity in the fifth year, though sometimes the latter ossifies by an extension from the greater rosity. These three nuclei coalesce at six years to form a single epiphysis, which joins the t about the twentieth year.

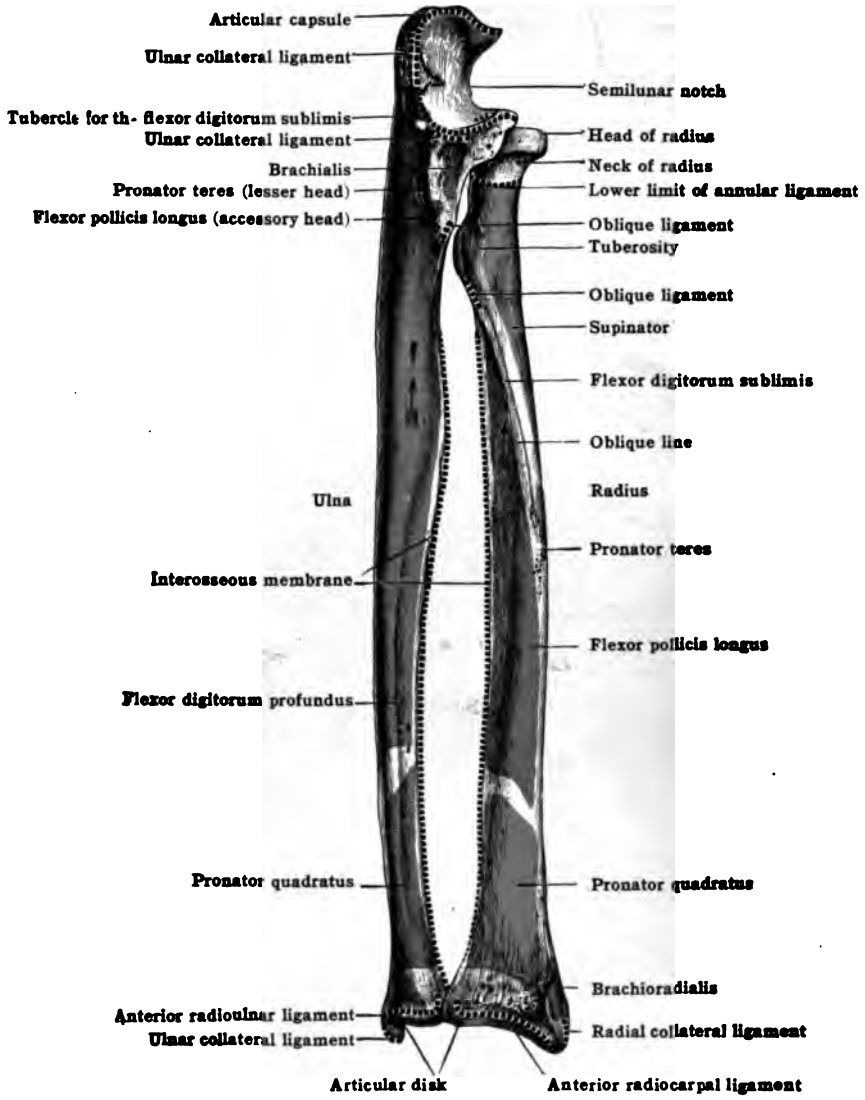
The inferior extremity ossifies from four centers: one for the capitulum appears in the third , a second for the medial epicondyle in the fifth year, a third for the trochlea in the tenth , and a fourth for the lateral epicondyle in the fourteenth year. The nuclei for the capitu- trochlea, and lateral epicondyle coalesce to form a single epiphysis which joins the shaft e seventeenth year (figs. 223, 1121). The nucleus of the medial epicondyle joins the shaft pendently at the age of eighteen years.

THE RADIUS

The **radius** (figs. 2172—22) is the lateral and shorter of the two bones of the forearm. Above, it articulates with the humerus; below, with the carpus; and on the medial side with the ulna. It presents a shaft and two extremities.

The **upper extremity,** smaller than the lower, includes the head, neck, and tuberosity. The **head** [capitulum], covered with cartilage in the recent state, is a circular disk forming the expanded, articular end of the bone. Superiorly it presents the capitular depression [fovea capituli] for the reception of the capitulum

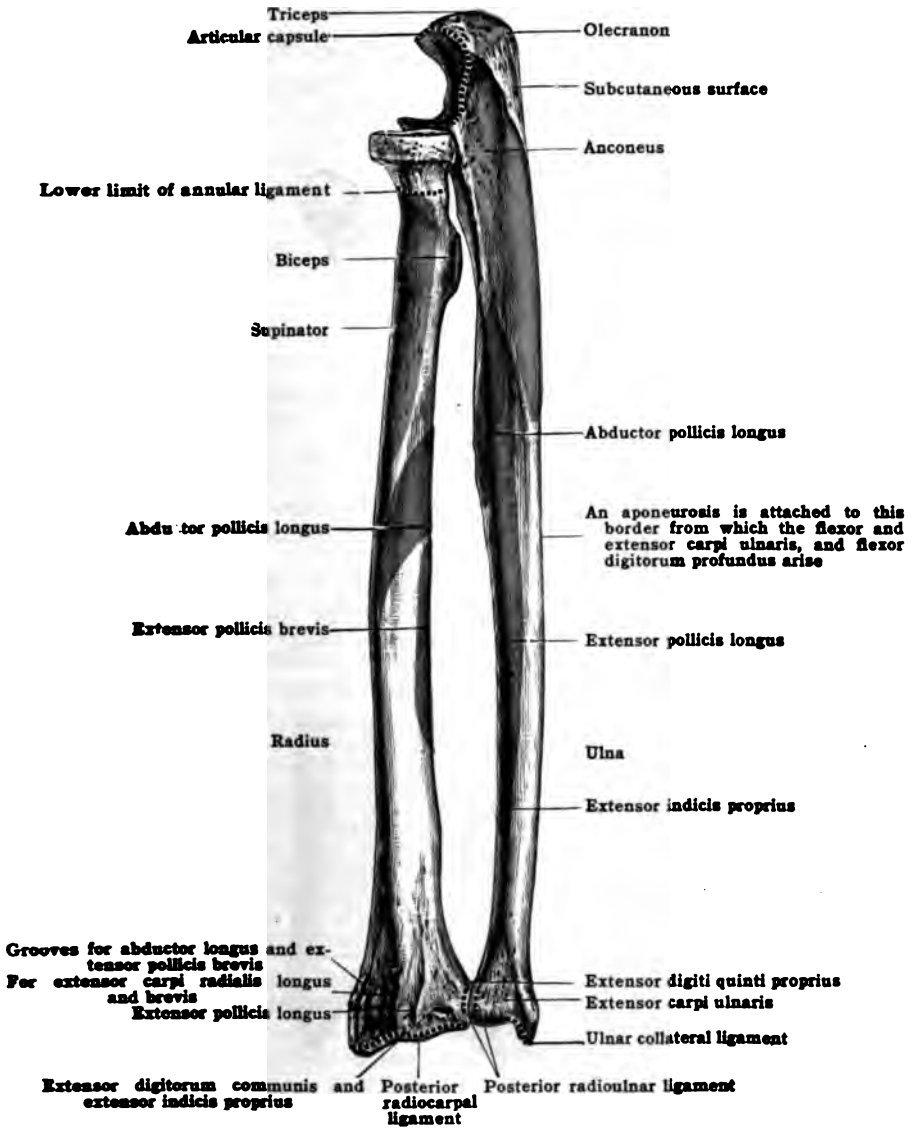
FIG. 217.—THE LEFT ULNA AND RADIUS. (Anteromedial view.)



of the humerus; its *circumference* [circumferentia articularis], deeper on the medial aspect, articulates with the radial notch (lesser sigmoid cavity) of the ulna, and is narrow elsewhere for the annular ligament by which it is embraced. Below the head is a short cylindrical portion of bone, somewhat constricted, and known as the **neck.** The upper part is surrounded by the ligament which embraces the head, and below this it gives insertion anterolaterally to the *supinator.* Below the neck, at the anteromedial aspect of the bone, is an oval eminence, the **radial tuberosity,** divisible into two parts: a rough posterior portion for the insertion of the tendon of the *biceps,* and a smooth anterior surface in relation with a bursa which is situated between the tendon and the tuberosity.

The body [corpus radii] or **shaft** is somewhat prismatic in form, gradually increasing in size from the upper to the lower end, and slightly curved so as to be concave toward the ulna. Three borders and three surfaces may be recognized. Of the borders, the medial or **interosseous crest** [crista interossea] is best marked. Commencing at the posterior edge of the tuberosity, its first part is round and indistinct, and receives the attachment of the oblique cord of the radius; it is continued as a sharp ridge which divides near the lower extremity to become continuous with the anterior and posterior margins of the ulnar notch (sigmoid cavity).

FIG. 218.—THE LEFT ULNA AND RADIUS. (Posterolateral view.)



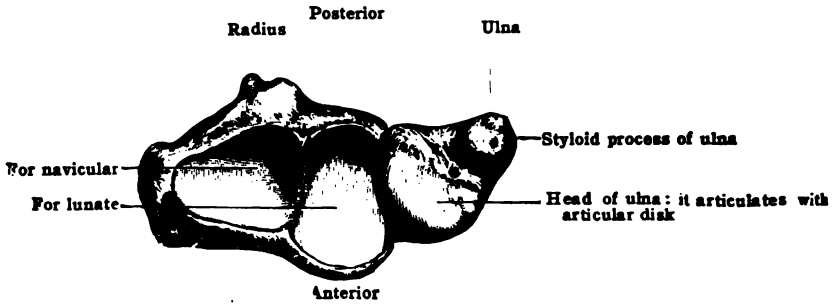
The prominent ridge and the posterior of the two lower lines give attachment to the interosseous membrane, whilst the triangular surface above the ulnar notch receives a part of the *pronator quadratus*. The interosseous crest separates the volar from the dorsal surface.

The volar border [margo volaris] runs from the tuberosity obliquely downward to the lateral side of the bone and then descends vertically to the anterior border of the styloid process. The upper third, constituting the oblique line of the radius, gives origin to the radial head of the *flexor digitorum sublimis*, limits the insertion of the *supinator* above, and the origin of the *flexor pollicis longus* below. The volar border separates the volar from the lateral surface. The dorsal border extends from the back of the tuberosity to the prominent middle tubercle on the

posterior aspect of the lower extremity. Separating the lateral from the dorsal surface, it is well marked in the middle third, but becomes indistinct above and below.

Surfaces.—The **volar** (or anterior) **surface** is narrow and concave above; broad, flat, and smooth below. The upper two-thirds is occupied chiefly by the *flexor pollicis longus* and a little less than the lower third by the *pronator quadratus.* Near the junction of the upper and middle thirds of the volar surface is the nutrient foramen, directed upward toward the proximal end of the bone. It transmits a branch of the volar interosseous artery. The **lateral surface** is convex, rounded above and affords insertion to the *supinator;* marked near the middle by a rough, low, vertical ridge for the *pronator teres;* smooth below, where the tendons of the

FIG. 219.—ARTICULAR FACETS ON THE LOWER END OF LEFT RADIUS AND ULNA.



extensor carpi radialis longus and *brevis* lie upon it, and where it is crossed by the *abductor pollicis longus* and *extensor pollicis brevis.* The **dorsal** (or posterior) **surface,** smooth and rounded above, is covered by the *supinator;* grooved longitudinally in the middle third for the *abductor pollicis longus* and the *extensor pollicis brevis;* the lower third is broad, rounded, and covered by tendons. The line which forms the upper limit of the impression for the *abductor pollicis longus* is known as the **posterior oblique line.**

The **lower extremity** of the radius is quadrilateral; its **carpal surface** [facies articularis carpea] is articular and divided by a ridge into a medial **quadrilateral** portion, concave for articulation with the lunate bone; and a lateral **triangular**

FIG. 220.—DORSAL VIEW OF THE LOWER END OF THE RADIUS AND ULNA.

portion, extending onto the styloid process for articulation with the navicular (scaphoid) bone. The medial surface, also articular, presents the **ulnar notch** (sigmoid cavity) for the reception of the rounded margin of the head of the ulna. To the border separating the ulnar and carpal articular surfaces the base of the articular disk is attached, and to the anterior and posterior borders, the anterior and posterior radioulnar ligaments respectively. The **anterior surface** is raised into a prominent area for the anterior ligament of the wrist-joint. The **lateral surface** is represented by the **styloid process,** a blunt pyramidal eminence, easily palpated beneath the skin; to its base the *brachioradialis* is inserted, whilst the tip serves for the attachment of the radial (external) collateral ligament of the wrist.

Its lateral surface is marked by two shallow furrows for the tendons of the *abductor pollicis longus* and *extensor pollicis brevis*. The **posterior surface** is convex, and marked by three prominent ridges separating three furrows. The posterior annular ligament is attached to these ridges, thus forming with the bone a series of tunnels for the passage of tendons (fig. 220).

The most lateral groove is broad, shallow, and frequently subdivided by a low ridge. The lateral subdivision is for the *extensor carpi radialis longus*, the medial for the *extensor carpi radialis brevis*. The middle groove is narrow and deep for the tendon of the *extensor pollicis longus*. The sharp tubercle which limits this groove laterally can be distinguished by palpation. The most medial is shallow and transmits the *extensor indicis proprius*, the *extensor digitorum communis*, the dorsal branch of the interosseous artery, and the dorsal interosseous nerve. When the radius and ulna are articulated, an additional groove is formed for the tendon of the *extensor digiti quinti proprius*.

Ossification.—The radius is ossified from a center which appears in the middle of the shaft in the eighth week of intrauterine life and from two epiphyseal centers which appear after birth. The nucleus for the lower end appears in the second year, and that for the upper end, which forms simply the disk-shaped head, from the fifth year to the tenth year. According to Pryor the distal epiphysis appears in female children at the eighth month; in males at fifteen months. The head unites with the shaft at the seventeenth year whilst the inferior epiphysis and the shaft join about the twentieth year.

Variations.—Congenital absence of the radius has frequently been observed; absence of the thumb has been noted in association with this variation in a number of cases. A sesamoid develops rarely in the tendon of the biceps over the tuberosity of the radius.

THE ULNA

The **ulna** (figs. 217, 218, 221, 224) is a long prismatic bone, thicker above than below, on the medial side of the forearm and parallel with the radius, which it exceeds in length by the extent of the olecranon process. It articulates at the upper end with the humerus, at the lower end indirectly with the carpus, and on the lateral side with the radius. It is divisible into a shaft and two extremities.

The upper extremity is of irreeular shape and forms the thickest and strongest part of the bone. The superior articular surface is concave from above downward, convex from side to side, and transversely constricted near the middle. It belongs partly to the **olecranon,** the thick upward projection from the shaft, and partly to the **coronoid process,** which projects horizontally forward from the front of the ulna. This semilunar excavation forms the **semilunar notch** (greater sinmoid cavity) and articulates with the trochlear surface of the humerus. The **olecranon** is the large curved eminence forming the highest part of the bone.

The superior surface of the olecranon, uneven and somewhat quadrilateral in shape, receives behind, where there is a rough impression, the insertion of the *triceps*, and along the anterior margin the articular capsule of the elbow-joint. The posterior surface, smooth and triangular in outline, is separated from the skin by a bursa and can be readily palpated. The anterior surface, covered with cartilage in the recent state, is directed downward and forward, and its margins give attachment to the articular capsule of the elbow-joint. This surface, as already noticed, forms the upper and back part of the semilunar notch. On the medial surface of the olecranon is a tubercle for the origin of the ulnar head of the *flexor carpi ulnaris*, and in front of this a fasciculus of the ulnar collateral ligament of the elbow-joint is attached to the bone; the lateral surface is rough, concave, and gives insertion to a part of the *anconeus*. The extremity of the olecranon lies during extension of the elbow in the olecranon fossa of the humerus.

The **coronoid process,** forming the lower and anterior part of the semilunar notch, has a superior articular surface continuous with the anterior surface of the olecranon, and, like it, covered with cartilage. The inferior aspect is rough and concave, and gives insertion to the *brachialis*.

It is continuous with the volar surface of the shaft, and near the junction of the two is a rough eminence named the **tuberosity of the ulna,** which receives the attachment of the oblique cord of the radius and the insertion of the *brachialis*. The medial side presents above a smooth tubercle for the origin of the ulnar portion of the *flexor digitorum sublimis*, and a ridge below for the lesser head of the *pronator teres* and the rounded accessory bundle of the *flexor pollicis longus*, whilst immediately behind the sublimis tubercle there is a triangular depressed surface for the upper fibers of the *flexor digitorum profundus*.

On the lateral surface is the **radial notch** (lesser sigmoid cavity), an oblong articular surface which articulates with the circumference of the head of the radius, the anterior and posterior margins of which afford attachment to the annular ligament and the radial collateral ligament of the elbow-joint. In flexion of the elbow the tip of the process is received into the coronoid fossa of the humerus.

FIG. 221.—UPPER END OF LEFT ULNA. (Lateral view.)

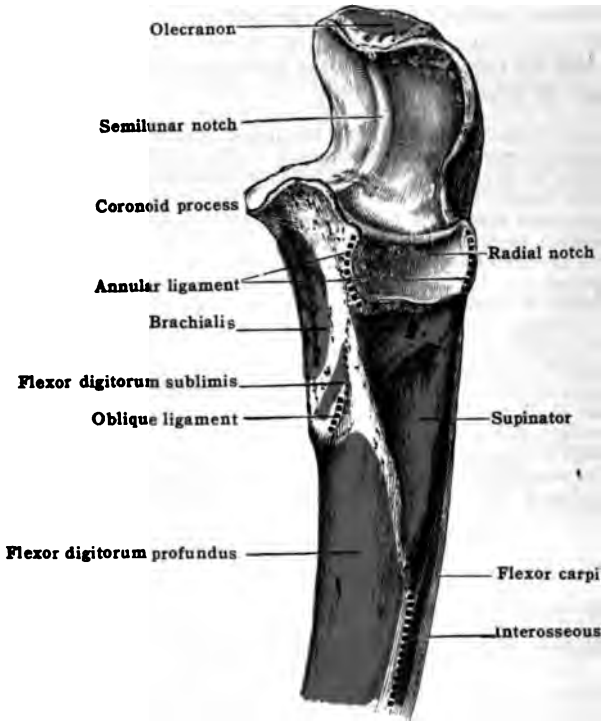
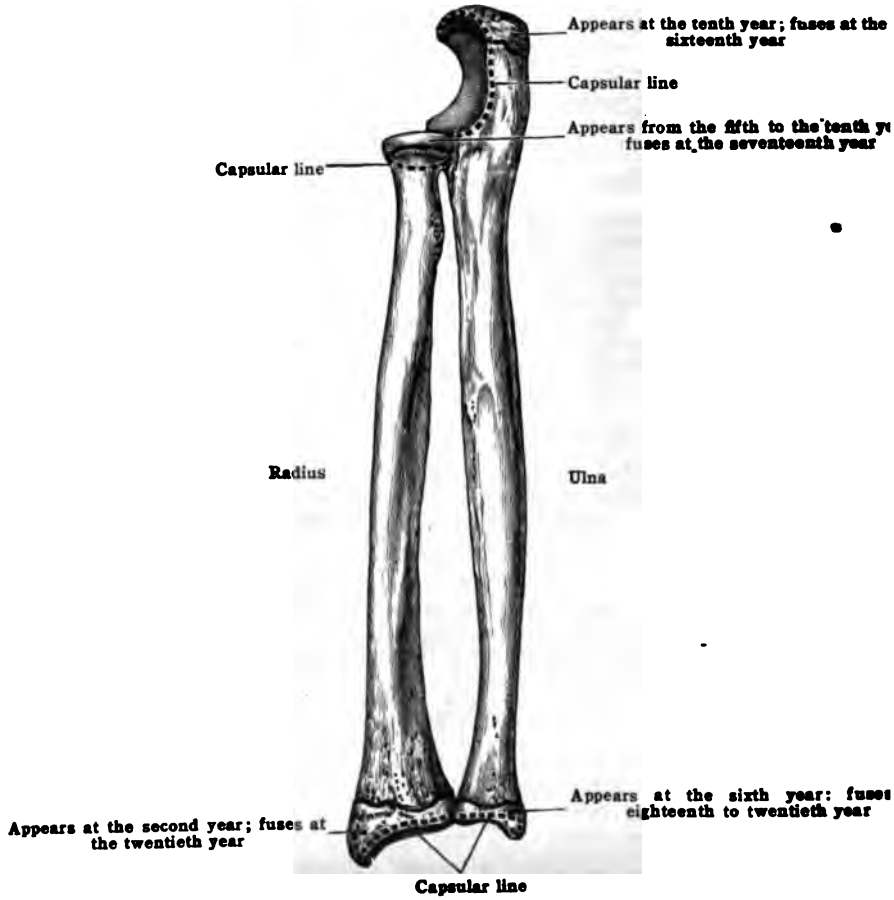
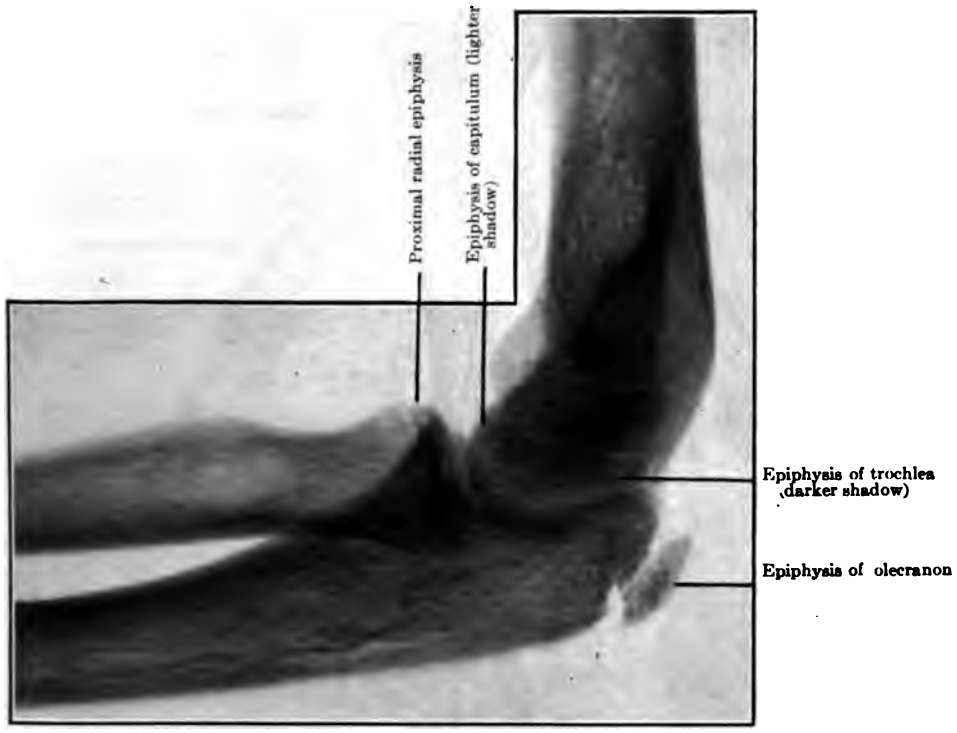


FIG. 222.—OSSIFICATION OF THE RADIUS AND ULNA; EPIPHYSIAL AND CAPSULAR LINE


Appears at the tenth year; fuses at the sixteenth year
Capsular line
Appears from the fifth to the tenth ye
fuses at the seventeenth year
Capsular line
Radius
Ulna
Appears at the sixth year: fuses
eighteenth to twentieth year
Appears at the second year; fuses at the twentieth year
Capsular line

The **body** [corpus ulnæ] or **shaft** throughout the greater part of its extent is three-sided, but tapers toward the lower extremity, where it becomes smooth and rounded. It has three borders and three surfaces. Of the three borders, the **lateral,** the **interosseous crest,** is best marked. In the middle three-fifths of the shaft it is sharp and prominent, but becomes indistinct below; above it is continued by two lines which pass to the anterior and posterior extremities of the radial notch and enclose a depressed triangular area (bicipital hollow), the fore part of which lodges the tuberosity of the radius and the insertion of the biceps tendon during pronation of the hand, while from the posterior part the *supinator* takes origin. The **interosseous crest** separates the volar from the dorsal surface and gives attachment by the lower four-fifths of its extent to the interosseous membrane. The **volar border** is directly continuous with the medial edge of the rough surface for the brachialis and terminates inferiorly in front of the styloid process. Throughout the greater part of its extent it is smooth and rounded, and affords origin to the *flexor digitorum profundus* and the *pronator quadratus.* It separates

FIG. 223.—RIGHT ELBOW-JOINT OF A BOY AGED SIXTEEN. From an *X*-ray Plate by Dr. Sherwood Moore, Washington University. (Cf. Fig. 1121.)


Proximal radial epiphysis
Epiphysis of capitulum (lighter shadow)
Epiphysis of trochlea (darker shadow)
Epiphysis of olecranon

the volar from the medial surface. The **dorsal border** commences above at the apex of the triangular subcutaneous area on the back of the olecranon, and takes a sinuous course to the back part of the styloid process. The upper three-fourths gives attachment to an aponeurosis common to three muscles, viz., the *flexor* and *extensor carpi ulnaris* and the *flexor digitorum profundus.* This border separates the medial from the dorsal surface, and is easily palpated throughout.

Surfaces.—The **volar** (or anterior) **surface** is grooved in the upper three-fourths of its extent for the origin of the *flexor digitorum profundus,* narrow and convex below, for the origin of the *pronator quadratus.* The upper limit of the area for the latter muscle is sometimes indicated by an oblique line—the **pronator ridge.** Near the junction of the upper and middle thirds of the anterior surface is the nutrient foramen, directed upward toward the proximal end of the bone. It transmits a branch of the volar interosseous artery. The **medial surface,** smooth and rounded, gives attachment, on the upper two-thirds, to the *flexor digitorum profundus,* whereas the lower third is subcutaneous. The **dorsal** (or posterior) **surface,** directed laterally as well as backward, presents at its upper part the

oblique line of the ulna running from the posterior extremity of the radial notch to the dorsal border.

The oblique line gives attachment to a few fibers of the *supinator* and marks off the posterior surface into two unequal parts. That above the line, much the smaller of the two, receives the insertion of the *anconeus*. The more extensive part below is subdivided by a vertical ridge into a medial portion, smooth, and covered by the *extensor carpi ulnaris*, and a lateral portion which gives origin to three muscles, viz., the *abductor pollicis longus*, the *extensor pollicis longus* and the *extensor indicis proprius*, from above downward.

The **lower extremity** of the ulna is of small size and consists of two parts, the **head** and the **styloid process**, separated from each other on the inferior surface by a groove into which the apex of the articular disk is inserted. That part of the head adjacent to the groove is semilunar in shape and plays upon the articular disk which thus excludes the ulna from the radiocarpal or wrist-joint. The mar-

FIG. 224.—THE LEFT RADIUS AND ULNA IN PRONATION. (Anterior view.)

gin of the head is also semilunar, and is received into the ulnar notch of the radius. In pronation the head of the ulna makes the rounded prominence on the dorsal side of the wrist. The **styloid process** projects from the medial and back part of the bone, and appears as a continuation of the dorsal border. To its rounded summit the ulnar collateral ligament of the wrist-joint is attached, and its dorsal surface is grooved for the passage of the tendon of the *extensor carpi ulnaris*. Immediately above the articular margin of the head the anterior and posterior radioulnar ligaments are attached in front and behind.

In contrast to the poor adaptation of the articular surfaces of the humerus and radius for security in the hinge-movements of the elbow is the perfect locking of the semilunar notch of the ulna with the trochlea of the humerus. The inferior extremity of the bone is adapted mainly to the radius in the pivotal movements of pronation and supination, and has undergone regression in those mammals in which the antibrachium is permanently fixed in pronation, as, for example, in the horse and ox.

The ratio between the lengths of the forearm and the arm is expressed by the ***humero-radial***

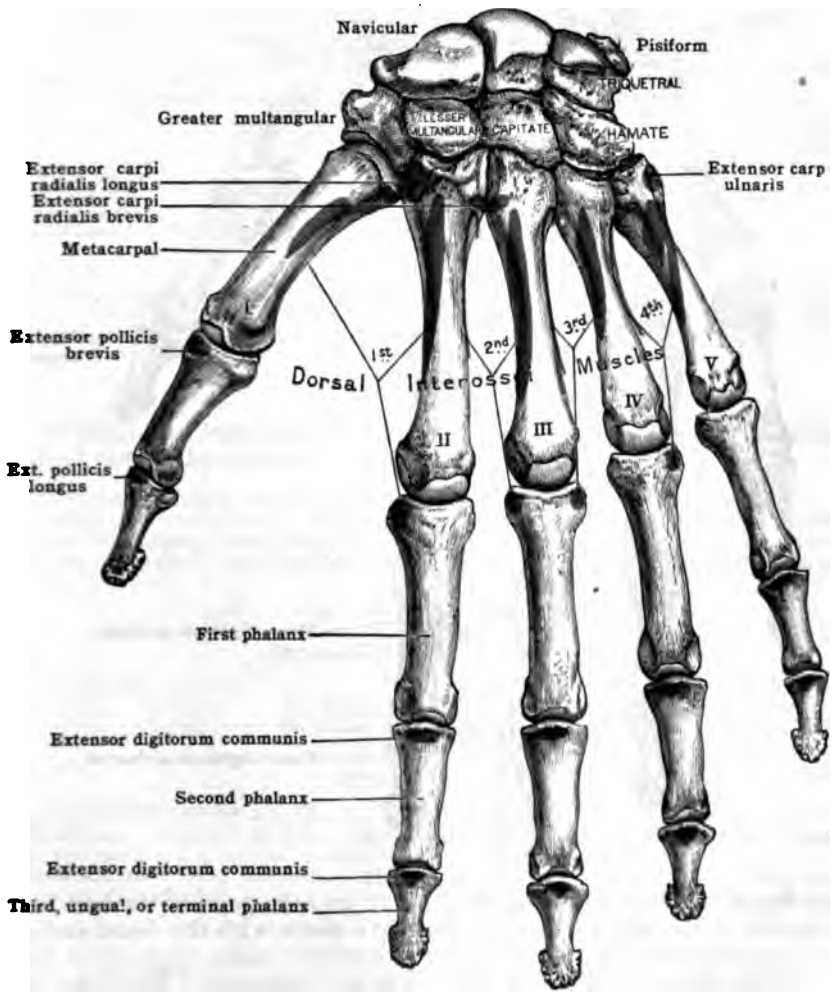
index, $\frac{\text{length of radius} \times 100}{\text{length of humerus}}$. The index is higher in the infant than in the adult; higher in women than in men. In Europeans the index has been found to be 74; in the negro, 79; in Andamanese 81. In the anthropoid apes, the gorilla has an index of 90; the orang, 100.

Ossification.—The ulna is ossified from three centers. The primary nucleus appears near the middle of the shaft in the eighth week of intrauterine life. At birth the inferior extremity and the greater portion of the olecranon are cartilaginous. The nucleus for the lower end appears during the sixth year (sixth to seventh year in girls; eighth to ninth in boys. Pryor) and the epiphysis joins with the shaft from the eighteenth to the twentieth year (fig. 241). The greater part of the olecranon is ossified from the shaft, but an epiphysis is subsequently formed from a nucleus which appears in the tenth year.

The epiphysis varies in size, and may be either scale-like and form a thin plate on the summit, or involve the upper fourth of the olecranon and the corresponding articular surface. In the latter case the epiphysis is probably composed of two parts fused together: (1) The scale on the summit of the olecranon process, and (2) the beak center which enters into the formation of the upper end of the semilunar notch. The epiphysis unites to the shaft in the sixteenth or seventeenth year.

Variations.—A sesamoid bone above the olecranon and lodged in the tendon of the triceps occurs rarely. Total absence of the ulna has been recorded.

FIG. 225.—BONES OF THE LEFT HAND. (Dorsal surface.)



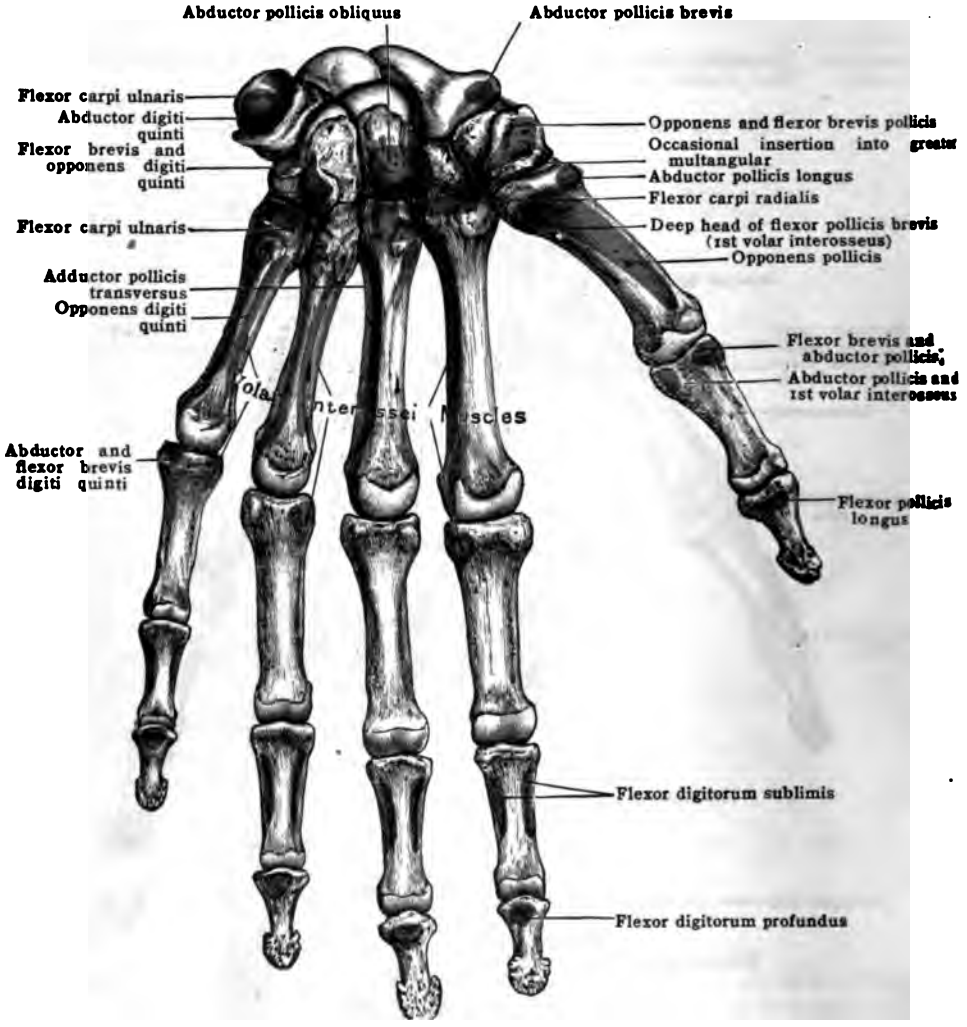
THE CARPUS

The carpus (figs. 225, 226) consists of eight bones, arranged in two rows, four bones in each row. Enumerated from the radial to the ulnar side, the bones of the proximal row are named **navicular** (scaphoid), **lunate** (semilunar), **triquetral (cuneiform), and pisiform**; those of the distal row, **greater multangular** (trape-

zium), **lesser multangular** (trapezoid), **capitate** (os magnum), **and hamate** (unciform).

When the bones of the carpus are articulated, they form a mass somewhat quadrangular in outline, wider below than above, and with the long diameter transverse. The dorsal surface is convex and the volar surface concave from side to side. The concavity is increased by four prominences, which project forward, one from each extremity of each row. On the radial side are the tuberosity of the navicular and the ridge of the greater multangular; on the ulnar side, the pisiform and the hook of the hamate. Stretched transversely between these prominences, in the recent state, is the transverse carpal ligament forming a canal for the pas-

FIG. 226.—BONES OF THE LEFT HAND. (Volar surface.)


Abductor pollicis obliquus
Abductor pollicis brevis
Flexor carpi ulnaris
Abductor digiti quinti
Flexor brevis and opponens digiti quinti
Flexor carpi ulnaris
Adductor pollicis transversus
Opponens digiti quinti
Abductor and flexor brevis digiti quinti
Opponens and flexor brevis pollicis
Occasional insertion into greater multangular
Abductor pollicis longus
Flexor carpi radialis
Deep head of flexor pollicis brevis (1st volar interosseus)
Opponens pollicis
Flexor brevis and abductor pollicis
Abductor pollicis and 1st volar interosseus
Flexor pollicis longus
Flexor digitorum sublimis
Flexor digitorum profundus

sage of the flexor tendons and the median nerve into the palm of the hand. The proximal border of the carpus is convex and articulates with the distal end of the radius and the articular disk. The pisiform, however, takes no share in this articulation, being attached to the volar surface of the triquetral. The distal border forms an undulating articular surface for the bases of the metacarpal bones. The line of articulation between the two rows of the carpus is concavoconvex from side to side, the lateral part of the navicular being received into the concavity formed by the greater multangular, lesser multangular, and capitate, and the capitate and hamate into that formed by the navicular, lunate, and triquetral bones.

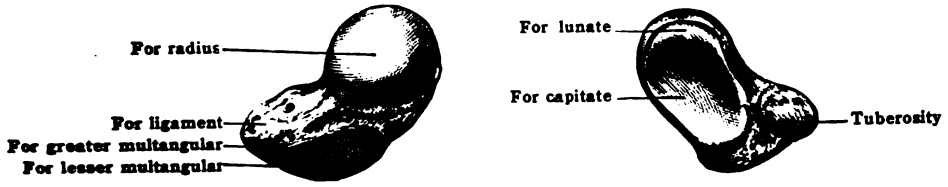
The individual carpal bones have several points of resemblance. Each bone (excepting the pisiform) has six surfaces, of which the anterior or volar and poste-

rior or dorsal are rough for the attachment of ligaments, the volar surface being the broader in the proximal row, the dorsal surface in the distal row. The superior and inferior surfaces are articular, the former being generally convex and the latter concave. The lateral surfaces, when in contact with adjacent bones, are also articular, but otherwise rough for the attachment of ligaments. Further, the whole of the carpus is cartilaginous at birth and each bone is ossified from a single center.

The Navicular

The **navicular** [os naviculare] or scaphoid (fig. 227) is the largest bone of the proximal row, and so disposed that its long axis runs obliquely downward and lateralward.

Fig. 227.—The Left Navicular.



The **superior surface** is convex and somewhat triangular in shape for articulation with the lateral facet on the distal end of the radius. The **inferior surface**, smooth and convex, is divided into two parts by a ridge running from before backward. The lateral part articulates with the greater multangular, the medial with the lesser multangular. The **volar surface**, rough and concave above, is elevated below into a prominent tubercle for the attachment of the transverse carpal ligament and the *abductor pollicis brevis*. The **dorsal surface** is narrow, being reduced to a groove running the whole length of the bone; it is rough and serves for the attachment of the dorsal radiocarpal ligament. The **medial surface** is occupied by two articular facets, of which the upper is crescentic in shape for the lunate bone, whilst the lower is deeply concave for the reception of the head of the capitate. The **lateral surface** is narrow and rough for the attachment of the radial collateral ligament of the wrist-joint.

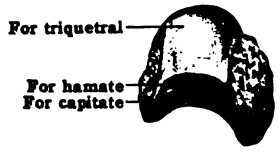
Articulations.—With the radius above, greater and lesser multangular below, lunate and capitate medially.

The Lunate

The **lunate** [os lunatum] or semilunar (fig. 228), placed in the middle of the proximal row of the carpus, is markedly crescentic in outline.

The **superior surface** is smooth and convex and articulates with the medial of the two facets on the distal end of the radius. The **inferior surface** presents a deep concavity divided into two parts by a line running from before backward. Of these, the lateral and larger articulates with the capitate; the medial and smaller with the hamate. The **volar surface** is large and convex,

Fig. 228.—The Left Lunate.



the **dorsal surface** narrow and flat, and both are rough for the attachment of ligaments. The **medial surface** is marked by a smooth quadrilateral facet for the base of the triquetral. The **lateral surface** forms a narrow crescentic articular surface for the lunate.

Articulations.—With the radius above, capitate and hamate below, navicular laterally and triquetral medially.

The Triquetral

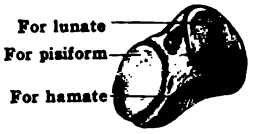
The **triquetral** [os triquetrum] or cuneiform (fig. 229) is pyramidal in shape and placed obliquely, so that its base looks upward and laterally and the apex downward and medially.

The **superior surface** presents laterally near the base a small, convex articular facet which plays upon the articular disk interposed between it and the distal end of the ulna, and medially a rough non-articular portion for ligaments. The **inferior surface** forms a large, triangular undulating facet for articulation with the hamate. The **volar surface** can be readily recognized by the conspicuous oval facet near the apex for the pisiform bone. The **dorsal surface** is rough for the attachment of ligaments. The **medial** and **lateral surfaces** are represented by the base

and the apex of the pyramid. The base is marked by a flat quadrilateral facet for the lunate. The apex forms the lowest part of the bone and is roughened for the attachment of the ulnar collateral ligament of the wrist.

Articulations.—With the pisiform in front, lunate laterally, hamate below, articular disk above.

FIG. 229.—THE LEFT TRIQUETRAL.



THE PISIFORM

The **pisiform** [os pisiforme] (fig. 230), the smallest of the carpal bones, is in many of its characters a complete contrast to the rest of the series. It deviates from the general type in its shape, size, position, use, and development. Forming a rounded bony nodule with the long axis directed vertically, it is situated on a plane in front of the other bones of the carpus.

On the **dorsal surface** is a single articular facet for the triquetral which reaches to the upper end of the bone, but leaves a free non-articular portion below. The **volar surface, rough** and rounded, gives attachment to the transverse carpal ligament, the *flexor carpi ulnaris*, the *ab-*

FIG. 230.—THE LEFT PISIFORM.

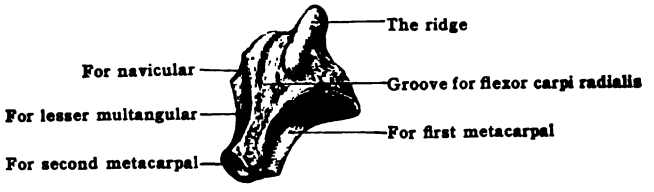
ductor digiti quinti, the pisometacarpal and the pisohamate ligaments. The **medial and lateral** surfaces are also rough and the lateral presents a shallow groove for the ulnar artery. It is usually considered that the pisiform is a sesamoid bone developed in the tendon of the *flexor carpi ulnaris*, though by some writers it is regarded as part of a rudimentary digit.

THE GREATER MULTANGULAR

The **greater multangular** [os multangulum majus] or **trapezium (fig. 231)**, situated between the navicular and first metacarpal, is oblong in form with the lower angle prolonged downward and medially.

The superior surface is concave and directed upward and medially for articulation with the lateral of the two facets on the distal surface of the navicular, and on the **inferior surface is a** saddle-shaped facet for the base of the first metacarpal. The **volar surface presents a prominent** ridge with a deep groove on its medial side which transmits the tendon of the *flexor carpi radialis*.

FIG. 231.—THE LEFT GREATER MULTANGULAR.



The **ridge** gives attachment to the transverse carpal ligament, the *abductor pollicis brevis*, the *opponens pollicis*, and occasionally a tendinous slip of insertion of the *abductor pollicis longus*. The **dorsal** and **lateral surfaces** are rough for ligaments. The **medial surface is** divided into two parts by a horizontal ridge. The upper and larger portion is concave and articulates with the lesser multangular; the lower—a small flat facet on the projecting lower **angle—articulates** with the base of the second metacarpal.

Articulations.—With the navicular above, first metacarpal below, the **lesser multangular** and second metacarpal on the medial side.

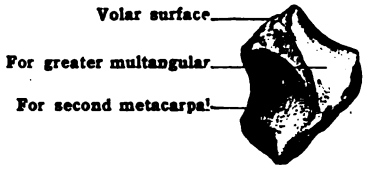
THE LESSER MULTANGULAR

The **lesser multangular** [os multangulum minus] or trapezoid **(fig. 232)**, the smallest of the bones in the distal row, is somewhat wedge-shaped, with the broader end dorsally and the narrow end ventrally.

The superior surface is marked by a small, quadrilateral, concave facet, for the medial f the two facets on the lower surface of the navicular. The **inferior suiface** is convex from side o side and concave from before backward, forming a saddle-shaped articular surface for the ase of the second metacarpal. Of the **volar** and **dorsal surfaces,** the former is narrow and ough, the latter broad and rounded, constituting the widest surface of the bone, and both are ough for the attachment of ligaments. The **lateral surface** slopes downward and medially and convex for articulation with the corresponding surface of the greater multangular. On the **iedial surface** in front is a smooth flat facet for the capitate; elsewhere it is rough for ligaments.

Articulations.—With the navicular above, second metacarpal below, greater multangular terally, and the capitate medially.

FIG. 232.—THE LEFT LESSER MULTANGULAR.

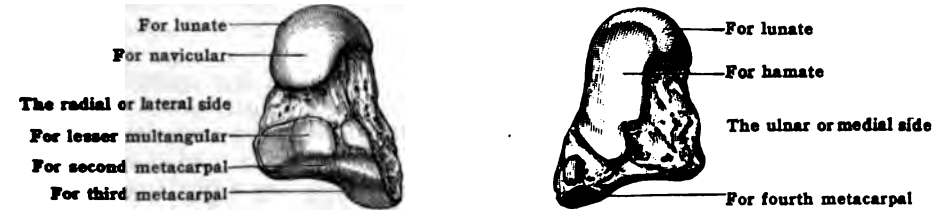


THE CAPITATE

The **capitate** [os capitatum] or os magnum (fig. 233) is the largest bone of the arpus. Situated in the center of the wrist, the upper expanded portion, globular n shape and known as the **head,** is received into the concavity formed above by he navicular and lunate. The cubical portion below forms the **body,** whilst the ntermediate constricted part is distinguished as the **neck.**

Of the six surfaces, the **superior** is smooth and convex, elongated from before backward or articulation with the concavity of the lunate bone. The **inferior surface** is divided into hree unequal parts by two ridges. The middle portion, much the larger, articulates with the ase of the third metacarpal; the lateral, narrow and concave, looks laterally as well as downward o articulate with the second metacarpal, whilst the medial portion is a small facet, placed on the

FIG. 233.—THE LEFT CAPITATE.



projecting angle of the bone dorsally, for the fourth metacarpal bone. The **volar surface** is convex and rough, giving origin to fibers of the oblique *abductor pollicis;* the **dorsal surface** is broad and deeply concave. The **lateral surface** presents, from above downward:—(1) a smooth convex surface, forming the outer aspect of the head, with the superior surface of which it is continuous, for articulation with the navicular; (2) a groove representing the neck, indented or ligaments; (3) a small facet, flat and smooth, for articulation with the lesser multangular. Behind this facet is a rough area for attachment of an interosseous ligament. The **medial surface** has extending along its whole hinder margin an oblong articular surface for the hamate; he lower part of this smooth area sometimes forms a detached facet. The volar part of the urface is rough for an interosseous ligament.

Articulations.—With the lunate and navicular above, second, third, and fourth meta-carpals below, lesser multangular laterally, and hamate medially.

THE HAMATE

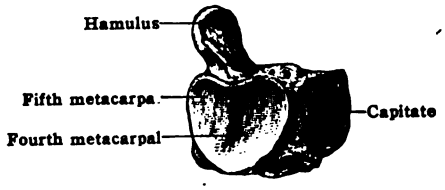
The **hamate** [os hamatum] or unciform (fig. 234) is a large wedge-shaped bone, bearing a hook-like process, situated between the capitate and triquetral, with the base directed downward and resting on the two medial metacarpals.

The apex of the wedge forms the narrow **superior surface,** directed upward and laterally or articulation with the lunate. The **inferior surface** or base is divided by a ridge into two quadrilateral facets for the fourth and fifth metacarpal bones. The **volar surface** is triangular n outline and presents at its lower part a prominent **hamulus** (unciform process), a hook-like minence, projecting forward and curved toward the carpal canal. It is flattened from side o side so as to present two surfaces, two borders, and a free extremity. To the latter the trans-verse carpal ligament and the *flexor carpi ulnaris* (by means of the pisohamate ligament) are ttached, whilst the medial surface affords origin to the *flexor brevis* and the *opponens digiti minimi.* The **lateral surface** is concave and in relation to the flexor tendons. The **dorsal surface**

is triangular and rough for ligaments. The **lateral surface** has extending along its upper and hinder edges a long flat surface, wider above than below, for articulation with the capitate. In front of this articular facet the surface is rough for the attachment of an interosseous ligament. The **medial surface** is oblong and undulating, *i. e.*, concavoconvex from base to apex, for articulation with the triquetral.

Articulations.—With the triquetral, lunate, capitate, and the fourth and fifth metacarpal bones.

FIG. 234.—THE LEFT HAMATE.



OSSIFICATION OF THE CARPAL BONES

Capitate	first year	Greater multangular	fifth year
Hamate	second year	Navicular	sixth year
Triquetral	third year	Lesser multangular	eighth year
Lunate	fourth year	Pisiform	twelfth year

According to the investigations of Pryor the centers of ossification of the carpal bones appear earlier in the female than in the male.

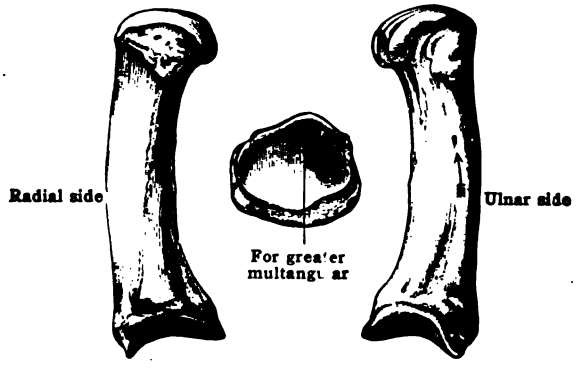
Variations.—Additional carpal elements are occasionally met with. The **os centrale** occurs normally in the carpus of many mammals, and in the human fœtus of two months it is present as a small cartilaginous nodule which soon becomes fused with the cartilage of the navicular. Failure of fusion, with subsequent ossification of the nodule, leads to the formation of an os centrale in the human carpus which is then found on the dorsal aspect, between the navicular, capitate and lesser multangular. In most individuals, however, it coalesces with the navicular or undergoes suppression.

An additional center of ossification, leading to the formation of an accessory carpal element, occasionally appears in connection with the greater multangular and the hamate. An accessory element (*os Vesalianum*) also occurs occasionally in the angle between the hamate and the fifth metacarpal, and others occur between the second and third metacarpals and the lesser multangular and capitate.

THE METACARPALS

The **metacarpus** (figs. 225, 226) consists of a series of five cylindrical bones [ossa metacarpalia], well described as 'long bones in miniature.' Articulated with the carpus above, they descend, slightly diverging from each other, to support the fingers, and are numbered from the lateral to the medial side. With the exception of the first, which in some respects resembles a phalanx, they conform to a general type.

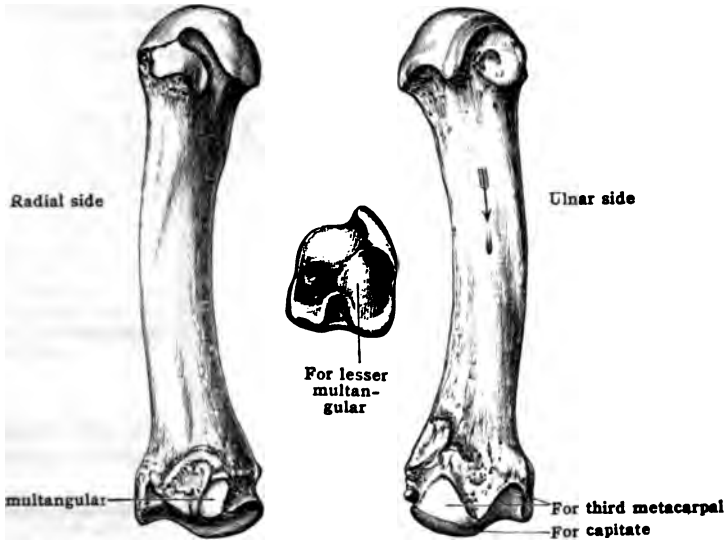
FIG. 235.—THE FIRST (LEFT) METACARPAL.



A typical metacarpal bone presents a shaft and two extremities. **The body or shaft** is prismatic and curved so as to be slightly convex toward the back of the hand. Of the three surfaces, two are **lateral** in position, separated in the middle part of the shaft by a prominent palmar ridge, and concave for the attachment of *interosseous* muscles. The third or **dorsal surface** presents a large, smooth, triangular area with the base below and apex above, covered in the recent state by the extensor tendons of the fingers, and two sloping areas, near the carpal ex-

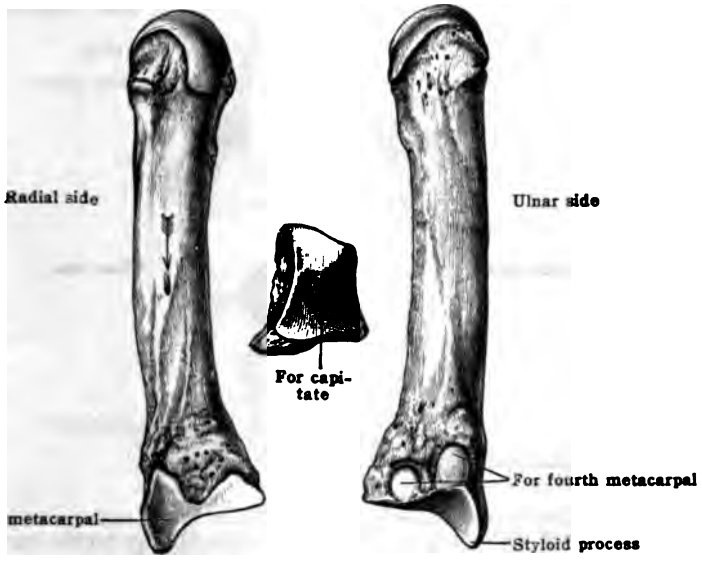
tremity, also for *interosseous* muscles. The triangular area is bounded by two lines, which commence below in two dorsal tubercles, and, passing upward, converge to form a median ridge situated between the sloping areas on either side. A little above or below the middle of the shaft, and near the volar border, is the medullary foramen, entering the bone obliquely upward. The **base** or carpal extremity, broader behind than in front, is quadrilateral, and both palmar and

FIG. 236.—THE SECOND (LEFT) METACARPAL.



dorsal surfaces are rough for ligaments; it articulates above with the carpus and on each side with the adjacent metacarpal bones. The **head** [capitulum] or digital extremity presents a large rounded articular surface, extending further on the palmar than on the dorsal aspect, for articulation with the base of the first phalanx. The volar surface is grooved for the flexor tendons and raised on each

FIG. 237.—THE THIRD (LEFT) METACARPAL.

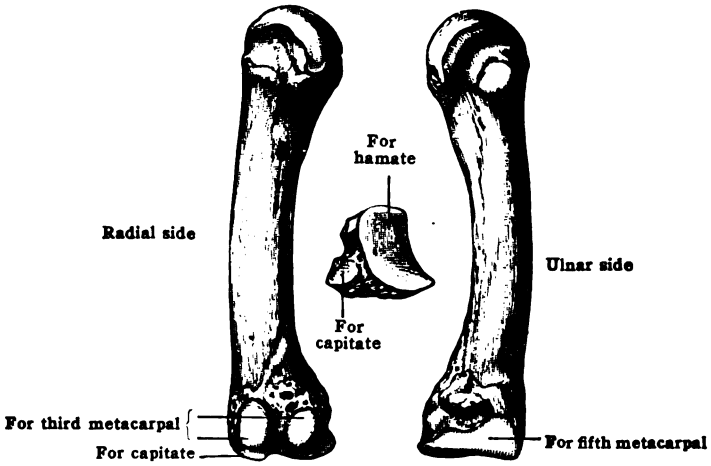


side into an articular eminence. On each side of the head is a prominent tubercle, and immediately in front of this a well-marked fossa, to both of which the collateral ligament of the metacarpophalangeal joint is attached.

The second is the longest of all the metacarpal bones, and the third, fourth, and fifth successively decrease in length. The several metacarpals possess distinctive characters by which they are readily identified.

The **first metacarpal** (fig. 235) is the shortest and widest of the series. Diverging from the carpus more widely than any of the others the **palmar surface** is directed medially and marked by a ridge placed nearer to the medial border. The lateral portion of the surface slopes gently to the lateral border and gives attachment to the *opponens pollicis;* the medial portion, the smaller of the two, slopes more abruptly to the medial border, is in relation to the deep head of the *flexor pollicis brevis,* and presents the nutrient foramen, directed downward toward the head of the bone and transmitting a branch of the arteria princeps pollicis. The **dorsal surface,** wide and flattened, is in relation to the tendons of the *extensor pollicis longus* and *brevis.* The **base** presents a saddle-shaped articular surface for the greater multangular, prolonged in front into a thin process. There are no lateral facets, but laterally a small tubercle receives the insertion of the *abductor pollicis longus.* Medially is a rough area from which fibers of the

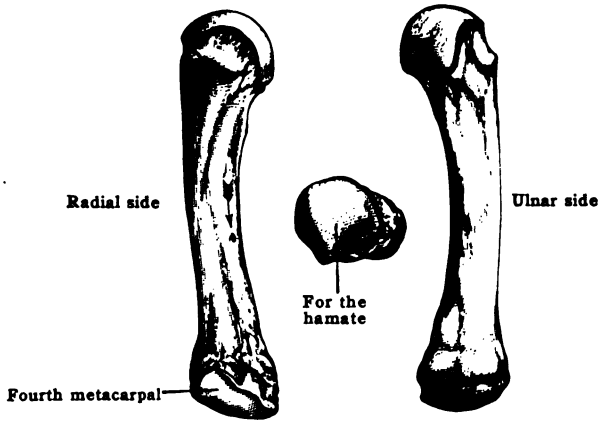
FIG. 238.—THE FOURTH (LEFT) METACARPAL.



inner head of the *flexor pollicis brevis* take origin. The margin of the articular surface gives attachment to the articular capsule of the carpo-metacarpal joint. The inferior extremity or **head** is rounded and articular, for the base of the first phalanx; the greatest diameter is from side to side and the surface is less convex than the corresponding surface of the other metacarpal bones. On the volar surface it presents two articular eminences corresponding to the two sesamoid bones of the thumb. Of the two margins, the medial gives origin to the lateral head of the *first dorsal interosseous,* the lateral receives fibers of insertion of the *opponens pollicis.*

The second metacarpal (fig. 236)—The distinctive features of the four remaining metacarpals are almost exclusively confined to the carpal extremities. The second is easily recognized by its deeply cleft base. The terminal surface presents three articular facets, arranged

FIG. 239.—THE FIFTH (LEFT) METACARPAL.



as follows, from lateral to medial border:—(1) a small oval facet for the greater **multangular;** (2) a hollow for the lesser multangular; and (3) an elongated ridge for the capitate. The dorsal surface is rough for the insertions of the *extensor carpi radialis longus* and a part of the *extensor carpi radialis brevis;* the palmar surface receives the insertion of the *flexor carpi radialis* and gives origin to a few fibers of the *oblique adductor pollicis.* The lateral aspect of the extremity is rough and non-articular; the medial surface bears a bilobed facet for the third metacarpal. The shaft of the second metacarpal gives attachment to three *interosseous* muscles, and the nutrient foramen, directed upward on the ulnar side, transmits a branch of the second volar metacarpal artery.

The **third metacarpal** (fig. 237) is distinguished by the prominent **styloid process projecting**

upward from the dorsolateral angle of the base. Immediately below it, on the dorsal surface, is a rough impression for the *extensor carpi radialis brevis*. The carpal surface is concave behind and convex in front, and articulates with the middle of the three facets on the inferior surface of the capitate. On the lateral side is a bilobed articular facet for the second metacarpal, and on the medial side two small oval facets for the fourth metacarpal. The volar aspect of the base is rough and gives attachment to fibers of the *oblique adductor pollicis* and sometimes a slip of insertion of the *flexor carpi radialis*. The shaft of the third metacarpal serves for the origin of the transverse *adductor pollicis* and two *interosseous* muscles. The nutrient foramen is directed upward on the radial side and transmits a branch of the second volar metacarpal artery.

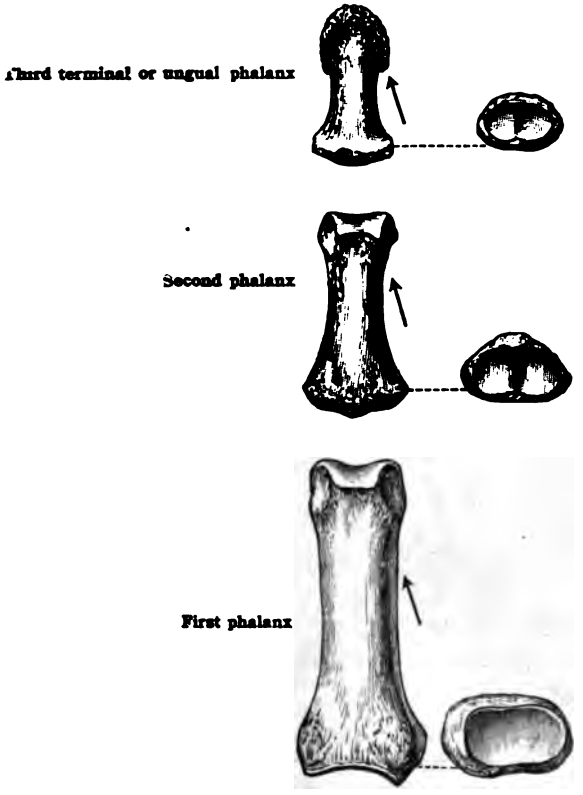
The fourth metacarpal (fig. 238) has a small base. The carpal surface presents two facets; a medial, large and flat, for articulation with the hamate, and a small facet, at the lateral and posterior angle, for the capitate. On the lateral side are two small oval facets for the corresponding surfaces on the third metacarpal and a single concave facet on the medial side for the fifth metacarpal. The shaft of the fourth metacarpal gives attachment to three *interosseous* muscles, and the nutrient foramen, directed upward on the radial side, transmits a branch of the third volar metacarpal artery.

The **fifth metacarpal** (fig. 239) is distinguished by a semilunar facet on the lateral side of the base for the fourth metacarpal, and a rounded tubercle on the medial side for the *extensor carpi ulnaris*, in place of the usual medial facet. The carpal surface is saddle-shaped for the hamate; the palmar surface is rough for ligaments including the pisometacarpal prolongation from the *flexor carpi ulnaris*. The dorsal surface of the shaft presents an *oblique line* separating a lateral concave portion for the fourth dorsal *interosseous* muscle from a smooth medial portion covered by the extensor tendons of the little finger. The palmar surface gives attachment laterally to the third palmar *interosseous* muscle and medially to the *opponens digiti quinti*. The nutrient foramen is directed upward on the radial side and transmits a branch of the fourth volar metacarpal artery.

THE PHALANGES

The **phalanges** (fig. 240) are the bones of the fingers, and number in all fourteen. Each finger contains three phalanges distinguished as first or proximal,

FIG. 240.—THE PHALANGES OF THE THIRD DIGIT OF THE HAND. (Dorsal view.)
(The arrows indicate the direction of the nutrient canals.)



second or middle, and third or distal. In the thumb, the second phalanx is wanting. Arranged in horizontal rows, the phalanges of each row resemble one another and differ from those of the other two rows. In all the phalanges the nutrient canal is directed downward, toward the distal extremity.

First phalanx.—The shaft of a phalanx from the first row is flat on the palmar surface, smooth and rounded on the dorsal surface, *i. e.*, semi-cylindrical in shape. The borders of the palmar surface are rough for the attachment of the sheaths of the flexor tendons. The base or metacarpal extremity presents a single concave articular surface, oval in shape, for the

FIG. 241.—SKELETON OF THE RIGHT HAND OF A BOY AGED 16 YEARS. (From an *X*-ray plate by Dr. Sherwood Moore, Washington University.)

convex head of the metacarpal bone. The distal extremity forms a pulley-like surface, grooved in the center and elevated at each side to form two miniature condyles, for articulation with the base of a second phalanx.

Second phalanx.—The second phalanges are four in number and are shorter than those of the first row, which they closely resemble in form. They are distinguished, however, by the articular surface on the proximal extremity, which presents two shallow depressions, separated

by a ridge and corresponding to the two condyles of the first phalanx. The distal end for the base of the third phalanx is trochlear or pulley-like, but smaller than that of the first phalanx. The palmar surface of the shaft presents on each side an impression for the tendon of the *flexor digitorum sublimis*, and the dorsal aspect of the base is marked by a projection for the insertion of the *extensor digitorum communis*.

Third phalanx.—A third phalanx is readily recognized by its small size. The proximal end is identical in shape with that of a second phalanx, and bears a depression in front for the tendon of the *flexor digitorum profundus*. The free, flattened and expanded distal extremity presents on its palmar surface a rough semilunar elevation for the support of the pulp of the finger. The somewhat horseshoe-shaped free extremity is known as the **ungual tuberosity** [tuberositas unguicularis], and the bone is accordingly referred to as the **ungual phalanx.**

Ossification of the Metacarpus and Phalanges

Each of the metacarpal bones and phalanges is ossified from a primary center for the greater part of the bone, and from one epiphysial center. The primary nucleus appears from the eighth to the tenth week of intrauterine life. In four metacarpal bones the epiphysis is distal, while in the first metacarpal bone, and in all the phalanges, it is proximal. The epiphysial nuclei appear from the third to the fifth year and are united to their respective shafts about the twentieth year. In many cases the first metacarpal has two epiphyses, one for the base in the third year and an additional one for the head in the seventh year, but the latter is never so large as in the other metacarpal bones. The third metacarpal occasionally has an additional nucleus for the prominent styloid process which may remain distinct and form a *styloid bone*, and traces of a proximal epiphysis have been observed in the second metacarpal bone. In many of the Cetacea (whales, dolphins, and porpoises) and in the seal, epiphyses are found at both ends of the metacarpal bones and phalanges (Flower).

The ossification of a terminal phalanx is peculiar. Like the other phalanges, it has a primary nucleus and a secondary nucleus for an epiphysis. But whereas in other phalanges the primary center appears in the middle of the shaft, in the case of the distal phalanges the earthy matter is deposited in the free extremity of the cartilaginous bar, the epiphysis ossifying in membrane.

Sesamoid bones.—The sesamoid bones are small and rounded and occur imbedded in certain tendons where they exert a considerable amount of pressure on subjacent bony structures. In the hand five sesamoid bones are of almost constant occurrence, namely, two over the metacarpophalangeal joint of the thumb in the tendons of the flexor pollicis brevis (fig. 241), one over the interphalangeal joint of the thumb, and one over the metacarpophalangeal joints of the second and fifth fingers. Occasionally sesamoids occur over the metacarpophalangeal joint of the third and fourth digits, and an additional one may occur over that of the fifth.

B. THE BONES OF THE LOWER EXTREMITY

The bones of the lower extremity may be arranged in four groups corresponding to the division of the limb into the *hip*, *thigh*, *leg*, and *foot*. In the *hip* is the coxal or hip-bone, which constitutes the pelvic girdle [cingulum extremitatis inferioris], and contributes to the formation of the pelvis; in the *thigh* is the femur; in the *leg*, the tibia and fibula, and in the *foot* the tarsus, metatarsus, and phalanges. Associated with the lower end of the femur is a large sesamoid bone, the patella or knee-cap.

THE COXAL BONE

The **coxal** (**innominate**) **bone** or hip-bone [os coxæ] (figs. 242, 243) is a large, irregularly shaped bone articulated behind with the sacrum, and in front with its fellow of the opposite side, the two bones forming the anterior and side walls of the pelvis. The coxal bone consists of three parts, named **ilium, ischium,** and **pubis,** which, though separate in early life (figs. 246, 247), are firmly united in the adult. The three parts meet together and form the **acetabulum** (or cotyloid fossa), a large, cup-like socket situated near the middle of the lateral surface of the bone for articulation with the head of the femur.

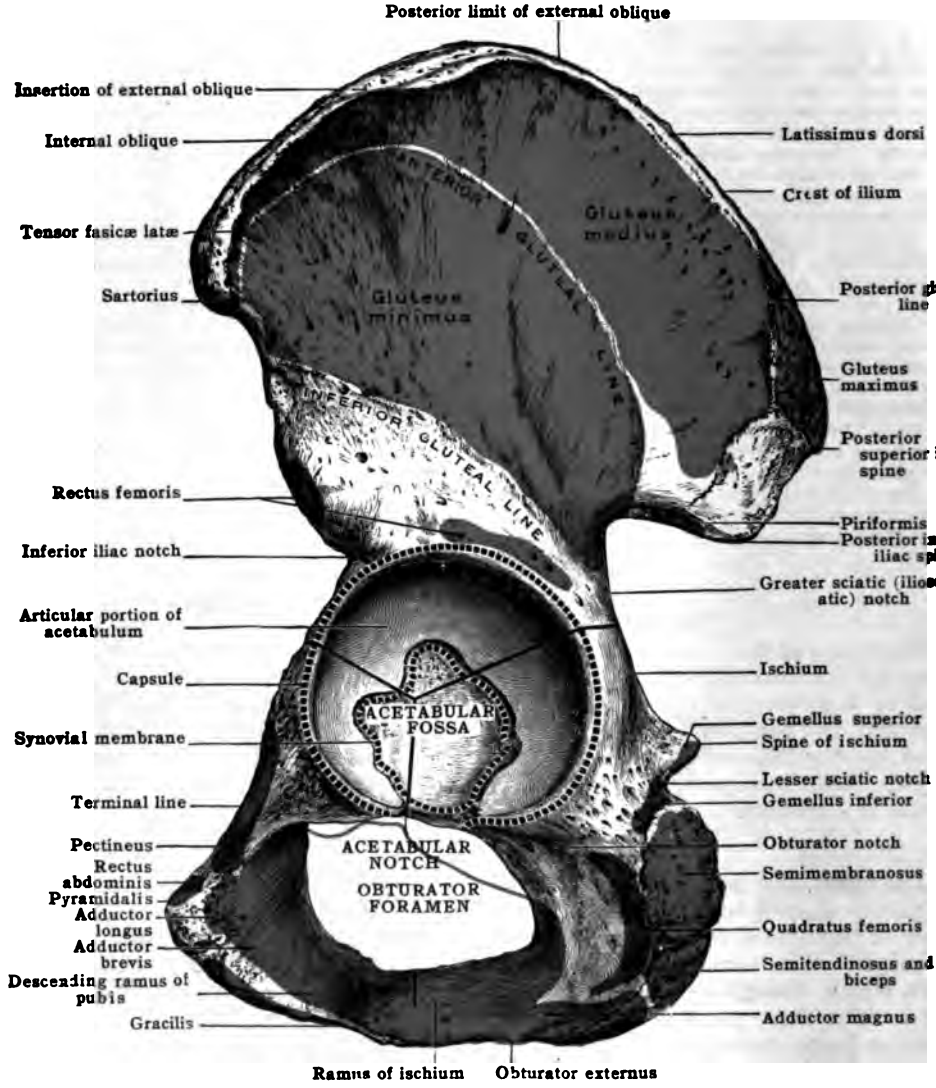
The **ilium** [os ilium] is the upper expanded portion of the bone, and by its inferior extremity forms the upper two-fifths of the acetabulum. It presents three borders and two surfaces.

Borders.—When viewed from above, the thick **crest** [crista iliaca] or superior border of the ilium is curved somewhat like the letter *f*, being concave medially in front and concave laterally behind. Its anterior extremity forms the **anterior superior iliac spine,** which gives attachment to the inguinal (Poupart's) ligament and the *sartorius;* the posterior extremity forms the **posterior superior iliac spine** and affords attachment to the sacrotuberous (great sacrosciatic) ligament, the posterior sacroiliac ligament, and the *multifidus*. The crest is narrow in the middle, thick at its extremities, and may be divided into an inner lip, an outer lip,

and an intermediate line. About 6 cm. (2½ in.) from the anterior superior spine is a prominent tubercle on its external lip.

The external lip of the crest gives attachment in front to the *tensor faciæ latæ;* along its whole length, to the *fascia lata;* along its anterior half to the *external oblique;* and behind this, for about an inch, to the *latissimus dorsi.* The anterior two-thirds of the intermediate line gives origin to the *internal oblique.* The internal lip gives origin, by its anterior two-thirds, to the *transversus;* behind this is a small area for the *quadratus lumborum,* and the remainder is occupied by the *sacrospinalis* (*erector spinæ*). The internal lip, in the anterior two-thirds, also serves for the attachment of the iliac fascia.

FIG. 242.—THE LEFT COXAL OR HIP-BONE. (Lateral view.)



The **anterior border** of the ilium extends from the **anterior superior iliac spine** to the margin of the acetabulum. Below the spine is a prominent notch from which fibers of the *sartorius* arise, and this is succeeded by the **anterior inferior iliac spine,** smaller and less prominent than the superior, to which the straight head of the *rectus* and the iliofemoral ligament are attached. On the medial side of the anterior inferior spine is a broad, shallow groove for the ***iliopsoas*** as it passes from the abdomen into the thigh, limited below by the **iliopectineal** eminence, which indicates the point of union of the ilium and pubis.

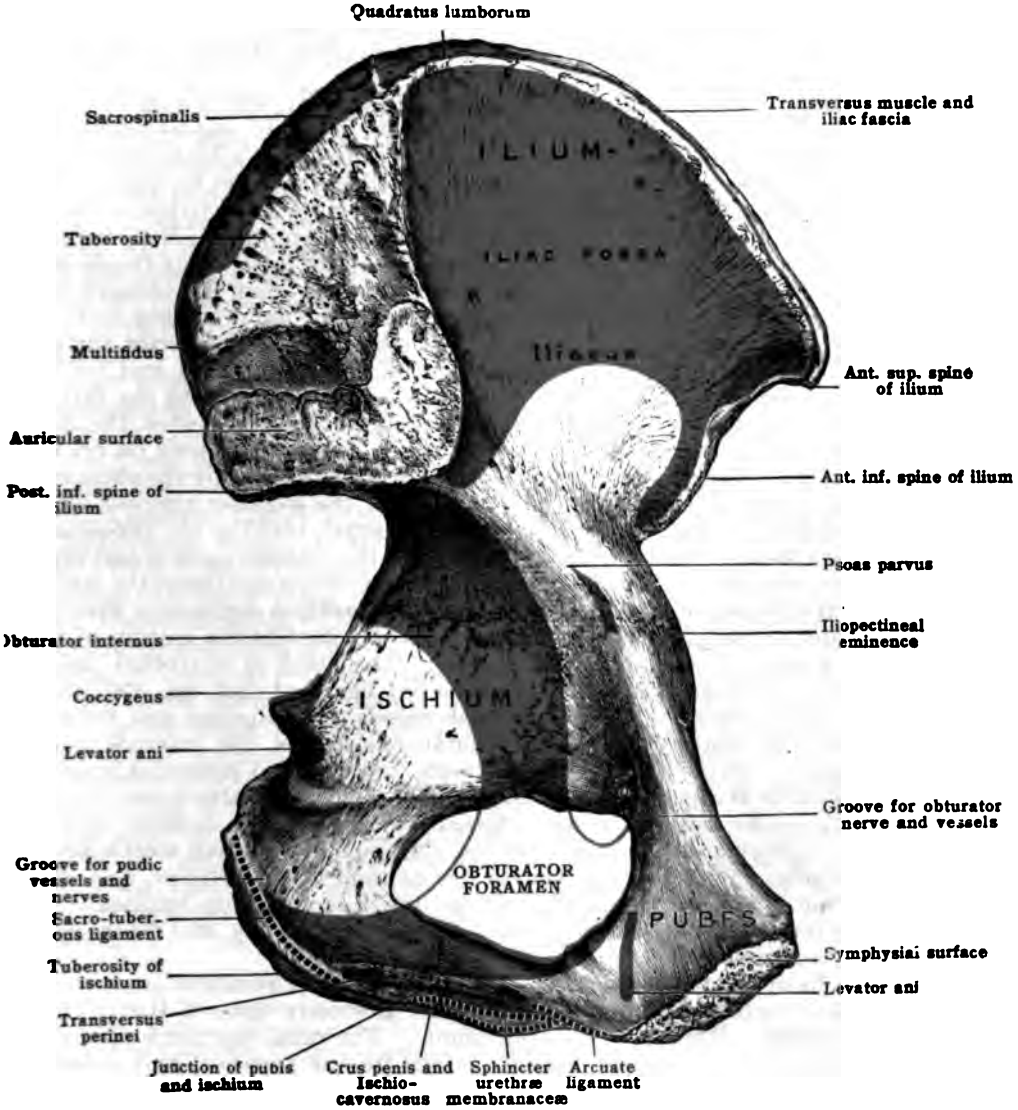
The **posterior border** of the ilium presents the **posterior superior iliac spine** and below this, a shallow notch terminating in the **posterior inferior iliac spin**

which corresponds to the posterior extremity of the auricular surface and gives attachment to a portion of the sacrotuberous (great sacrosciatic) ligament. Below the spine the posterior border of the ilium forms the upper limit of the greater sciatic notch.

Surfaces.—The **external surface** or **dorsum** is concave behind, convex in front, limited above by the thick superior border or **crest,** and traversed by threeg luteal lines.

The **posterior gluteal line** commences at the crest about two inches from the posterior superior iliac spine and curves downward to the upper margin of the **greater sciatic notch.**

FIG. 243.—THE LEFT COXAL OR HIP-BONE. (Medial aspect.)



The space included between this ridge and the crest affords origin at its upper part to the *gluteus maximus*, and at its lower part, to a few fibers of the *piriformis*, while the intermediate portion is smooth and free from muscular attachment. The **anterior gluteal line** begins at the crest, one inch behind its anterior superior iliac spine, and curves across the dorsum to terminate near the lower end of the superior line, at the upper margin of the greater sciatic notch. The surface of bone between this line and the crest gives origin to the *gluteus medius*. The **inferior gluteal line** commences at the notch immediately below the anterior superior iliac spine and terminates posteriorly at the front part of the greater sciatic notch. The space between the anterior and inferior gluteal lines, with the exception of a small area adjacent to the anterior end of the spine for the *tensor fasciæ latæ*, gives origin to the *gluteus minimus*. Between the inferior gluteal line and the margin of the acetabulum the surface affords attach-

ment to the capsule of the hip-joint, and on a rough area (sometimes a depression) toward its anterior part, to the *reflected tendon of the rectus femoris.*

The **internal surface** presents in front a smooth concave portion termed the **iliac fossa,** which lodges the *iliacus* muscle. The fossa is limited below by the linea arcuata, the iliac portion of the terminal (iliopectineal) line. This is a rounded border separating the fossa from a portion of the internal surface below the line, which gives attachment to the *obturator internus* and enters into the formation of the minor (true) pelvis. Behind the iliac fossa the bone is uneven and presents an **auricular surface,** covered with cartilage in the recent state, for articulation with the lateral aspect of the upper portion of the sacrum; above the auricular surface are some depressions for the posterior sacroiliac ligaments and a rough area reaching as high as the crest, from which parts of the *sacrospinalis* (*erector spinæ*) and *multifidus* take origin. The rough surface above the auricular facet is known as the **tuberosity of the ilium.**

The **ischium** [os ischii] consists of a body, a tuberosity, and a ramus. The **body,** which has somewhat the form of a triangular pyramid, enters superiorly into the formation of the acetabulum, to which it contributes a little more than two-fifths, and forms the chief part of the non-articular portion or floor. The **inner surface** forms part of the minor (true) pelvis and gives origin to the *obturator internus.* It is continuous with the ilium a little below the terminal (iliopectineal) line, and with the pubis in front, the line of junction with the latter being frequently indicated in the adult bone by a rough line extending from the iliopectineal eminence to the margin of the obturator foramen. The **outer surface** includes the portion of the acetabulum formed by the ischium. The **posterior surface** is broad and bounded laterally by the margin of the acetabulum and behind by the posterior border. The capsule of the hip-joint is attached to the lateral part and the *piriformis,* the great sciatic and posterior cutaneous nerves, the inferior gluteal (sciatic) artery, and the nerve to the *quadratus femoris* lie on the surface as they leave the pelvis. Inferiorly this surface is limited by the **obturator groove,** which receives the posterior fleshy border of the *obturator externus* when the thigh is flexed. Of the three borders, the **external,** forming the prominent rim of the acetabulum, separates the posterior from the external surface and gives attachment to the glenoid lip. The **inner border** is sharp and forms the lateral boundary of the obturator foramen. The **posterior border** is continuous with the posterior border of the ilium, with which it joins to complete the margin of the **great sciatic notch** [incisura ischiadica major]. The notch is converted into a foramen by the sacrospinous (small sacrosciatic) ligament (see fig. 306), and transmits the *piriformis* muscle, the gluteal vessels, the superior and inferior gluteal nerves, the sciatic and posterior cutaneous nerves, the internal pudic vessels and nerve, and the nerves to the *obturator internus* and *quadratus femoris.* Below the notch is the prominent **ischial spine,** which gives attachment internally to the *coccygeus* and *levator ani,* externally to the *gemellus superior,* and at the tip to the sacrospinous ligament. Below the spine is the **small sciatic notch** [incisura ischiadica minor], covered in the recent state with cartilage, and converted into a foramen by the sacrotuberous (great sacrosciatic) ligament. It transmits the tendon of the *obturator internus,* its nerve of supply, and the internal pudic vessels and nerve.

The **rami** form the flattened part of the ischium which runs first downward, then upward, forward and medially from the tuberosity toward the inferior ramus of the pubis, with which it is continuous. The **rami** together form an L-shaped structure with an upper vertical ramus [ramus superior] and a lower horizontal ramus [ramus inferior]. The outer surface of the rami gives origin to the *adductor magnus* and *obturator externus;* the inner surface, forming part of the anterior wall of the pelvis, receives the crus penis (or clitoridis) and the *ischiocavernosus,* and gives origin to a part of the *obturator internus.* Of the two borders, the upper is thin and sharp, and forms part of the boundary of the obturator foramen; the lower is rough and corresponds to the inferior ramus. It is somewhat everted and gives attachment to the fascia of Colles, and the *transversus perinei.* To a ridge immediately above the impression for the crus penis (or clitoridis) and the *ischiocavernosus,* the urogenital diaphragm is attached. The posterior and inferior aspect of the superior ramus is an expanded area forming the **tuberosity** [tuber ischiadicum].

The tuberosity is that portion of the ischium which supports the body in the sitting posture. It forms a rough, thick eminence continuous with the inferior border of the inferior ramus, and is marked by an oblique line separating two impressions, an upper and lateral for the *semimembranosus*, and a lower and medial for the common tendon of the *biceps* and *semitendinosus*, while the lower part is markedly uneven and gives origin to the *adductor magnus*. The upper border gives origin to the *inferior gemellus;* the inner border, sharp and prominent, receives the sacrotuberous (great sacrosciatic) ligament, while the surface of the tuberosity immediately in front is in relation with the internal pudic vessels and nerve. The outer border gives origin to the *quadratus femoris*.

The **pubis** [os pubis] consists of a **body** and two **rami**—superior and inferior. The **body** is somewhat quadrilateral in shape and presents for examination two surfaces and three borders. The **anterior surface** looks downward, forward and slightly outward, and gives origin to the *adductor longus*, the *adductor brevis*, the *obturator externus*, and the *gracilis*. The **posterior surface** is smooth, looks into the pelvis, and affords origin to the *levator ani*, the *obturator internus*, and the puboprostatic ligaments. The **upper border** or crest of the body is rough and presents laterally a prominent bony point, known as the **tubercle** [tuberculum pubicum] or spine, for the attachment of the inguinal (Poupart's) ligament. The upper border extends from the pubic tubercle medialward to the upper end of the symphysis, with which it forms the *angle* of the pubis. The upper border gives attachment to the *rectus abdominis* and *pyramidalis*. The **medial border** is oval in shape, rough, and articular, forming with the bone of the opposite side the *symphysis pubis* [facies symphyseos]. The **lateral border** is sharp and forms part of the boundary of the obturator foramen.

The **inferior ramus,** like the inferior ramus of the ischium, with which it is continuous, is thin and flattened. To its **anterior surface** are attached the *adductor brevis*, *adductor magnus*, and *obturator externus*. The **posterior surface** is smooth and gives attachment to the *crus penis* or *clitoridis*, the *sphincter urethræ* (**urogenitalis**), the *obturator internus*, and the urogenital diaphragm. The **lateral border forms part of the** circumference of the obturator foramen, and the **medial border forms part of the** pubic arch and gives attachment to the *gracilis*.

The **superior ramus** extends from the body of the pubis to the ilium, forming by its lateral extremity the anterior one-fifth of the articular surface of the acetabulum. It is prismatic in shape and increases in size as it passes laterally. Above it presents a sharp ridge, the **pecten** or pubic portion of the terminal (iliopectineal) line continuous with the iliac portion at the **iliopectineal eminence,** and affording attachment to the conjoined tendon [falx aponeurotica inguinalis], the lacunar (Gimbernat's) ligament, the reflected inguinal ligament, and the pubic portion of the fascia lata; the iliac portion of the terminal line gives attachment to the *psoas minor*, the iliac fascia, and the pelvic fascia. Immediately in front of the pubic portion of the line is the **pectineal surface;** it gives origin at its posterior part to the *pectineus*, and is limited below by the **obturator crest,** which extends from the pubic tubercle to the acetabular notch. The **inferior surface** of the superior ramus forms the upper boundary of the obturator foramen and presents a deep groove [sulcus obturatorius] for the passage of the obturator vessels and nerve. The **posterior surface** is smooth, forms part of the anterior wall of the pelvic cavity, and gives attachment to a few fibers of the *obturator internus*.

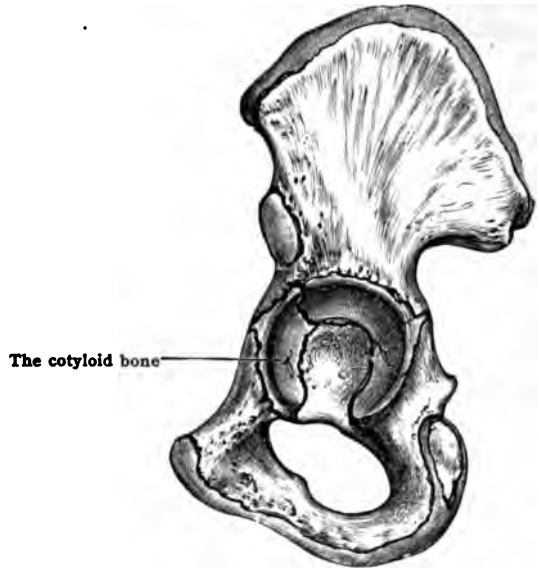
According to the BNA, the body [corpus ossis pubis] is the portion corresponding to the acetabulum. The remainder of the bone is described as consisting of the ramus superior and the ramus inferior, which meet at the symphysis. Thus the divisions according to the BNA are different from those in the description above given.

The **acetabulum** (figs. 242, 244) is a circular depression in which the head of the femur is lodged and consists of an articular and a non-articular portion. The articular portion is circumferential and semilunar in shape [facies lunata], with the deficiency in the lower segment. One-fifth of the acetabulum is formed by the pubis, two-fifths by the ischium, and the remaining two-fifths are formed by the ilium. The non-articular portion [fossa acetabuli] is formed mainly by the ischium, and is continuous below with the margin of the obturator foramen. The articular portion presents a lateral rim to which the glenoid lip is attached, and a medial margin to which the synovial membrane which excludes the ligamentum teres from the synovial cavity is connected. The opposite extremities of the articular lunate surface which limit the **acetabular notch** are united by

the transverse ligament, and through the **acetabular foramen** thus formed a nerve and vessels enter the joint.

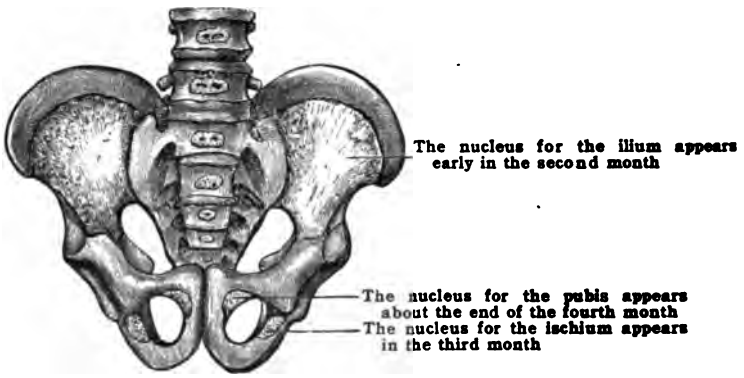
The **obturator** (thyroid) **foramen** (figs. 242, 243) is situated between the ischium and pubis. Its margins are thin, and serve for the attachment of the obturator membrane. At the upper and posterior angle it is deeply grooved for the passage of the obturator vessels and nerve.

FIG. 244.—AN IMMATURE COXAL (INNOMINATE) BONE, SHOWING A COTYLOID BONE.



Blood-supply.—The chief vascular foramina of the coxal bone are found where the bone is thickest. On the inner surface, the ilium receives twigs from the iliolumbar, deep circumflex iliac, and obturator arteries, by foramina near the crest, in the iliac fossa, and below the terminal line near the greater sciatic notch. On the outer surface the chief foramina are found below the inferior gluteal line and the nutrient vessels are derived from the gluteal arteries. The ischium receives nutrient vessels from the obturator, internal and external circumflex arteries, and the largest foramina are situated between the acetabulum and the ischial tuberosity. The pubis is supplied by twigs from the obturator, internal and external circumflex arteries, and from the pubic branches of the common femoral artery.

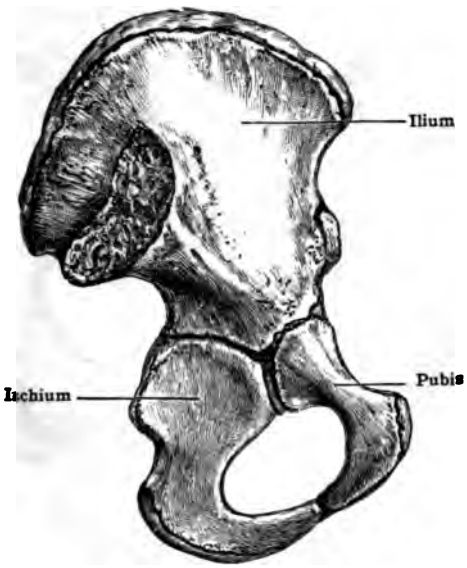
FIG. 245.—THE PELVIS OF A FETUS AT BIRTH, TO SHOW THE THREE PORTIONS OF THE COXAL BONES.


The nucleus for the ilium appears early in the second month
The nucleus for the pubis appears about the end of the fourth month
The nucleus for the ischium appears in the third month

Ossification.—The cartilaginous representative of the hip-bone consists of three distinct portions, an **iliac**, an **ischiatic**, and a **pubic** portion; the iliac and ischiatic portions first unite, and later the pubic portion, so that eventually there is found a single cartilaginous mass. In the second month a center of ossification appears above the acetabulum for the ilium. Later a second nucleus appears below the cavity for the ischium, and this is followed in the fourth month by a deposit in the pubic portion of the cartilage. At birth, the three nuclei are of considerable size, but are surrounded by relatively wide tracts of cartilage (fig. 245); ossification has, however, extended into the margin of the acetabulum. In the eighth year the

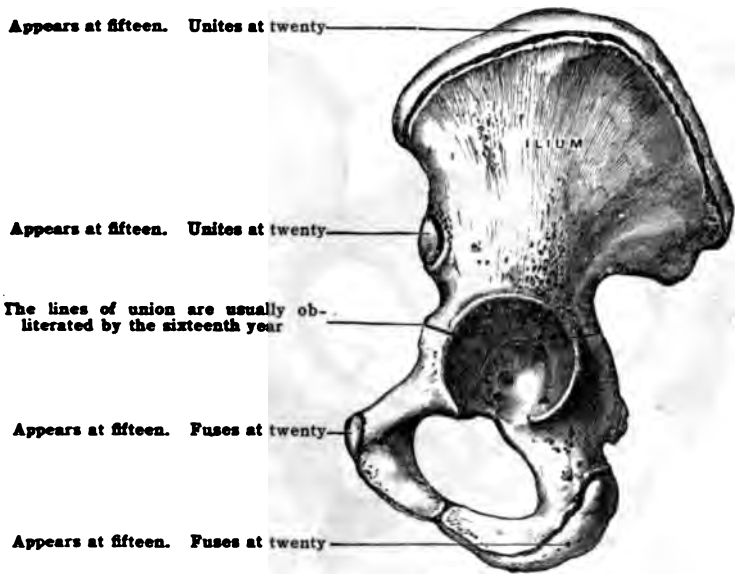
rami of the pubis and ischium become united by bone, and in the twelfth year the triradiate cartilage which separates the three segments of the bone in the acetabulum begins to ossify from several centers. Of these, one is more constant than the others and is known as the acetabular nucleus. The triangular piece of bone to which it gives rise is regarded as the representative of the *cotyloid* or acetabular bone (fig. 244), constantly present in a few mammals.

FIG. 246.—COXAL OR HIP-BONE, SHOWING SECONDARY CENTERS.



It is situated at the medial part of the acetabulum and is of such a size as to exclude entirely the pubis from the cavity. With this bone, however, it eventually fuses, and afterward becomes joined with the ilium and ischium, so that by the eighteenth or twentieth year the several parts of the acetabulum have become united. In the fifteenth year other centers appear in the cartilage of the crest of the ilium, the anterior inferior iliac spine, the tuberosity of the ischium,

FIG. 247.—COXAL OR HIP-BONE (INNER SURFACE) AT THE EIGHTEENTH YEAR.


Appears at fifteen. Unites at twenty
ILIUM
Appears at fifteen. Unites at twenty
The lines of union are usually obliterated by the sixteenth year
Appears at fifteen. Fuses at twenty
Appears at fifteen. Fuses at twenty

and the pubic pecten. The epiphyses fuse with the main bone about the twentieth year. The fibrous tissue connected with the tubercle of the pubis is believed to represent the epipubic bones of marsupials.

Variations.—The hip-bone is subject to relatively little variation. The cotyloid bone was noted above. Conversion of the obturator groove into a bony walled foramen, and defective union of the rami of the pubis and ischium are the chief variations observed.

THE PELVIC SKELETON

The skeletal **pelvis** (figs. 248, 249) is composed of four bones: the two **coxæ** or hip-bones, the sacrum, and the coccyx. The hip-bones form the lateral and anterior boundaries, meeting each other in front to form the pubic symphysis

FIG. 248.—THE MALE PELVIS. (Anterior view.)

[symphysis ossium pubis]; posteriorly they are separated by the sacrum. The interior of the pelvis is divided into the **major** and **minor** pelvic cavities.

The **major** (or false) **pelvis** is that part of the cavity which lies above the terminal (iliopectineal) lines and between the iliac fossæ. This part belongs really to the abdomen, and is in relation with the hypogastric and iliac regions.

FIG. 249.—THE FEMALE PELVIS. (Anterior view.)

The **minor** (or true) **pelvis** is situated below the terminal (iliopectineal) lines. The upper circumference, known as the **superior aperture** (inlet or brim) of the pelvis, is bounded anteriorly by the crest and pecten of the pubis on each side, posteriorly by the anterior margin of the base of the sacrum, and laterally by the terminal lines. The inlet in normal pelves is heart-shaped, being obtusely pointed in front; posteriorly it is encroached upon by the promontory of the sacrum. It

principal **diameters**; of these, the anteroposterior, called the **conjugate** [conjugata], is measured from the **sacrovertebral angle** to the symphysis. **sverse** diameter represents the greatest width of the pelvic cavity. The iameter is measured from the sacroiliac synchondrosis of one side to the eal eminence of the other.

avity of the minor (true) pelvis is bounded in front by the pubes, behind crum and coccyx, and laterally by a smooth wall of bone formed in part um and in part by the ischium. The cavity is shallow in front, where it by the pubes, and is deepest posteriorly.

ıterior aperture, or outlet, of the minor pelvis is very irregular, and en- upon by three bony processes: the posterior process is the coccyx, and lateral processes are the ischial tuberosities. They separate three The anterior notch is the **pubic arch** (or angle), and is bounded on each ıe conjoined rami of the pubes and ischium. Each of the two remaining ınded by the ischium anteriorly, the sacrum and coccyx posteriorly, and above, corresponds to the greater and lesser sciatic notches. These are l into foramina by the sacrotuberous and sacrospinous ligaments.

sition of the pelvis.—In the erect position of the skeleton the plane of the pelvic s an angle with the horizontal plane, which varies in individuals from 50° to 60°. of the sacrum in an average pelvis lies nearly ten cm. (four inches) above the upper the symphysis pubis.

is of the pelvis.—This is an imaginary curved line drawn through the minor pelvis gles to the planes of the **inlet, cavity,** and **outlet** through their central points. posterior wall, formed by sacrum and coccyx, is 12 cm. (five inches) long and con- the anterior wall at the symphysis pubis 3.5 to 5 cm. long, it follows that the axis ırved.

erage measurements of the diameters of the minor pelvis in the three planes are w:—

	Conjugate or Anteroposterior.	Oblique.	Transverse.
.....	10.6 cm. (4¼ inches)	12.5 cm. (5 inches)	13.0 cm. (5¼ inches)
.....	11.8 cm. (4¾ inches)	13.0 cm. (5¼ inches)	11.8 cm. (4¾ inches)
.....	9.0 cm. (3¾ inches)	11.2 cm. (4½ inches)	10.6 cm. (4¼ inches)

s, however, a difference between the sexes, the diameters of the male pelvis in general slightly less, and those of the female slightly greater than the figures above given.

nces according to sex.—There is a marked difference in the size and form of the emale pelvis, the pecularities of the latter being necessary to qualify it for its func- ırturition. The various points of divergence may be tabulated as follows:—

Male.	Female.
vier and rougher.	Bones more slender.
ırrower; more curved.	Sacrum broader; less curved.
rtical.	Ilia more vertical.
deeper.	Iliac fossæ shallower.
tic notch narrower.	Great sciatic notch wider.
vis relatively wider.	Major pelvis relatively narrower.
vis deeper and narrower.	Minor pelvis shallower and wider.
f minor pelvis less.	Capacity of minor pelvis greater.
perture more heart-shaped.	Superior aperture more oval.
deeper.	Symphysis shallower.
es of ischia inflexed.	Tuberosities of ischia everted.
le narrow and pointed.	Pubic arch wider and more rounded.
f ischiopubic rami more everted.	Margins of ischiopubic rami less everted.
foramen oval.	Obturator foramen triangular.

parison with the pelves of lower animals, which, speaking generally, are elongated w, the human pelvis is characterized by its breadth, shallowness, and great capacity. s are also to be recognized in the form of the pelvis in the various races of mankind, the rtant being the relation of the anteroposterior to the transverse diameter, measured t. This is expressed by the *pelvic index* $= \frac{100 \times \text{conjugate diameter}}{\text{transverse diameter}}$.

average European male the index is about 80; in the lower races of mankind, 90 to 95. h an index below 90 are *platypellic*, from 90 to 95 are *mesatipellic*, and above 95 *ic.* (Sir William Turner.)

e **development and growth** of the pelvis, see p. 32.

THE FEMUR

emur or thigh-bone (figs. 250, 251) is the largest and longest bone in the , and transmits the entire weight of the trunk from the hip to the tibia.

FIG. 250.—THE LEFT FEMUR. (Anterior view.)

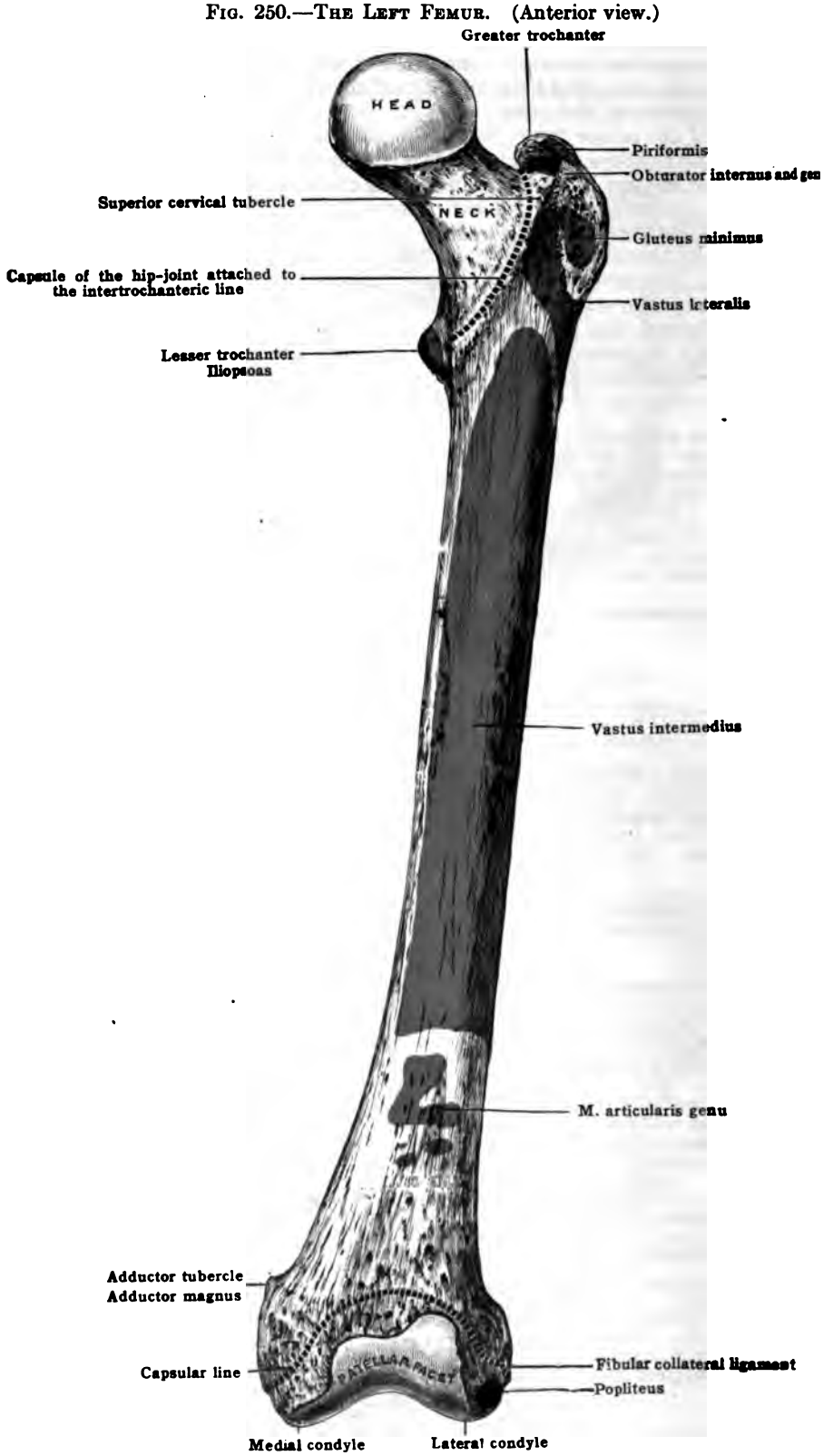
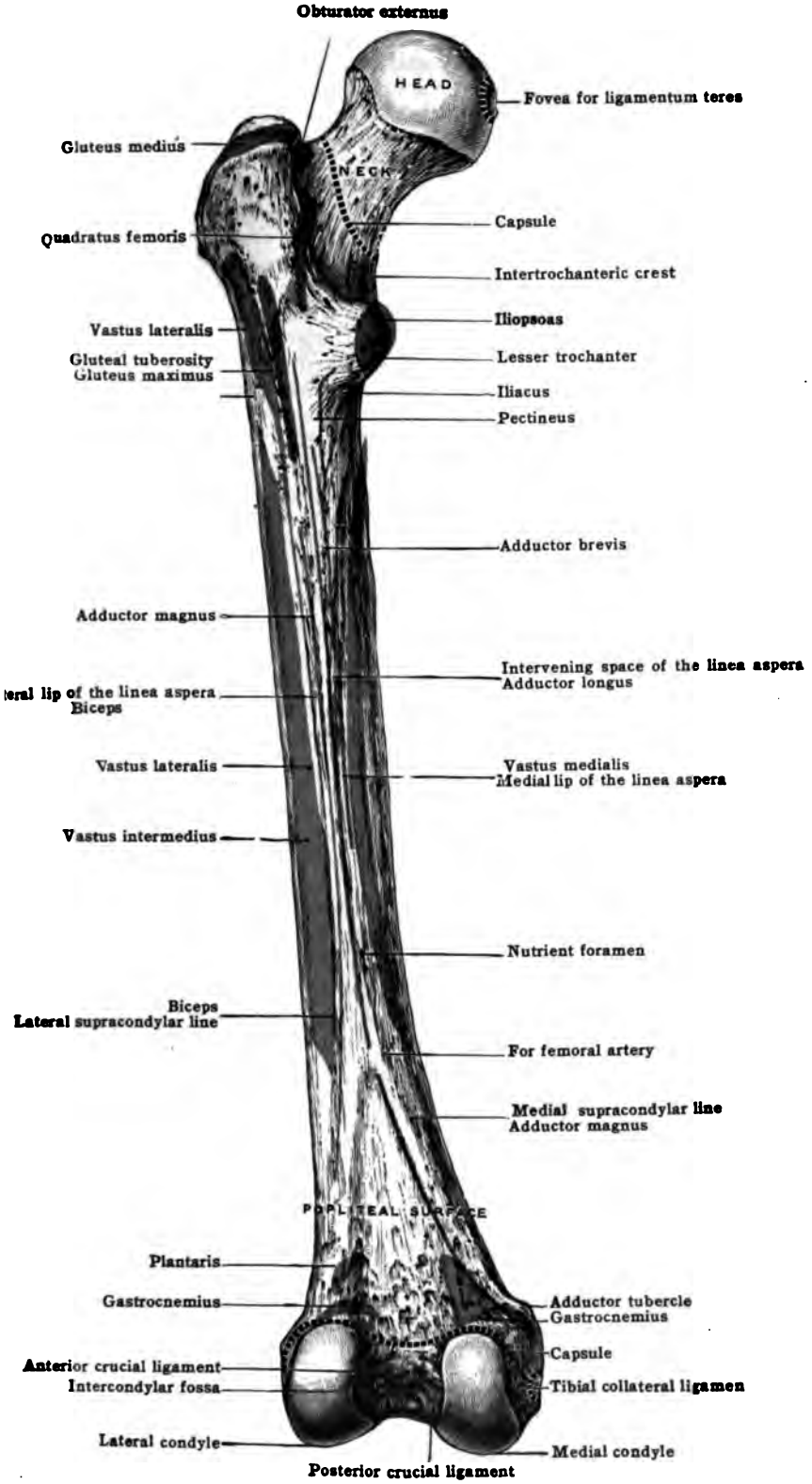


FIG. 251.—THE LEFT FEMUR. (Posterior view.)



In the erect posture it inclines from above downward, slightly backward and medially, approaching at the lower extremity its fellow of the opposite side, but separated from it above by the width of the minor pelvis. It presents a superior extremity, including the head, neck and two trochanters, a shaft, and an inferior extremity, expanded laterally into two condyles.

The **upper extremity** is surmounted by a smooth, globular portion called the **head** [caput femoris] forming more than half a sphere, directed upward and medially for articulation with the acetabulum. Its surface is covered with cartilage in the recent state, with the exception of a small rough depression, the **fovea,** for the ligamentum teres, a little below and behind the center of the head. The head is connected with the shaft by the **neck** [collum femoris], a stout rectangular column of bone which forms with the shaft, in the adult, an angle of about 125°. The anterior surface of the neck is in the same plane with the front aspect of the shaft, but is marked off from it by a ridge to which the capsule of the hip-joint is attached. The ridge, which commences at the great trochanter in a small prominence, or **tubercle,** extends obliquely downward, and winding to the back of the femur, passes by the lesser trochanter and becomes continuous with the medial lip of the linea aspera, on the posterior aspect of the shaft. This ridge forms the **intertrochanteric line** or **spiral line** of the femur.

The intertrochanteric line receives the bands of the iliofemoral thickening of the capsule of the hip-joint. The posterior surface of the neck is smooth and concave and its medial two-thirds is enclosed in the capsule of the hip-joint. The superior border of the neck, perforated by large nutrient foramina, is short and thick, and runs downward to the great trochanter. The inferior border, longer and narrower than the superior, curves downward to terminate at the lesser trochanter. At the junction of the neck and head there is a sharp line of demarcation excepting in front, where the iliofemoral ligament exerts great pressure upon the bone.

The **trochanters** are the prominences which afford attachment to the rotator muscles of the thigh; they are two in number—great and lesser.

The **great trochanter** [trochanter major] is a thick, quadrilateral process surmounting the junction of the neck with the shaft, and presents two surfaces and four borders. The lateral surface is broad, rough, and continuous with the lateral surface of the shaft. It is marked by a diagonal ridge running from the posterosuperior to the anteroinferior angle, which receives the insertion of the *gluteus medius.* The ridge divides the surface into two triangular areas: an upper, covered by the *gluteus medius,* and occasionally separated from it by a bursa, and a lower, covered by a bursa to permit the free gliding of the tendon of the *gluteus maximus.* Of the medial surface the lower and anterior portion is joined with the rest of the bone; the upper and posterior portion is free, concave, and presents a deep depression, the **trochanteric** or **digital fossa,** which receives the tendon of the *obturator externus.* The fore part of the surface is marked by an impression for the insertion of the *obturator internus* and two *gemelli.*

Of the four borders, the superior, thick and free, presents near the center an oval mark for the insertion of the *piriformis;* the anterior border, broad and irregular, receives the *gluteus minimus;* the posterior border, thick and rounded, is continuous with the **intertrochanteric crest,** the prominent ridge uniting the two trochanters behind. Above the middle of this line is an elevation, termed the **tubercle of the quadratus,** for the attachment of the upper part of the *quadratus femoris.* The inferior border corresponds with the line of junction of the base of the trochanter with the shaft; it is marked by a prominent ridge for the origin of the upper part of the *vastus lateralis.*

The **lesser trochanter** [trochanter minor] is a conical eminence projecting medially from the posterior and medial aspect of the bone, where the neck is continuous with the shaft. Its summit is rough and gives attachment to the tendon of the *iliopsoas.* The fibers of the *iliacus* extend beyond the trochanter and are inserted into the surface of the shaft immediately below.

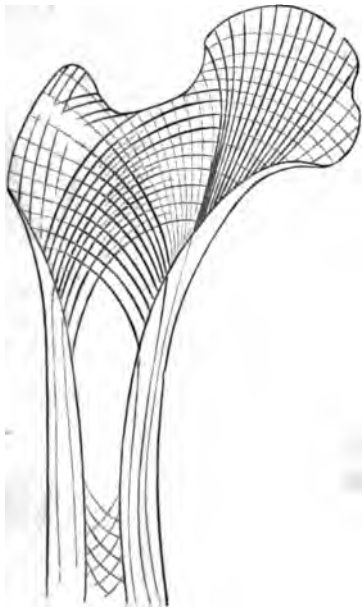
The **body** [corpus femoris] or **shaft** of the femur is almost cylindrical, but is slightly flattened in front and strengthened behind by a projecting longitudinal ridge, the **linea aspera,** for the origin and insertion of muscles. The linea aspera extends along the middle third of the shaft and presents a medial lip and a lateral lip separated by a narrow interval. When followed into the upper third of the shaft, the three parts diverge. The lateral lip becomes continuous with the **gluteal tuberosity** and ends at the base of the great trochanter. The ridge affords insertion to the *gluteus maximus,* and when very prominent is termed the **third trochanter.** The medial lip curves medialward below the lesser trochanter,

where it becomes continuous with the intertrochanteric line; the intervening portion bifurcates and is continued upward as two lines, one of which ends at the small trochanter, and receives some fibers of the *iliacus*, whilst the other is the **linea pectinea** and marks the insertion of the pectineus muscle.

Toward the lower third of the shaft the medial and lateral lips of the linea aspera again diverge, and are prolonged to the condyles by the **medial** and **lateral supracondylar lines,** enclosing between them a triangular surface of bone, the popliteal surface **[planum popliteum]** of the femur, which forms the upper part of the floor of the popliteal space. The lateral line is the more prominent and terminates below in the lateral epicondyle. The medial one is interrupted above, where the femoral vessels are in relation with the bone, better marked below, where it terminates in the **adductor tubercle,** a small sharp projection at the summit of the medial epicondyle, which affords insertion to the tendon of the *adductor magnus*.

Near the center of the linea aspera is the foramen for the medullary artery, directed upward toward the head of the bone. From the medial lip of the linea aspera and the lower part of the intertrochanteric line arises the *vastus medialis* (internus), and from the lateral lip and the side

FIG. 252.—A DIAGRAM TO SHOW THE PRESSURE AND TENSION CURVES OF THE FEMUR. (After Wagstaffe.)



of the gluteal ridge arises the *vastus lateralis* (externus). The *adductor magnus* is inserted into the medial lip of the linea aspera, from the medial side of the gluteal tuberosity above, and the medial supracondylar line below. Between the *adductor magnus* and *vastus medialis* (internus) four muscles are attached: the *pectineus* and *iliacus* above, then the *adductor brevis*, and lowest of all, the *adductor longus*. Above, in the interval between the *adductor magnus* and the *vastus lateralis* (externus), the *gluteus maximus* is inserted; in the interval lower down is the short head of the *biceps*, taking origin from the lower two-thirds of the lateral lip of the linea aspera and the upper two-thirds of the lateral supracondylar line. On the popliteal surface of the bone, just above the condyles, are two rough areas from which the two heads of the *gastrocnemius* take origin. Above the area for the lateral head of the gastrocnemius is a slight roughness for the *plantaris*.

For purposes of description it is convenient to regard the shaft of the femur as presenting anterior, medial, and lateral surfaces, although all three surfaces are smooth and the anterior is not separated from the lateral by ridges of any kind. In the middle third of the shaft the medial and lateral surfaces approach each other behind, being separated by the linea aspera.

The shaft is overlapped on its medial side by the *vastus medialis* (internus), and on its lateral side by the *vastus lateralis* (externus). The upper three-fourths of the anterior and lateral surfaces afford origin to the *vastus intermedius* (crureus), and the lower fourth of the anterior surface, to the *articularis genu* (subcrureus). The medial surface is free from muscular attachment.

The **lower extremity** presents two cartilage-covered eminences or **condyles,** separated behind by the **intercondyloid fossa.** The lateral condyle is wider than its fellow and more prominent anteriorly; the medial condyle is narrower,

FIG. 253.—TRANSVERSE SECTION OF SHAFT OF FEMUR TO SHOW THE MEDULLARY CAVITY.

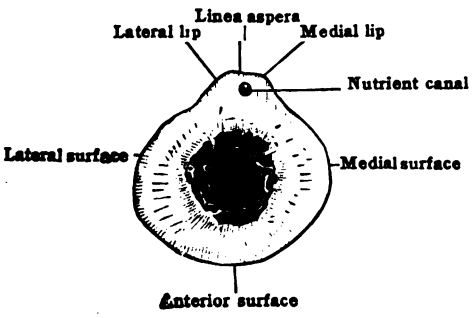
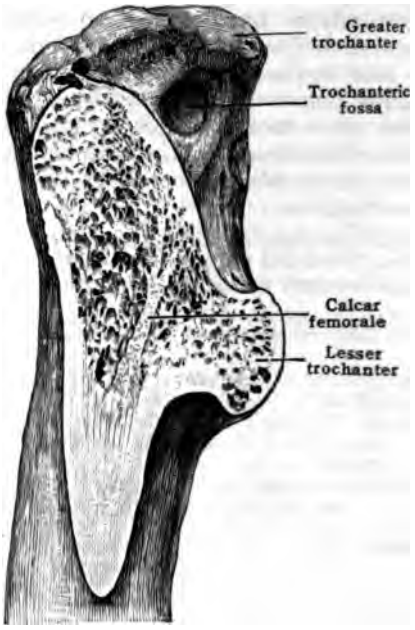
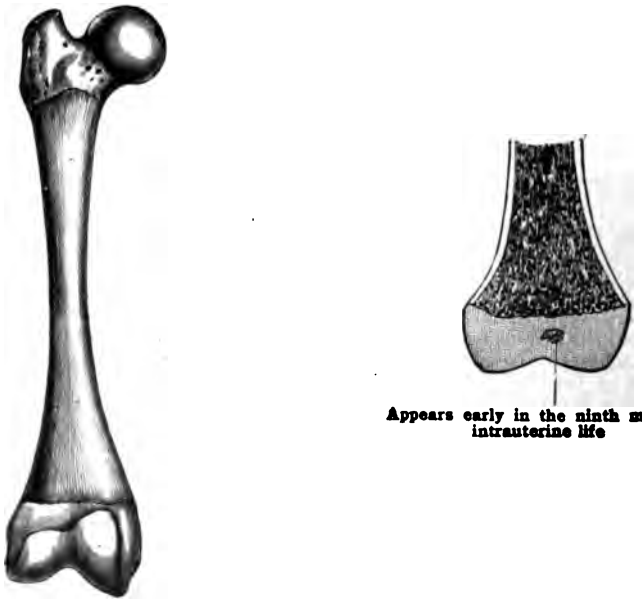


FIG. 254.—SECTION OF UPPER END OF FEMUR TO SHOW THE CALCAR FEMORALE.



more prominent, and longer, to compensate for the obliquity of the shaft. When the femur is in the natural position, the inferior surfaces of the condyles are on the same plane, and almost parallel, for articulation with the upper surfaces on the

FIG. 255.—THE FEMUR AT BIRTH.



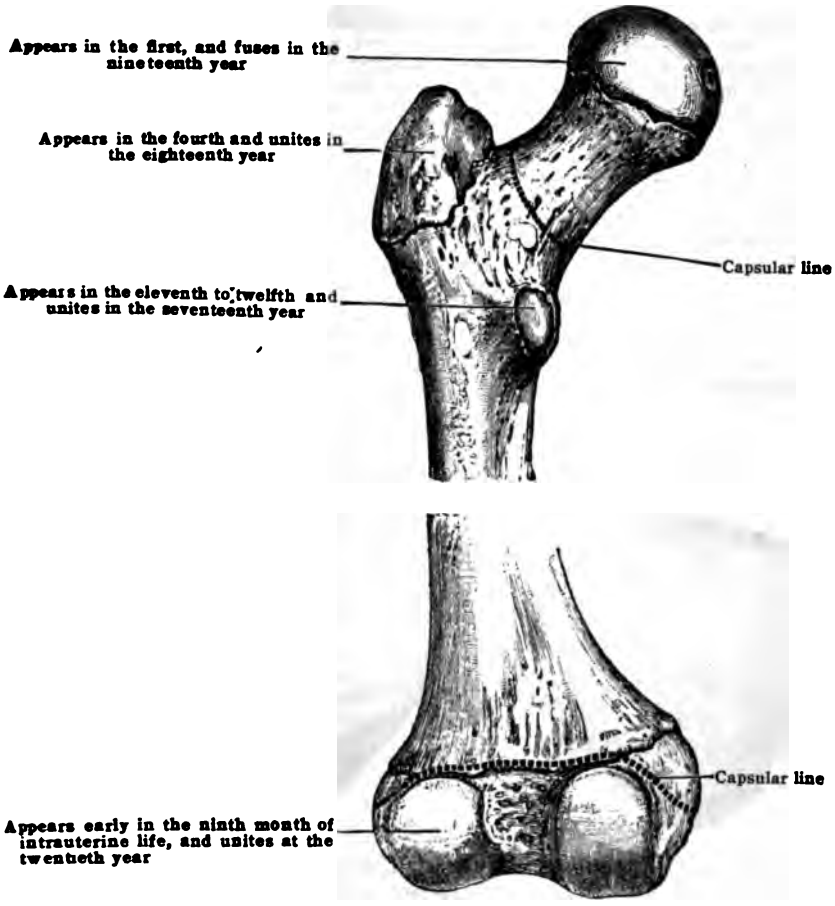
head of the tibia. The two condyles are continuous in front, **forming a smooth trochlear surface** [facies patellaris] for articulation with the patella.

The trochlear surface presents a median vertical groove and two convexities, **the lateral of** which is wider, more prominent, and prolonged farther upward The **patellar surface is**

faintly marked off from the tibial articular surfaces by two irregular grooves, best seen while the lower end is still coated with cartilage. The lateral groove commences on the medial margin of the lateral condyle near the front of the intercondylar fossa, and extends obliquely forward to the lateral margin of the bone. The general direction of the medial groove is from front to back, turning medially in front and extending backward as a faint ridge which marks off from the rest of the medial condyle a narrow semilunar facet for articulation with the medial perpendicular facet of the patella in extreme flexion. The grooves receive the semilunar menisci (see fig. 353) in the extended position of the joint. The tibial surfaces are almost parallel except in front, where the medial turns laterally to become continuous with the patellar surface.

The opposed surfaces of the two condyles form the boundaries of the **intercondylar fossa** and give attachment to the crucial ligaments which are lodged within it. The posterior crucial ligament is attached to the fore part of the lateral surface of the medial condyle and the anterior crucial ligament to the back part of the medial surface of the lateral condyle. The two remaining surfaces of the

FIG. 256.—THE LEFT FEMUR AT THE TWENTIETH YEAR. (Posterior view.)
The figure shows the relations of the epiphysial and capsular lines.


Appears in the first, and fuses in the nineteenth year
Appears in the fourth and unites in the eighteenth year
Capsular line
Appears in the eleventh to twelfth and unites in the seventeenth year
Capsular line
Appears early in the ninth month of intrauterine life, and unites at the twentieth year

condyles are broad and convex, and each presents an **epicondyle** (tuberosity) for the attachment of lateral ligaments. The medial epicondyle, the larger of the two, is surmounted by the adductor tubercle, behind which is an impression for the medial head of the *gastrocnemius* on the upper aspect of the condyle; below and behind the lateral epicondyle is a deep groove which receives the tendon of the *popliteus* muscle when the knee is flexed, and its anterior end terminates in a pit from which the tendon takes origin. Above the lateral epicondyle is a rough impression for the lateral head of the *gastrocnemius*.

The interior of the shaft of the femur is hollowed out by a large medullary canal, and the extremities are composed of cancellated tissue invested by a thin compact layer (figs. 252–254) The arrangement of the cancelli in the upper end of the bone forms a good illustration of the adaptation to mechanical conditions to which bones are subject. In the upper end of the bone the cancellous tissue is arranged in divergent curves. One system springs from the lower part

of the neck and upper end of the shaft medially and spreads into the great trochanter ('pressure lamellæ'). A second system springs from the lateral part of the shaft and arches upward into the neck and head ('tension lamellæ'), crossing the former almost at right angles. A second set of pressure lamellæ springs from the lower thick wall of the neck, and extends into the upper part of the head to end perpendicularly in the articular surface mainly along the lines of greatest pressure. A nearly vertical plate of compact tissue, the **calcar femorale** (fig. 254) projects into the neck of the bone from the inferior cervical region toward the great trochanter. This is placed in the line through which the weight of the body falls, and adds to the stability of the neck of the bone; it is said to be liable to absorption in old age. In the lower end of the bone the vertical and horizontal fibers are so disposed as to form a rectangular meshwork.

Blood-supply. The head and neck of the femur receive branches from the inferior gluteal, obturator, and circumflex arteries, and the trochanters from the circumflex arteries. The nutrient vessel of the shaft is derived from either the second or third perforating artery, or there may be two nutrient vessels arising usually from the first and third perforating. The vessels of the inferior extremity arise from the articular branches of the popliteal and the anastomotic branch of the femoral (genu suprema).

The angle which the neck of the femur forms with the shaft at birth measures, on an average, 160°. In the adult it varies from 110° to 140°; hence the angle decreases greatly during the period of growth. When once growth is completed, the angle, as a rule, remains fixed. (Humphry.)

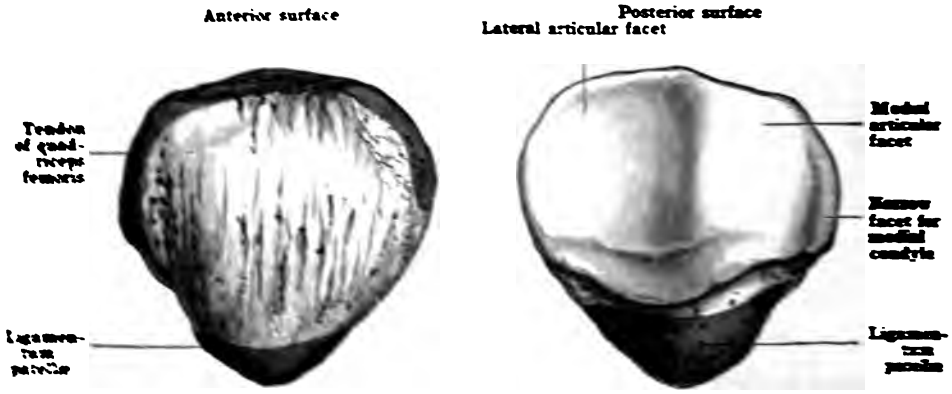
Ossification. The femur is ossified from one primary center for the shaft and from four epiphysial centers. The shaft begins to ossify in the seventh week of intra-uterine life. Early in the ninth month a nucleus appears for the lower extremity. During the first year the nucleus for the head of the bone is visible, and in the fourth year that for the trochanter major. The center for the lesser trochanter appears about the eleventh or twelfth year. The lesser trochanter joins the shaft at the seventeenth, the great trochanter at the eighteenth, the head about the nineteenth, and the lower extremity at the twentieth year (figs. 256, 1147).

Variations. *Platymerism* is the name given to a tendency to anteroposterior flattening of the femoral shaft. The variation of the gluteal tuberosity to form a third trochanter has been referred to; the tuberosity may be absent and its place taken by a hypotrochanteric fossa. The adductor tubercle may form a large spine.

THE PATELLA

The **patella** (figs. 257, 261) or knee-pan, situated in front of the knee-joint, is a sesamoid bone, triangular in shape, developed in the tendon of the *quadriceps femoris*. Its **anterior surface**, marked by numerous longitudinal striæ, is slightly

FIG. 257. THE LEFT PATELLA.



convex, and perforated by small openings which transmit nutrient vessels to the interior of the bone. It is covered in the recent state by a few fibers prolonged from the common tendon of insertion. Superficial to the tendon of the quadriceps femoris is the bursa patellæ subcutanea, and it is separated from the skin by one or more bursæ. The **posterior surface** is largely articular, covered with cartilage in the recent state, and divided by a slightly marked vertical ridge, corresponding to the groove on the anterior surface of the femur, into a lateral and a medial facet. The lateral facet, which is the larger, presents two or three vertical lines, and the medial facet a faint vertical ridge, sometimes marked at a corresponding distance from the medial margin of the medial facet. Below the articular surface is a rough area for the attachment of the ligamentum patellæ, and the intervening portion is separated by a mass

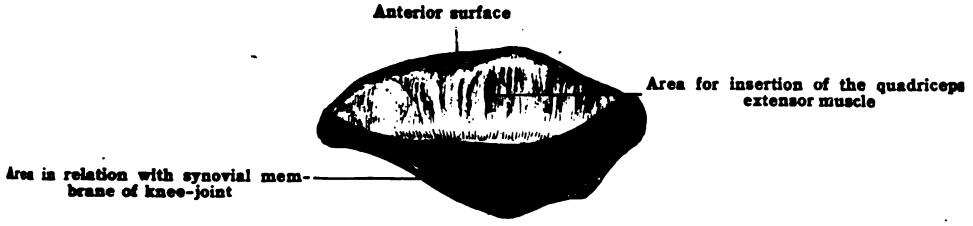
The **base** is directed upward, and receives the attachment of the quadriceps femoris; its attachment extends near the posterior margin to the common

tendon of the *quadriceps*. The **borders**, thinner than the base, converge to the apex below, and receive parts of the two *vasti* muscles. The **apex** forms a blunt point directed downward, and gives attachment to the ligamentum patellæ, by which the patella is attached to the tibia.

Structurally the patella consists of dense cancellous tissue covered by a thin compact layer, and it receives nutrient vessels from the articular branch of the genu suprema (anastomotic), the anterior tibial recurrent, and the inferior articular branches of the popliteal.

Ossification.—The cartilaginous deposit in the tendon of the *quadriceps* muscle takes place in the fourth month of intrauterine life. Ossification begins from a single center during the third year, and is completed about the age of puberty.

FIG. 258.—THE SUPERIOR BORDER OR BASE OF THE LEFT PATELLA.


Anterior surface
Area for insertion of the quadriceps extensor muscle
Area in relation with synovial membrane of knee-joint

THE TIBIA

The **tibia** (figs. 259, 260) or shin-bone is situated at the front and medial side of the leg and nearly parallel with the fibula. Excepting the femur, it is the largest bone in the skeleton, and alone transmits the weight of the trunk to the foot. It articulates above with the femur, below with the tarsus, and laterally with the fibula. It is divisible into two extremities and a shaft.

The **upper extremity** (or head) consists of two lateral eminences, or **condyles** which contribute to the roundness of the knee and are subcutaneous in front and at either side. Their superior articular surfaces receive the condyles of the femur, the articular parts being separated by a non-articular interval, to which ligaments are attached.

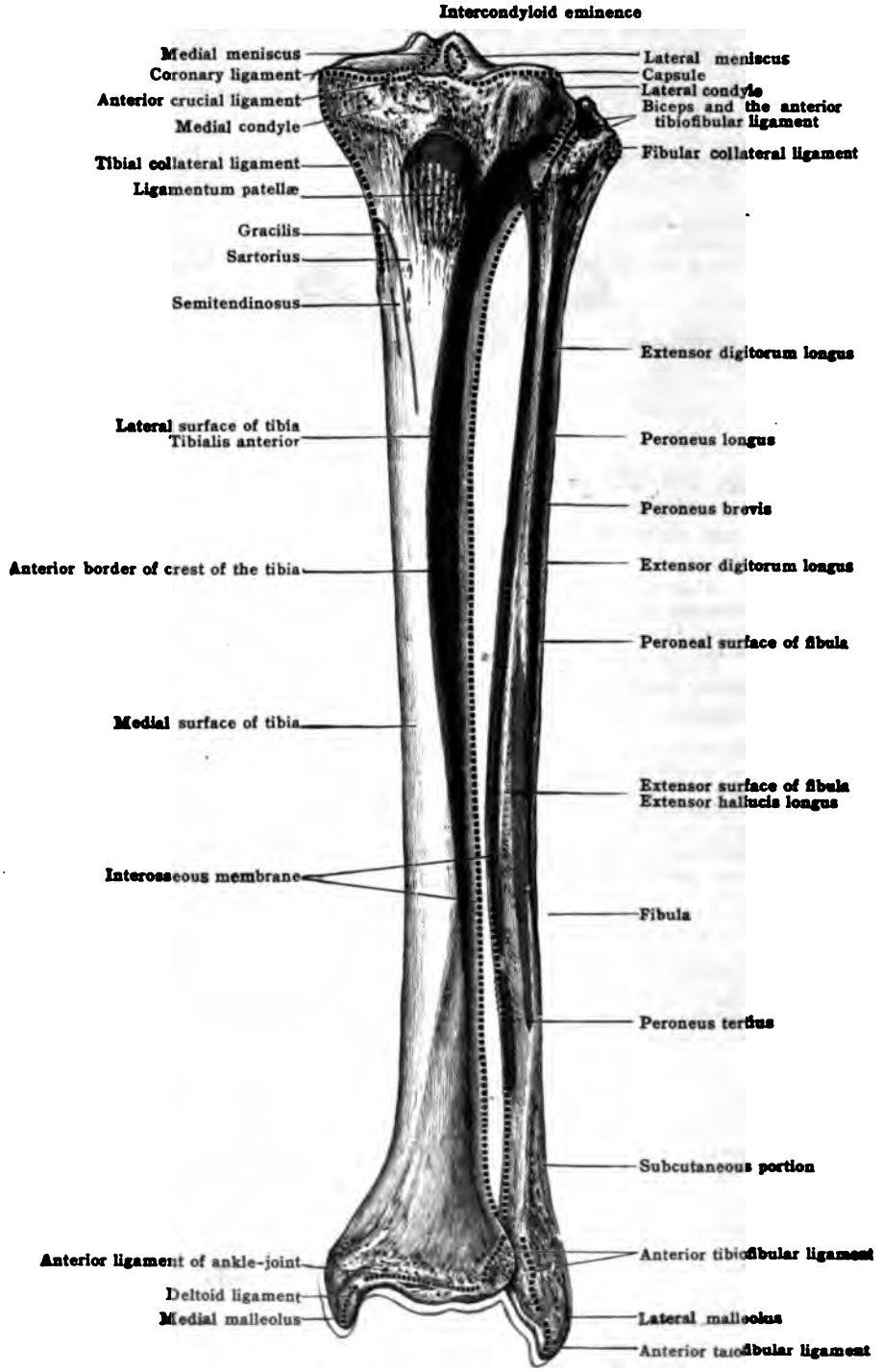
The *medial articular surface* is oval in shape and concave for the medial condyle of the femur. The *lateral articular surface* is smaller, somewhat circular in shape, and presents an almost plane surface for the lateral condyle. The peripheral portion of each articular surface is overlaid by a fibrocartilaginous meniscus of semilunar shape, connected with the margins of the condyles by bands of fibrous tissue termed coronary ligaments (fig. 353). Each semilunar meniscus is attached firmly to the rough interval separating the articular surfaces. This interval is broad and depressed in front, the **anterior intercondyloid fossa**, where it affords attachment to the anterior extremities of the medial and lateral menisci and the anterior crucial ligament; elevated in the middle to form the **intercondyloid eminence** or spine of the tibia, a prominent eminence, presenting at its summit two compressed **intercondyloid tubercles**, on to which the condylar articular surfaces are prolonged; the posterior aspect of the base of the eminence affords attachment to the posterior extremities of the lateral and medial semilunar menisci. A deep notch, the **posterior intercondyloid fossa** or popliteal notch, separates the condyles on the posterior aspect of the head and gives attachment to the posterior crucial ligament, and part of the posterior ligament of the knee-joint.

Anteriorly, the two condyles are confluent, and form a somewhat flattened surface of triangular outline, the apex of which forms the **tuberosity** of the tibia. The tuberosity is divisible into two parts. The upper part, rounded and smooth receives the insertion of the ligamentum patellæ. The lower part is rough, and into its lateral edges prolongations of the ligamentum patellæ are inserted. A prominent bursa intervenes between the ligament and the anterior aspect of the upper extremity of the bone.

The medial condyle is less prominent though more extensive than the lateral, and near the posterior part of its circumference is a deep horizontal groove for the attachment of the central portion of the *semimembranosus* tendon. The margins of this groove, and the surface of bone below, give attachment to the tibial (internal) lateral ligament of the knee. On the under aspect of the lateral condyle is a rounded articular facet for the head of the fibula, flat and nearly circular in outline, directed downward, backward, and laterally. The circumference of the facet is rough and gives attachment to the ligaments of the superior tibiofibular joint, while above and in front of the facet, at the junction of the anterior and lateral surfaces of the condyle, is a ridge for the iliotibial band. Slips from the tendons of the *biceps*, the *extensor digitorum longus* and *peroneus longus* muscles are attached to the head below the iliotibial band.

The **shaft** or **body** [corpus] of the tibia, thick and prismatic above, becor thinner as it descends for about two-thirds of its length, and then gradually pands toward its lower extremity. It presents three borders and three surfa

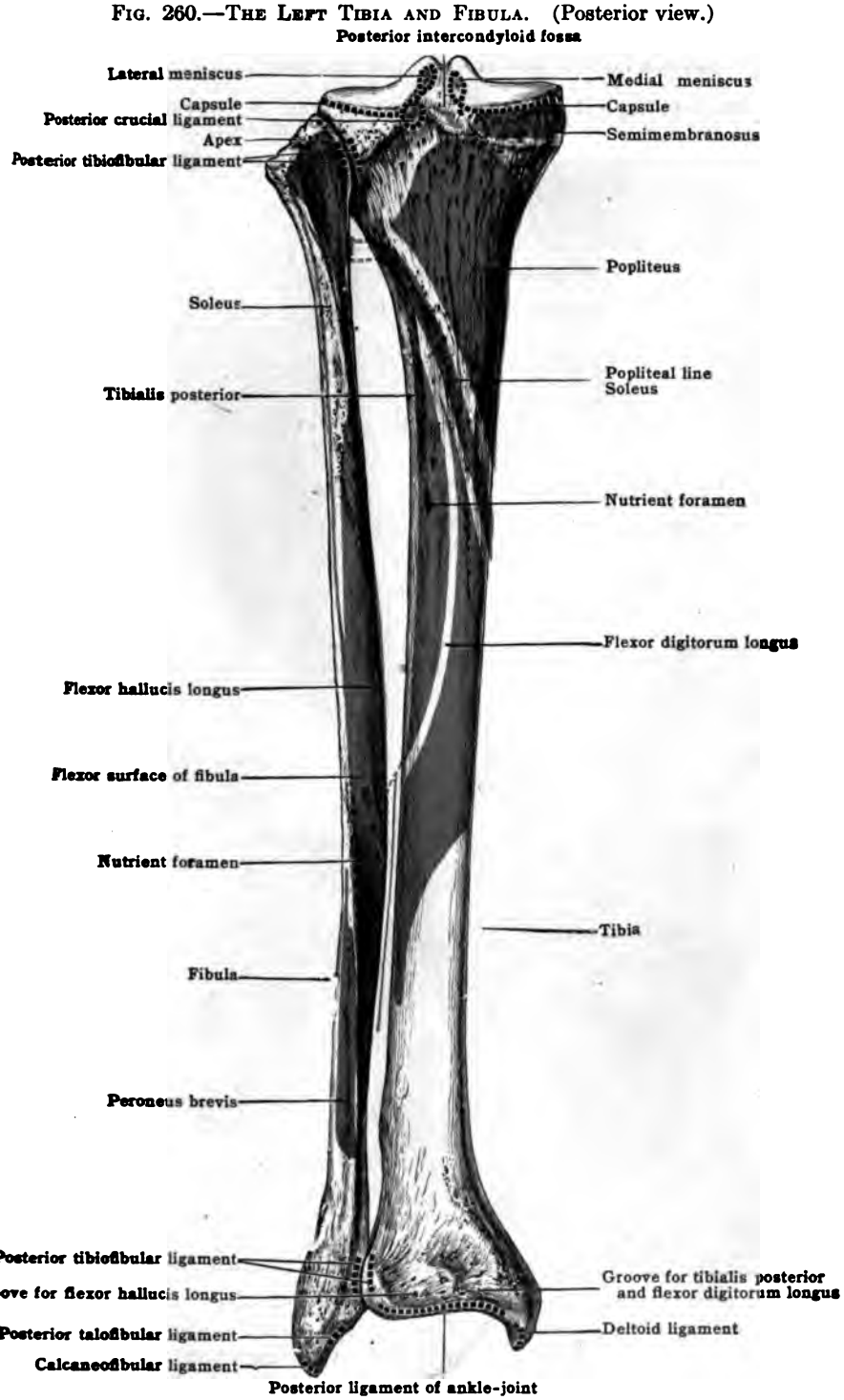
FIG. 259.—THE LEFT TIBIA AND FIBULA. (Anterior view.)



The **anterior border** is very prominent, subcutaneous, and known as the ant **crest** of the tibia. It commences above on the lateral edge of the tuberosity terminates below at the anterior margin of the medial malleolus. It runs a s what sinuous course, and gives attachment to the deep fascia of the leg.

medial border extends from the back of the medial condyle to the posterior margin of the medial malleolus, and affords attachment above, for about three inches, to the tibial (internal) lateral ligament of the knee-joint and in the middle third, to

FIG. 260.—THE LEFT TIBIA AND FIBULA. (Posterior view.)



e soleus. The **interosseous crest** or lateral border, thin and prominent, gives tachment to the interosseous membrane. It commences in front of the fibular cet, on the upper extremity, and toward its termination bifurcates to enclose a

triangular area for the attachment of the interosseous ligament uniting the lower ends of the tibia and fibula.

The **medial surface** is bounded by the medial margin and the anterior crest: it is broad above, where it receives the insertions of the *satorius, gracilis,* and *semi-tendinosus;* convex and subcutaneous in the remainder of its extent. The **lateral surface** lies between the crest of the tibia and the interosseous crest. The upper two-thirds presents a hollow for the origin of the *tibialis anterior;* the rest of th

FIG. 261.—KNEE-JOINT OF A BOY OF SIXTEEN YEARS. From an X-ray plate by Dr. Sherwood Moore, Washington University.

surface is convex and covered by the extensor tendons and the anterior tibial vessels. The **posterior surface** is limited by the interosseous crest and the medial border. The upper part is crossed obliquely by a rough **popliteal line,** extending from the fibular facet on the lateral condyle to the medial border, a little above the middle of the bone.

The popliteal line gives origin to the *soleus* and attachment to the popliteal fascia, while the triangular surface above is occupied by the *popliteus* muscle. Descending along the posterior surface from near the middle of the popliteal line is a vertical ridge, well marked at

its commencement, but gradually becoming indistinct below. The portion of the surface between the ridge and the medial border gives origin to the *flexor digitorum longus;* the lateral and narrower part, between the ridge and the interosseous border, to fibers of the *tibialis posterior*. The lower third of the posterior surface is covered by flexor tendons and the posterior tibial vessels. Immediately below the popliteal line and near the interosseous border is the large medullary foramen directed obliquely downward.

The **lower extremity,** much smaller than the upper, is quadrilateral in shape and presents a strong process called the **medial malleolus,** projecting downward from its medial side. The anterior surface of the lower extremity is smooth and rounded above, where it is covered by the extensor tendons, rough and depressed below for the attachment of the anterior ligament of the ankle-joint. It sometimes bears a facet for articulation with the neck of the talus (astragalus). The posterior surface is rough and is marked by two grooves. The medial and deeper of the two encroaches on the malleolus, and receives the tendons of the *tibialis posterior* and *flexor digitorum longus;* the lateral, very shallow and sometimes indistinct, is for the tendon of the *flexor hallucis longus*. The lateral surface is triangular and hollowed for the reception of the lower end of the fibula and rough for the interosseous ligament which unites the two bones, except near the lower border, where there is usually a narrow surface, elongated from before backward, covered with cartilage in the recent state for articulation with the fibula. The lines in front of and behind the triangular surface afford attachment to the anterior and posterior ligaments of the inferior tibiofibular articulation. The medial surface, prolonged downward on the medial malleolus, is rough, convex, and subcutaneous. The lateral surface of this process is smooth and articulates with the facet on the medial side of the talus (astragalus). Its lower border is notched, and from the notch, as well as from the tip and anterior border, the deltoid ligament of the ankle-joint descends. The inferior or terminal surface, by which the tibia articulates with the talus, is of quadrilateral form, concave from before backward, wider in front than behind, and laterally than medially where it is continuous with the lateral surface of the malleolus.

Variations.—The occasional facet on the anterior surface of the lower extremity of the tibia is a pressure facet, produced by extreme flexion of the ankle joint. It is constantly present in aboriginal peoples who assume the squatting position and is therefore sometimes designated as the 'squatting facet.' Two other variations are: the bilateral compression of the shaft called *platycnemism;* and the retroversion of the head of the tibia. Both have been observed in ancient races and also in some of the living aboriginal races.

The tibia is relatively longer in the lower races than in white and yellow people as shown by the femorotibial index: $\frac{\text{length of tibia} \times 100}{\text{length of femur}}$.

Blood-supply.—The tibia is a very vascular bone. The nutrient artery of the shaft is furnished by the posterior tibial, and is the largest of its kind in the body. The head of the bone receives numerous branches from the inferior articular arteries of the popliteal and the recurrent branches of the anterior and posterior tibial. The lower extremity receives twigs from the posterior and anterior tibial, the peroneal, and the medial malleolar arteries.

Ossification.—The tibia is ossified from one principal center for the shaft, which appears in the seventh week (forty-second day, Mall) of intrauterine life, and two epiphyses, the centers for which appear in the cartilaginous head of the bone toward the end of the ninth month, and in the lower extremity during the second year. The latter unites with the shaft at eighteen, (figs. 261, 1146) but the union of the head with the shaft does not take place until the twenty-first year, and it may even be delayed until twenty five. The tubercle of the tibia is ossified from a nucleus which appears from the seventh to the fifteenth year in a strip of cartilage prolonged down from the cartilage of the head of the bone; the center fuses with the proximal epiphysis about the fifteenth year.

THE FIBULA

The **fibula** (figs. 259, 260) is situated on the lateral side of the leg and, in proportion to its length is the most slender of all the long bones. It is placed nearly parallel to the tibia with which it is connected above and below. In man it is a rudimentary bone and bears none of the weight of the trunk, but is of importance on account of its muscular attachments and its participation in the formation of the ankle-joint. Like other long bones, it is divisible into a shaft and two extremities.

The **head** [capitulum fibulæ] or upper extremity, is a rounded expansion of the bone which produces the prominence at the lateral side of the knee posterior and inferior to the lateral condyle of the tibia. Its upper surface presents laterally a rough eminence for the attachment of the *biceps* tendon and the fibular

(long external) collateral ligament of the knee-joint, and medially a round or oval facet [facies articularis capituli], directed upward, forward, and medially, for articulation with the lateral condyle (tuberosity) of the tibia. The margin of the facet gives attachment to the articular capsule of the superior tibiofibular articulation. Posteriorly, the head rises into a pointed **apex** (styloid process), which affords attachment to the short lateral ligament of the knee-joint, and on the lateral side, to part of the *biceps* tendon.

The posterior aspect of the head gives attachment to the *soleus*, the lateral aspect, extending also in front of the eminence for the *biceps*, to the *peroneus longus;* from the anterior aspect fibers of the *extensor digitorum longus* arise, whilst the medial side lies adjacent to the tibia.

The **shaft** [corpus fibulæ], in its upper three-fourths, is quadrangular, possessing four borders and four surfaces, whereas its lower fourth is flattened from side to side, so as to be somewhat triangular. The borders and surfaces vary exceedingly so that their description is difficult.

The **anterior crest** (or anterolateral border) commences in front of the head and terminates below by dividing to enclose a subcutaneous surface, triangular in shape, immediately above the lateral malleolus. It gives attachment to a septum separating the extensor muscles in front from the peronei muscles on the lateral aspect. The **interosseous crest** (or anteromedial border), so named from giving attachment to the interosseous membrane, also commences in front of the head, close to the anterior crest, and terminates below by dividing to enclose a rough triangular area immediately above the facet for the talus (astragalus); this area gives attachment to the inferior interosseous ligament, and may present at its lower end a narrow facet for articulation with the tibia. The **medial crest** (or posteromedial border), sometimes described as the **oblique line** of the fibula, commences at the medial side of the head and terminates below by joining the interosseous crest, in the lower fourth of the shaft. It gives attachment to an aponeurosis separating the *tibialis posterior* from the *soleus* and *flexor hallucis longus*. The **lateral crest** (or posterolateral border) runs from the back of the head to the medial border of the peroneal groove on the back of the lower extremity; it gives attachment to the fascia separating the peronei from the flexor muscles.

The **anterior** or **extensor surface** is the interval between the interosseous and anterior crests. In the upper third it is extremely narrow, but broadens out below, where it is slightly grooved longitudinally. It affords origin to three muscles: laterally, in the upper two-thirds, to the *extensor digitorum longus*, and, in the lower third, to the *peroneus tertius;* medially, in the middle third, also to the *extensor hallucis longus*. The **medial surface**, situated between the interosseous and medial crests, is narrow above and below, and broadest in the middle. It is grooved and sometimes crossed obliquely by a prominent ridge, the **secondary oblique line** of the fibula; the surface gives origin to the *tibialis posterior*, and the ridge to a tendinous septum in the substance of the muscle. The **posterior surface** is the interval between the medial and lateral crests, and is somewhat twisted so as to look backward above and medially below. It serves, in its upper third, for the origin of the *soleus*, and in its lower two-thirds for the *flexor hallucis longus*. Near the middle of the surface is the medullary foramen, directed downward toward the ankle. The **lateral surface**, situated between the anterior and lateral crests, is also somewhat twisted, looking laterally above and backward below, where it is continuous with the groove on the back of the lateral malleolus. The surface is often deeply grooved and is occupied by the *peroneus longus* in the upper two-thirds and by the *peroneus brevis* in the lower two-thirds.

The **lateral malleolus** or lower extremity is pyramidal in form, somewhat flattened from side to side, and joined by its base to the shaft. It is longer, more prominent, and descends lower than the medial malleolus. Its lateral surface is convex, subcutaneous, and continuous with the triangular subcutaneous surface on the shaft, immediately above. The medial surface is divided into an anterior and upper area [facies articularis malleoli], triangular in outline and convex from above downward for articulation with the lateral side of the talus (**astragalus**), and a lower and posterior excavated area, the **digital fossa**, in which are attached the transverse inferior tibiofibular ligament and the posterior talofibular ligament of the ankle. The anterior border is rough and gives attachment to the anterior talofibular ligament of the ankle, and the anterior inferior tibiofibular ligament. The posterior border is grooved for the peronei tendons, and near its upper part gives attachment to the posterior inferior tibiofibular ligament. The apex or summit of the process affords attachment to the calcaneofibular ligament of the ankle.

Blood-supply.—The shaft of the fibula receives its nutrient artery from the peroneal branch of the posterior tibial. The head is nourished by branches from the inferior lateral articular branch of the popliteal artery, and the lateral malleolus is supplied mainly by the peroneal, and its perforating and malleolar branches.

Ossification.—The shaft of the fibula commences to ossify in the eighth week (fifty-fifth day, Mall) of intrauterine life. A nucleus appears for the lower extremity in the second year, and one in the upper extremity during the fourth or fifth year. The lower extremity fuses with the shaft about twenty (fig. 1146), but the upper extremity remains separate until the twenty-second year or even later.

It is interesting, in connection with the times of appearance of the two epiphyses of the fibula, to note that the ossification of the lower epiphysis is contrary to the general rule—viz., that the epiphysis toward which the nutrient artery is directed is the last to undergo ossification. This is perhaps explained by the rudimentary nature of the upper extremity. In birds the head of the bone is large and enters into the formation of the knee-joint; and in human embryos, during the second month, the fibula is quite close up to the femur.

The human fibula is characterized by the length of its malleolus, for in no other vertebrate does this process descend so far below the level of the tibial malleolus. On the other hand, in the majority of mammals the tibial descends to a lower level than the fibular malleolus. In the human embryo of the third month, the lateral is equal in length to the medial malleolus; but the former grows more rapidly and by the second year it assumes its adult proportion.

The chief **variations** of the fibula are fluctuations in the form and relative size of the surfaces of the shaft, correlated with the attachment of muscles and the occasional absence of the bone.

THE TARSUS

The **tarsal bones** [ossa tarsi] (figs. 262, 263) are grouped in two rows:—a proximal row, consisting of the **talus** and **calcaneus**, and a distal row, consisting of four bones which, enumerated from the tibial side, are the **first, second,** and **third cuneiform** bones and the **cuboid.** Interposed between the two rows on the tibial side of the foot is a single bone, the **navicular**; on the fibular side the proximal and distal rows come into contact.

Compared with the carpus, the tarsal bones present fewer common characters, and greater diversity of size and form, modifications correlated with the function of supporting the weight of the trunk. On each, however, six surfaces can generally be recognized, articular when in contact with neighboring bones, elsewhere subcutaneous or rough for the attachment of ligaments. As regards ossification, they correspond in the main with the bones of the carpus.

The Talus

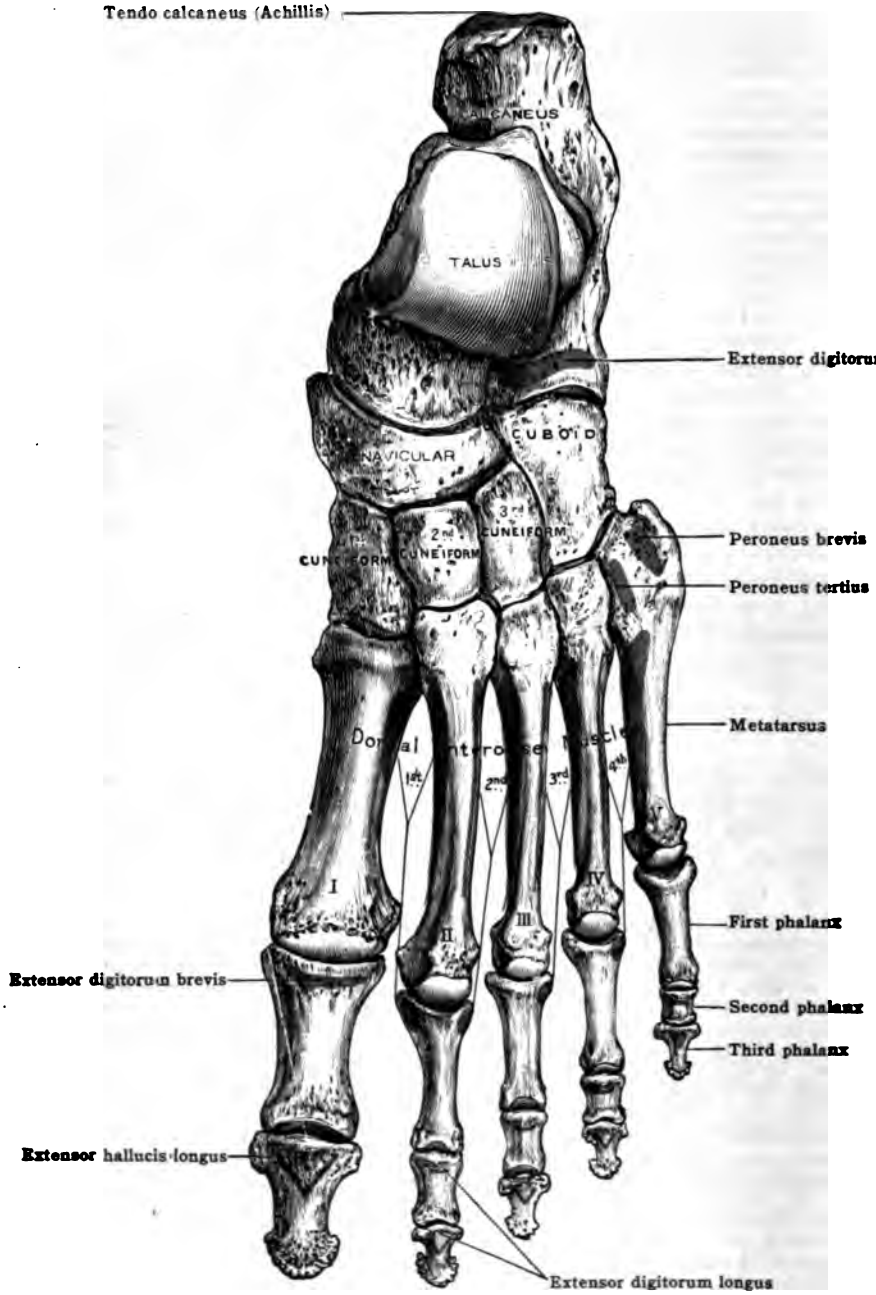
The **talus** (or astragalus) (figs. 264, 265) is, next to the calcaneus, the largest of the bones of the tarsus. Above it supports the tibia, below it rests on the calcaneus, at the sides it articulates with the two malleoli, and in front it is received into the navicular. For descriptive purposes, it may be divided into a **head, neck,** and **body.**

The **body** is somewhat quadrilateral in shape. The **upper surface** presents a broad, smooth surface for the tibia, slightly concave from side to side, convex from before backward, and wider in front than behind. The diminution in width posteriorly is associated with an obliquity of the lateral margin, which is directed medially as well as backward and downward. The **inferior surface** is occupied by a transversely disposed oblong facet [facies articularis calcanea posterior], deeply concave from side to side, which articulates with a corresponding surface on the calcaneus. Of the malleolar surfaces, the lateral is almost entirely occupied by a large triangular facet, broad above, where it is continuous with the superior surface, concave from above downward, for articulation with the lateral malleolus; on the **medial malleolar surface** is a pyriform facet continuous with the superior surface, broad in front and narrow behind, which articulates with the medial malleolus. Below this facet the medial surface is rough for the attachment of the deep fibers of the deltoid (internal lateral) ligament of the ankle. The superior surface and the two malleolar surfaces together constitute the **trochlea.** The **posterior surface** is of small extent and marked by a groove which lodges the tendon of the *flexor hallucis longus.* Bounding the groove on either side are two tubercles, of which the lateral [processus posterior tali] is usually the more prominent, for attachment of the posterior talofibular ligament of the ankle-joint; the medial tubercle gives attachment to the medial talocalcaneal ligament. Continuous with the anterior aspect of the body is the **neck,** a constricted part of the bone supporting the head. Above it is rough, and perforated by numerous vascular foramina. Below, it presents a deep groove [*sulcus tali*], directed from behind forward and lateralward. When the talus is articulated with the calcaneus, this furrow is converted into a canal [*sinus tarsi*] in which is lodged the interosseous talocalcaneal ligament. The **head** is the rounded anterior end of the bone, and its large articular surface is divisible into three parts: in front, a smooth, oval convex area, directed downward and forward for the navicular bone; below, an elongated facet, convex from front to back, for articulation with the sustentaculum tali of the calcaneus; and between these is a small facet which rests on the calcaneo-

navicular ligament, separated from it by the synovial membrane of the talocalcaneonavicular joint.

Articulations.—The talus articulates with four bones and two ligaments. Above and medially with the tibia, below with the calcaneus, in front with the navicular, laterally with the fibula. The head articulates with the calcaneonavicular ligament and the lateral border of the superior surface, at its posterior part, with the transverse ligament of the inferior tibiofibular joint.

FIG. 262.—BONES OF THE LEFT FOOT (Superior Surface.)

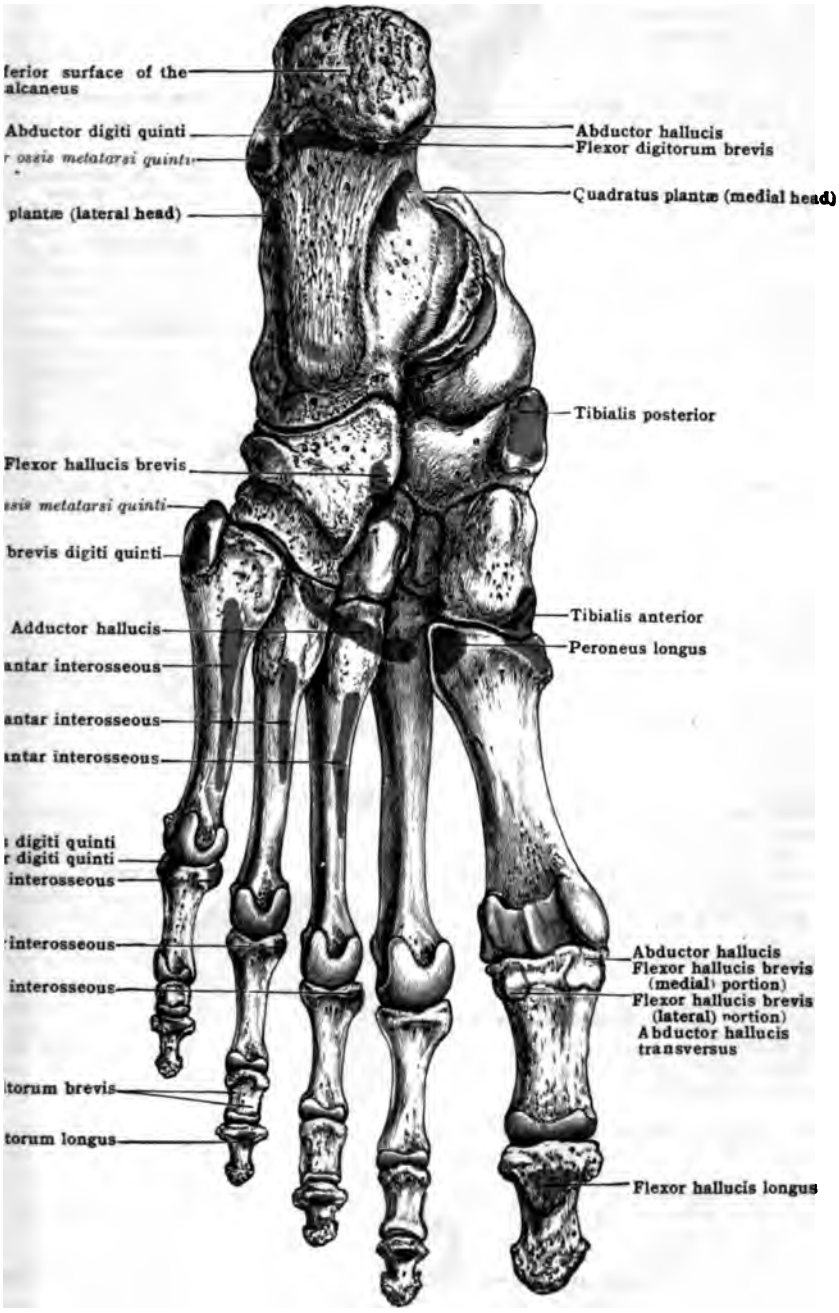


The talus is a very vascular bone and is nourished by the dorsalis pedis artery and its tarsal branch. It gives attachment to no muscles.

Ossification.—The talus is ossified from one nucleus, occasionally from two. The principal center for this bone appears in the middle of the cartilaginous talus at the seventh month of intrauterine life. The additional center is deposited in the posterior portion of the bone, and forms the lateral posterior tubercle which may remain separate from the rest of the bone and form the os trigonum (fig. 265). At birth, the talus presents some important peculiarities in

›n of the articular facet on the tibial side of its body, and in the obliquity of its neck. lt talus, a line be drawn through the middle of the superior trochlear surface parallel ial border, and a second line be drawn along the lateral side of the neck of the bone ect the first, the angle formed by these two lines will express the obliquity of the bone. This in the adult varies greatly, but the average may be taken as 10°. angle averages 35°, while in a young orang it measures 45°. In the normal he articular surface on the tibial side is limited to the body of the bone. In the

FIG. 263.—BONES OF THE LEFT FOOT. (Plantar surface.)



it extends for some distance on to the neck, and sometimes reaches almost as far he navicular facet on the head of the bone. This disposition of the medial malleolar aracteristic feature of the talus in the chimpanzee and the orang. It is related to l position of the foot which is found in the human fetus almost up to the period of of interest to the surgeon in connection with some varieties of club-foot. (Shattock)

FIG. 264.—THE LEFT TALUS. (Plantar view.)

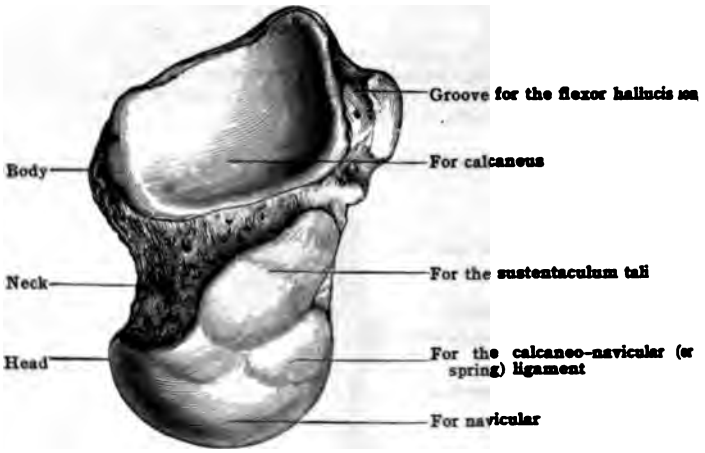
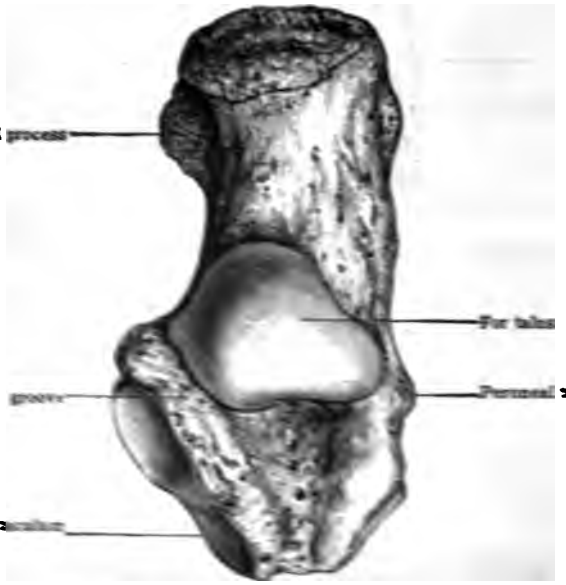


FIG. 265.—A TALUS WITH THE OS TRIGONUM.

FIG. 266.—THE LEFT CALCANEUS. (Superior view.)



The Calcaneus

The **calcaneus** (or os calcis) (figs. 266, 267) is the largest and strongest bone of the foot. It is of an elongated form, flattened from side to side, and expanded at its posterior extremity, which projects downward and backward to form the heel. It presents six surfaces, superior, inferior, lateral, medial, anterior and posterior.

The **superior surface** presents in the middle a large, oval, convex, articular facet for the under aspect of the body of the talus. In front of the facet the bone is marked by a deep depression, the floor of which is rough for the attachment of ligaments, especially the talocalcaneal, and the origin of the *extensor digitorum brevis* muscle; when the calcaneus and talus are articulated, this portion of the bone forms the floor of a cavity called the **sinus tarsi**. Medially, the upper surface of the bone presents a well-marked process, the **sustentaculum tali**, furnished with an elongated concave facet, occasionally divided into two, for articulation with the under aspect of the head of the talus. The posterior part of the upper surface is non-articular, convex from side to side, and in relation with a mass of fat placed in front of the tendo Achillis.

The **inferior surface** is narrow, rough, uneven, and ends posteriorly in two **processes**: the **medial** is the larger and broader, the **lateral** is narrower but prominent. The medial process affords origin to the *abductor hallucis*, the *flexor digitorum brevis*, and the *abductor digiti quinti;* the last muscle also arises from the lateral process and from the ridge of bone between. The rough surface in front of the tubercles gives attachment to the long plantar ligament (calcaneocuboid) and the lateral head of the *quadratus plantæ*. Near its anterior end this surface forms a rounded eminence, the **anterior tubercle**, from which (as well as from the shallow groove in front) the plantar (short) calcaneocuboid ligament arises.

The **lateral surface** is broad, flat, and slightly convex. It represents near the middle a small eminence for the calcaneofibular ligament of the ankle-joint. Below and in front of this is a well-marked tubercle—the **trochlear process** (or peroneal tubercle), separating two grooves, the upper for the *peroneus brevis* and the lower for the *peroneus longus*.

Fig. 267.—The Calcaneus at the Fifteenth Year, showing the Epiphysis.

Appears at the tenth, and unites at the sixteenth year

The **medial surface** is deeply concave, the hollow being increased by the prominent medial process behind and the overhanging **sustentaculum** tali in front. The latter forms a prominence of bone projecting horizontally, concave and articular above, grooved below for the tendon of the *flexor hallucis longus*, and giving attachment to a slip of the tendon of the *tibialis posterior*, the inferior calcaneonavicular ligament, and some fibers of the deltoid ligament of the ankle-joint. The hollow below the process receives the plantar vessels and nerves and its lower part gives attachment to the medial head of the *quadratus plantæ*.

The **anterior surface** is somewhat quadrilateral in outline with rounded angles, and presents a saddle-shaped articular surface for the cuboid.

The **posterior surface** is oval in shape, rough, and convex. It is divided into three parts:—an upper, smooth and separated by a bursa from the tendo Achillis; a middle part giving insertion to the *tendo Achillis* and the *plantaris*, and a lower part in relation to the skin and fat of the heel. The expanded posterior extremity of the bone is known as the **tuber calcanei**.

Articulations.—The calcaneus articulates with two bones, the talus above and the cuboid in front.

Blood-supply.—The calcaneus is nourished by numerous branches from the posterior tibial and the medial and lateral malleolar arteries. They enter the bone chiefly on the inferior and medial surfaces.

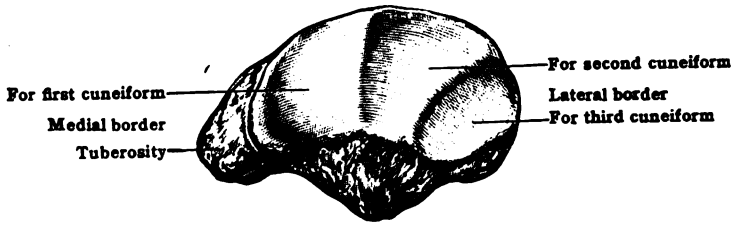
Ossification.—The primary nucleus appears in the sixth month of intrauterine life. The epiphysis, for its posterior extremity, begins to be ossified in the sixth to the tenth year and is united to the body of the bone between the thirteenth and twentieth years (girls earlier than boys). The epiphysis may extend over the whole of the posterior surface, as shown in fig. 267, or over the lower two-thirds only, leaving a part above in relation to the bursa beneath the tendo Achillis, which is formed from the pimary nucleus. The medial and lateral processes are formed by the epiphysis.

The Navicular

The **navicular** [os naviculare pedis] (figs. 268, 269) is oval in shape, flattened from before backward, and situated between the talus behind and the three cuneiform bones in front. It is characterized by a large oval, concave, articular

facet on the **posterior surface,** which receives the head of the talus; a broad, rough, rounded eminence on the **medial surface,** named the **tuberosity** of the navicular, the lower part of which projects downward and gives insertion to the tendon of the *tibialis posterior;* and an oblong-shaped **anterior surface,** convex and divided by two vertical ridges into three facets which articulate with the three cuneiform bones. The **superior** (dorsal) **surface** is rough, convex, and slopes downward to the tuberosity; the **inferior** (plantar) **surface** is irregular and rough for the attachment of the inferior calcaneonavicular ligament, and the **lateral surface** is rough and sometimes presents a small articular surface for the cuboid.

FIG. 268.—THE LEFT NAVICULAR. (Anterior view.)

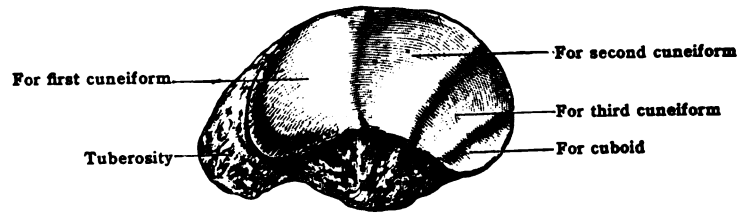


The tuberosity can be easily distinguished by palpation and constitutes an important surgical landmark of the foot.

Articulations.—With the talus behind, with the three cuneiform bones in front, and occasionally with the cuboid on its lateral aspect.

Ossification.—The nucleus for the navicular appears in the course of the fourth year. The tuberosity of the navicular, into which the *tibialis posterior* acquires its main insertion, occasionally develops separately, and sometimes remains distinct from the rest of the bone.

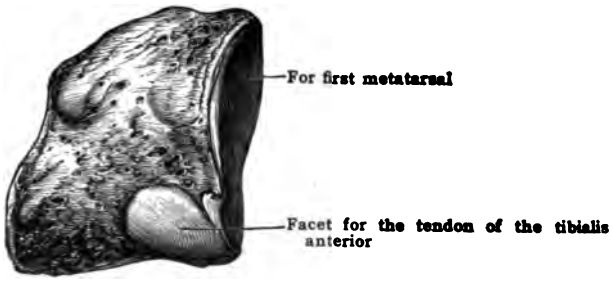
FIG. 269.—THE LEFT NAVICULAR SHOWING A FACET FOR THE CUBOID.



THE CUNEIFORM BONES

Of the three cuneiform bones (figs. 262, 263), the first is the largest, the second is the smallest, and the third intermediate in size. They are wedge-shaped bones placed between the navicular and the first, second and third metatarsal bones. Posteriorly, the ends of the bones lie in the same transverse line, but in front, the first and third project farther forward than the second, and form the sides of a deep recess into which the base of the second metatarsal bone is received.

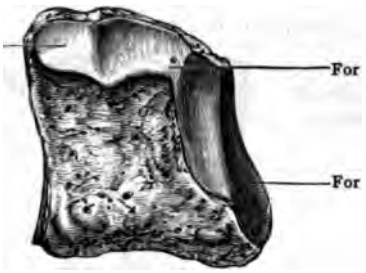
FIG. 270.—THE LEFT FIRST CUNEIFORM. (Medial surface.)



The **first cuneiform** [os cuneiforme primum] (figs. 270, 271) is distinguished by its large size and by the fact that when articulated, the base of the wedge is directed downward and the apex upward. The **posterior surface** is concave and pyriform for articulation with the medial facet on the anterior surface of the navicular. The **anterior surface** forms a reniform articular

he base of the first metatarsal. The **medial surface** is rough, and presents an oblique
: the tendon of the *tibialis anterior;* this groove is limited inferiorly by an oval facet
ı a portion of the tendon is inserted. The **lateral surface** is concave and presents along
or and posterior borders a reversed L-shaped facet for articulation with the second
, and, at its anterior extremity, with the second metatarsal. Anteriorly it is rough

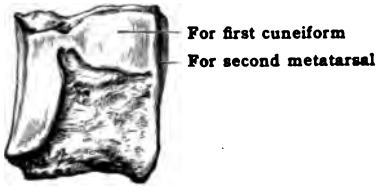
FIG. 271.—THE LEFT FIRST CUNEIFORM. (Lateral aspect.)



nts. The **inferior surface** is rough for the insertion of the *peroneus longus, tibialis* nd (usually) the *tibialis posterior.* The **superior surface** is the narrow part of the l is directed upward.

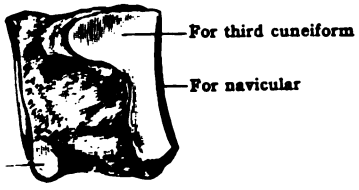
lations.—With the navicular behind, second cuneiform and second metatarsal on side, and first metatarsal in front.

FIG. 272.—THE LEFT SECOND CUNEIFORM. (Medial surface.)



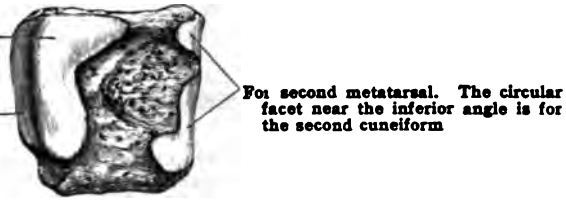
ation.—From a single nucleus which appears in the course of the third year. **econd cuneiform** [os cuneiforme secundum] (figs. 272, 273) is placed with the broad upward and the narrow end downward, and is readily recognized by its nearly se. The **posterior surface,** triangular and concave, articulates with the middle facet terior surface of the navicular. The **anterior surface,** also triangular, but narrower

FIG. 273.—THE LEFT SECOND CUNEIFORM. (Lateral surface.)



posterior surface, articulates with the base of the second metatarsal. The **medial** is a reversed L-shaped facet running along its superior and posterior margins for n with the corresponding facet on the first cuneiform, and is rough elsewhere for the t of ligaments. On the **lateral surface** near its posterior border is a vertical facet, bilobed, for the third cuneiform, and occasionally a second facet at the anterior

FIG. 274.—THE LEFT THIRD CUNEIFORM. (Medial surface.)


For second cuneiform
For navicular
For second metatarsal. The circular facet near the inferior angle is for the second cuneiform

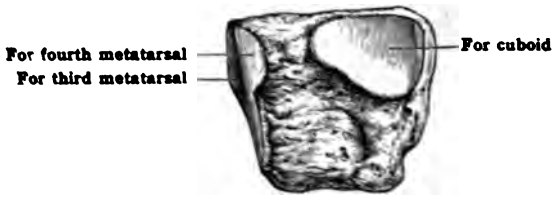
gle. The **superior surface** forms the square-cut base of the wedge and is rough for ment of ligaments. The **inferior surface** is sharp and rough for ligaments and a slip ion of the *tibialis posterior.*

ations.—With the navicular behind, second metatarsal in front, third cuneiform on l side, and first cuneiform on the medial side.

Ossification.—From a single nucleus which appears in the fourth year.

The **third cuneiform bone** (figs. 274, 275) also placed with the broad end directed upward and the narrow end downward, is distinguished by the oblong shape of its base. Like the second cuneiform, the **posterior surface** presents a triangular facet for the navicular; and the **anterior surface** a triangular facet, longer and narrower, for the third metatarsal. The **medial surface** has a large facet extending along the posterior border for the second cuneiform, and along the anterior border a narrow irregular facet for the lateral side of the base of the second

FIG. 275.—THE LEFT THIRD CUNEIFORM. (Lateral surface.)



metatarsal. Occasionally, a small facet is present near the anterior inferior angle for the second cuneiform. The **lateral surface** has a large distinctive facet near its posterior superior angle for the cuboid, and at the anterior superior angle there is usually a small facet for the medial side of the base of the fourth metatarsal. The **superior surface**, oblong in shape, is rough for ligaments, and the **inferior**, forming a rounded margin, receives a slip of the *tibialis posterior* and gives origin to a few fibers of the *flexor hallucis brevis*.

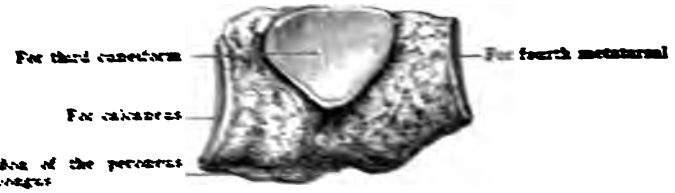
Articulations. With the navicular behind, third metatarsal in front, cuboid and fourth metatarsal on the lateral side, second cuneiform and second metatarsal on the medial side.

Ossification. A single nucleus appears in the course of the first year.

THE CUBOID

The **cuboid** (figs. 276–278), irregularly cubical in shape, is placed on the lateral aspect of the foot, forming a continuous line with the calcaneus and the fourth and fifth metatarsals.

FIG. 276.—THE LEFT CUBOID. (Medial view.)



Its **posterior surface** is [illegible] and presents a saddle-shaped [illegible] for the calcaneus. Its lateral angle is somewhat prolonged backward beneath the [illegible] process of the cuboid, by which the upward or outward movement of the bone is opposed. This process occasionally terminates in a [illegible] at the side of the [illegible] for the calcaneo-navicular ligament. The **anterior surface** is [illegible] by a vertical ridge into two [illegible] facets, the lateral for the base of the fifth and the medial for the base of the fourth metatarsal. The **superior surface** is [illegible] and directed upward. The **inferior surface** presents a [illegible] for the plantar calcaneo-cuboid ligament.

FIG. 277.—THE LEFT CUBOID. (Medial view.)

[illegible]

frequently seen (fig. 277). Generally the two facets are confluent and then form an elliptical surface (fig. 278). The remainder of this surface is rough for the attachment of strong interosseous ligaments.

The **lateral surface,** the smallest and narrowest of all surfaces, presents a deep notch which leads into the peroneal gooves.

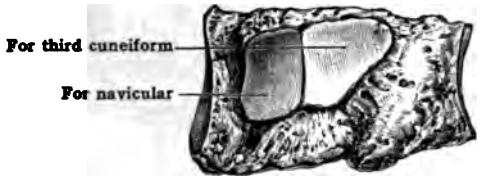
Articulations.—With the calcaneus behind, fourth and fifth metatarsals in front, third cuneiform and frequently the navicular on the medial side; occasionally also the talus.

Ossification.—The cuboid is ossified from a single nucleus which appears about the time of birth.

Accessory tarsal elements.—As in the carpus, a number of additional elements may occur in the tarsus. The most frequent of these is the **os trigonum,** which has already been noticed. Next in frequency is an additional first cuneiform, resulting from the ossification of the plantar half of that bone independently of the dorsal half, so that the bone is represented by a plantar and a dorsal first cuneiform. Other additional elements may occasionally occur at the upper posterior angle of the sustentaculum tali; at the anterior superior angle of the calcaneus, between that bone and the navicular; in the angle between the first cuneiform and the first and second metatarsals; and in the lateral angle between the fifth metatarsal and the cuboid (**os Vesalianum.**)

The lateral portion of the navicular is sometimes united to the cuboid and quite separate from the rest of the navicular, the cuboid in such cases articulating with the talus. This condition suggests the recognition of this portion of the navicular as a distinct accessory tarsal element, the *cuboides secundarium,* though it has not yet been observed as an independent bone in the human foot.

FIG. 278.—THE LEFT CUBOID. (Medial view.)



THE METATARSUS

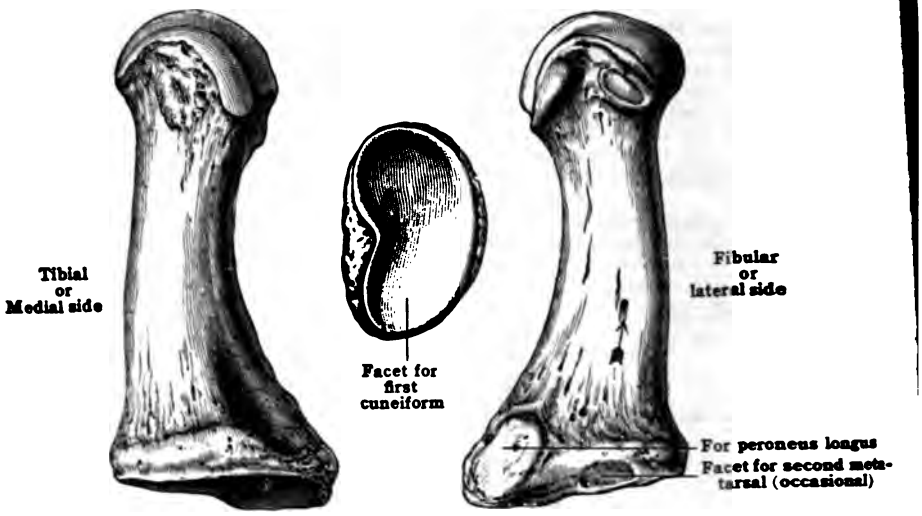
The **metatarsus** [ossa metatarsalia] consists of a series of five somewhat cylindrical bones (figs. 262, 263). Articulated with the tarsus behind, they extend forward, nearly parallel with each other, to their anterior extremities, which articulate with the phalanges, and are numbered according to their position from great toe to small toe. Like the corresponding bones in the hand, each presents a three-sided shaft, a proximal extremity termed the base, and a distal extremity or head. The shaft tapers gradually from the base to the head, and is slightly curved longitudinally so as to be convex on the dorsal and concave on the plantar aspect.

A typical metatarsal bone.—The **shaft** [corpus] is compressed laterally and presents three borders and three surfaces. The two **borders,** distinguished as **medial** and **lateral,** are sharp and commence behind, one on each side of the dorsal aspect of the tarsal extremity, and, gradually approaching in the middle of the shaft, separate at the anterior end to terminate in the corresponding tubercles. The **inferior border** is thick and rounded and extends from the under aspect of the tarsal extremity to near the anterior end of the bone, where it bifurcates, the two divisions terminating in the articular eminences on the plantar aspect of the head. Of the three surfaces, the **dorsal** is narrow in the middle and wider at either end. It is directed upward and is in relation with the extensor tendons. The **medial** and **lateral surfaces,** more extensive than the dorsal, corresponding with the interosseous spaces, are separated above, but meet together at the inferior border; they afford origin to the *interosseous* muscles. The **base** is wedge-shaped, articulating by its terminal surface with the tarsus, and on each side with the adjacent metatarsal bones. The dorsal and plantar surfaces are rough for the attachment of ligaments. The **head** presents a semicircular articular surface for the base of the first phalanx, and on each side a depression, surmounted by a tubercle, for the attachment of the lateral ligaments of the metatarsophalangeal joint. The inferior surface of the head is grooved for the passage of the flexor tendons and is bounded by two eminences continuous with the terminal articular surface.

The several metatarsals possess distinctive characters by which they can be readily recognized

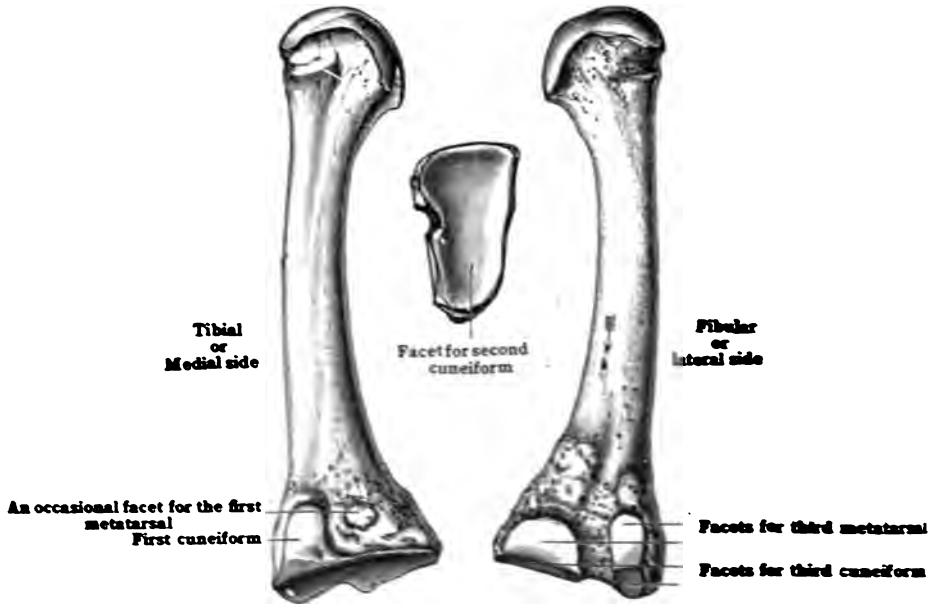
The **first metatarsal** (fig. 279) is the most modified of all the metatarsal bones, and deviates widely from the general description given above. It is the shortest, the thickest, the strongest, and most massive of the series. The **base** presents a large reniform, slightly concave facet for the first cuneiform and projects downward into the sole to form the **tuberosity**, a rough eminence into which the *peroneus longus* and a slip of the *tibialis anterior* are inserted. A little above the tuberosity, on its lateral side, there is occasionally a shallow, but easily recognized

FIG. 279.—THE FIRST (LEFT) METATARSAL.


Tibial or Medial side
Facet for first cuneiform
Fibular or lateral side
For peroneus longus
Facet for second metatarsal (occasional)

facet, for articulation with the base of the second metatarsal. The **head** is marked on the plantar surface by two deep grooves, separated by a ridge, in which the two sesamoid bones of the *flexor hallucis brevis* glide. The **shaft** is markedly prismatic. The **dorsal surface** is smooth, broad, and convex, directed obliquely upward; the **plantar surface** is concave longitudinally and covered by the *flexor hallucis longus* and *brevis*, whilst the **lateral surface** is triangular in outline, almost vertical, and in relation with the first *dorsal interosseous* and *adductor hallucis*

FIG. 280.—THE SECOND (LEFT) METATARSAL.

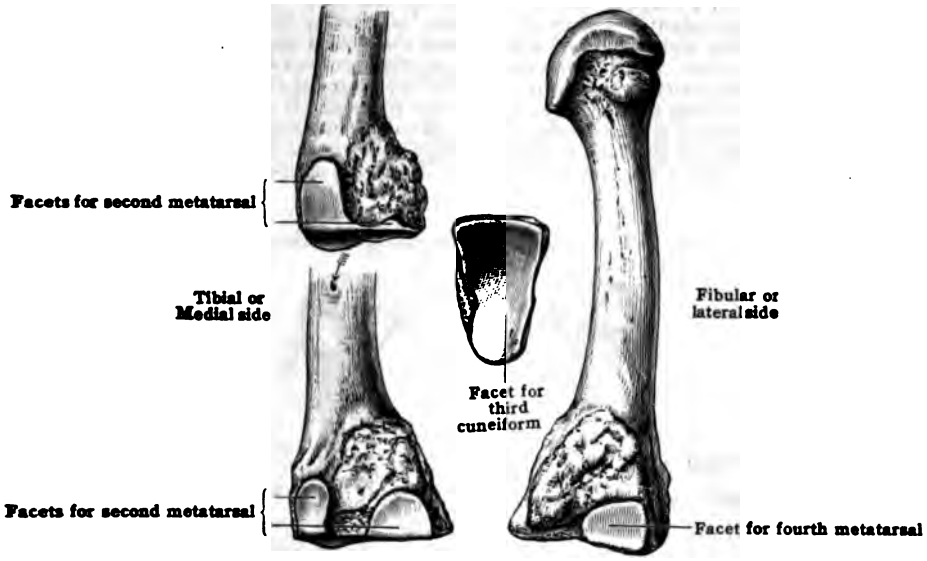

Tibial or Medial side
Facet for second cuneiform
Fibular or lateral side
An occasional facet for the first metatarsal
First cuneiform
Facets for third metatarsal
Facets for third cuneiform

obliquus. A few fibers of the medial head of the first *dorsal interosseous* occasionally arise from the hinder part of the surface adjoining the base, or from the border separating the lateral from the dorsal surface. Somewhere near the middle of the shaft, and on its fibular side, is the nutrient foramen, directed toward the head of the bone.

The second metatarsal (fig. 280) is the longest of the series. **Its base is prolonged backward** to occupy the space between the first and third cuneiform, **and accordingly it is marked**

by facets for articulation with each of these bones. The tarsal surface is triangular in outline, with the base above and apex below, and articulates with the second cuneiform bone. On the tibial side of the base, near the upper angle, is a small facet for the first cuneiform, and occasionally another for the first metatarsal a little lower down. The fibular side of the base presents an upper and a lower facet, separated by a non-articular depression, and each facet is divided by a vertical ridge into two, thus making four in all. The two posterior facets articulate with the third cuneiform and the two anterior with the third metatarsal. The base gives

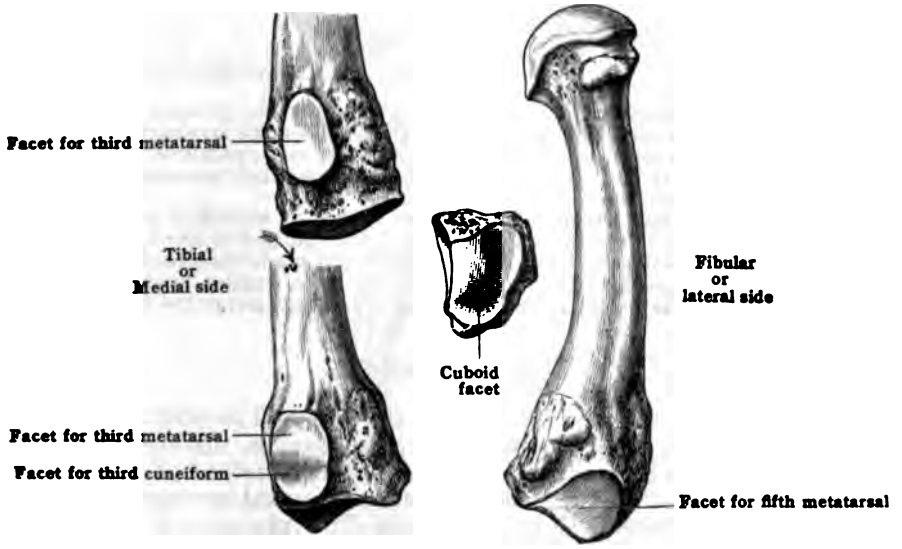
FIG. 281.—THE THIRD (LEFT) METATARSAL.


Facets for second metatarsal
Tibial or Medial side
Facets for second metatarsal
Facet for third cuneiform
Fibular or lateral side
Facet for fourth metatarsal

insertion to a slip of the *tibialis posterior* and the *adductor hallucis obliquus*, while from the shaft the first and second *dorsal interosseous* muscles take origin. The nutrient foramen is situated on the fibular side of the shaft near the middle and is directed toward the base of the bone.

The **third metatarsal** (fig. 281), a little shorter than the second, articulates by the triangular surface of its base with the third cuneiform. On the medial side are two small facets,

FIG. 282.—THE FOURTH (LEFT) METATARSAL.



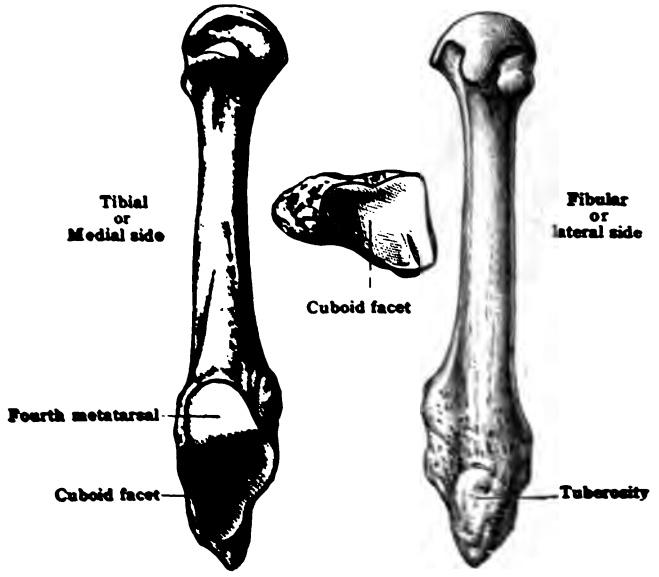
one below the other, for the second metatarsal, and on the lateral side, a single large facet for the fourth metatarsal. The base gives attachment to a slip of the *tibialis posterior* and the *adductor hallucis obliquus*, and from the shaft three *interosseous* muscles take origin. The nutrient foramen is situated on the tibial side of the shaft and is directed toward the base.

The **fourth metatarsal** (fig. 282), smaller in size than the preceding, is distinguished by the quadrilateral facet on the base, for the cuboid. The medial side presents a large facet

divided by a ridge into an anterior portion for articulation with the third metatarsal and a posterior portion for the third cuneiform. Occasionally the cuneiform part of the facet is wanting. On the lateral side of the base is a single facet for articulation with the fifth metatarsal.

The **fifth metatarsal** (fig. 283), is shorter than the fourth, but longer than the first. It is recognized by the large nipple-shaped process, known as the **tuberosity,** which projects on the lateral side of the base. It constitutes the hindmost part of the bone and gives insertion to the *peroneus brevis* on the dorsal aspect, and *flexor brevis digiti quinti* and the occasional *abductor ossis metatarsi quinti* on the plantar aspect. The fifth metatarsal articulates behind by an obliquely directed triangular facet with the cuboid, and on the medial side with the fourth metatarsal. The plantar aspect of the base is marked by a shallow groove which lodges the tendon of the *abductor digiti quinti,* and the dorsal surface, continuous with the superior surface of the shaft, receives the insertion of the *peroneus tertius.* The **head** is small and turned somewhat laterally in consequence of the curvature of the shaft in the same direction. The **shaft** differs from that of any of the other metatarsals in being compressed from above downward, instead of from side to side, so as to present superior, inferior, and medial surfaces. It gives origin to the lateral head of the fourth *dorsal interosseous* and the third *plantar interosseous* muscles. The nutrient foramen is situated on its tibial side and is directed toward the base.

FIG. 283.—THE FIFTH (LEFT) METATARSAL.



Ossification.—Each metatarsal ossifies from two centers. The primary nucleus for the shaft appears in the eighth week of embryonic life in the middle of the cartilaginous metatarsus. At birth, each extremity is represented by cartilage, and that at the proximal end is ossified by extension from the primary nucleus, except in the case of the first metatarsal. For this, a nucleus appears in the third year.

The distal ends of the four lateral metatarsals are ossified by secondary nuclei which make their appearance about the third year. Very frequently an epiphysis is found at the distal end of the first metatarsal as well as at its base. The shafts and epiphyses consolidate in a period extending from the fourteenth to twenty-first year, earlier in females, later in males. The sesamoids belonging to the flexor hallucis brevis begin to ossify about the fifth year.

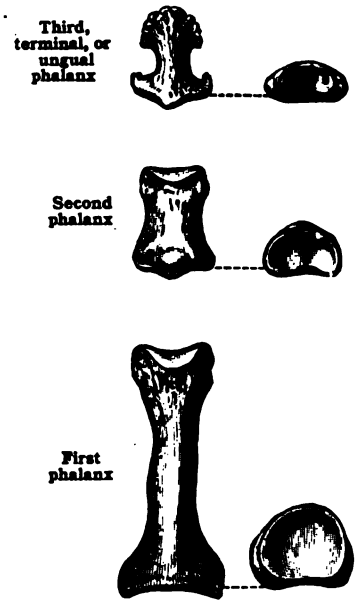
THE PHALANGES

The **phalanges** fig. 284 are the bones of the toes, and number in all fourteen. Except the great toe, each consists of three phalanges, distinguished as first (proximal), second and third (distal); in the great toe the second phalanx is absent. There is thus a similarity as regards number and general arrangement with the phalanges of the fingers. With the exception of the phalanges of the great toe, which are larger than those of the thumb, the bones of the toes are smaller and more rudimentary than the corresponding bones of the fingers. In all the phalanges, the nutrient foramen is directed toward the distal extremity.

The phalanges of the first row are constricted in the middle and expanded at either extremity. The shafts are narrow and laterally compressed, rounded on the dorsal and concave on the plantar aspects. The base of each presents a single oval concave facet for the convex

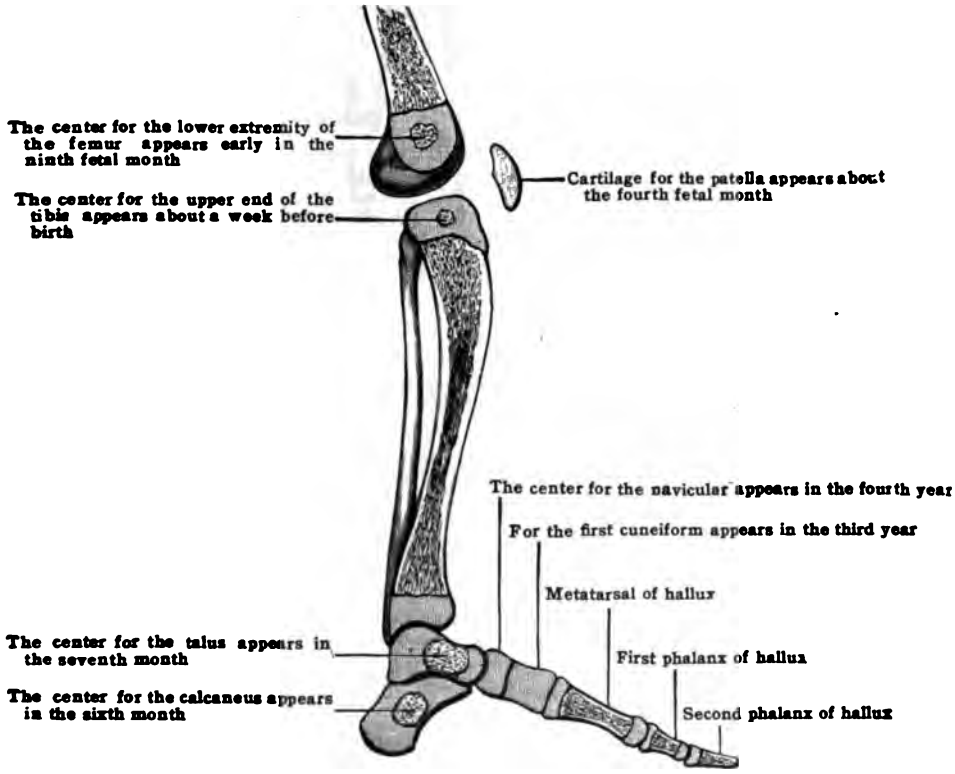
dead of the corresponding metatarsal, whilst the head forms a pulley-like surface [trochlea phalangis], grooved in the center and elevated on each side for the second phalanx.

FIG. 284.—THE PHALANGES OF THE MIDDLE TOE.



The phalanges of the second row are stunted, insignificant bones. Their shafts, beside being much shorter, are flatter than those of the first row. The bases have two depressions separated by a vertical ridge, and the heads present trochlear surfaces for the ungual phalanges

FIG. 285.—A LONGITUDINAL SECTION OF THE BONES OF THE LOWER LIMB AT BIRTH.


The center for the lower extremity of the femur appears early in the ninth fetal month
Cartilage for the patella appears about the fourth fetal month
The center for the upper end of the tibia appears about a week before birth
The center for the navicular appears in the fourth year
For the first cuneiform appears in the third year
Metatarsal of hallux
The center for the talus appears in the seventh month
First phalanx of hallux
The center for the calcaneus appears in the sixth month
Second phalanx of hallux

The third, or ungual phalanges are easily recognized. The bases articulate with the second phalanges; the shafts are expanded, forming the ungual tuberosities which support the nails, and their plantar surfaces are rough where they come into relation with the pulp of the digits.

The muscles attached to the various phalanges may be tabulated thus:—

The **first phalanx of the hallux** gives insertion to the flexor hallucis brevis; abductor hallucis; adductor hallucis transversus and obliquus; extensor digitorum brevis.

The **first phalanx of second toe**: The first and second dorsal interosseous.

The **first phalanx of third toe**: Third dorsal interosseous; first plantar interosseous.

The **first phalanx of fourth toe**: Second plantar interosseous; fourth dorsal interosseous.

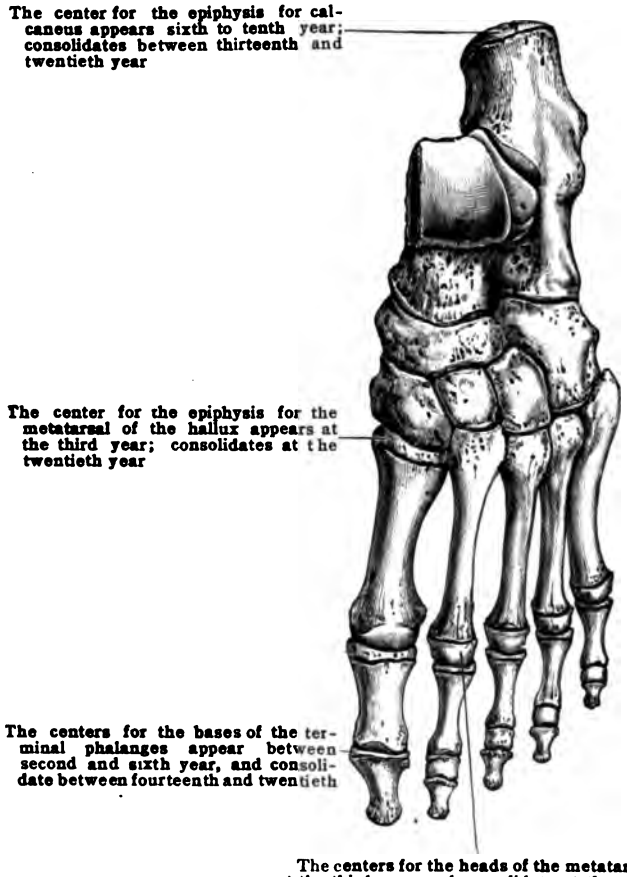
The **first phalanx of fifth toe**: Third plantar interosseous; flexor digiti quinti brevis; and abductor digiti quinti.

The **terminal phalanx of hallux**: Flexor hallucis longus; extensor hallucis longus.

The **second phalanges of the remaining toes**: Dorsal expansion of the extensor tendons, including extensor digitorum longus, extensor digitorum brevis (except in the case of the fifth toe), and expansions from the interossei and lumbricales.

The **third phalanges**: Flexor digitorum longus; dorsal expansion of the extensor tendon with the associated muscles.

FIG. 286.—THE SECONDARY OSSIFIC CENTERS OF THE FOOT.


The center for the epiphysis for calcaneus appears sixth to tenth year; consolidates between thirteenth and twentieth year
The center for the epiphysis for the metatarsal of the hallux appears at the third year; consolidates at the twentieth year
The centers for the bases of the terminal phalanges appear between second and sixth year, and consolidate between fourteenth and twentieth
The centers for the heads of the metatarsals appear at the third year, and consolidate at the twentieth year

Ossification.—Like the corresponding bones of the fingers, the phalanges of the toes ossify from a primary and a secondary nucleus. The centers for the shaft appear during the period extending between the eighth week and tenth month of prenatal life; those for the distal phalanges appear earliest; the middle appear last. The secondary center forms a scale-like epiphysis for the proximal end between the second and sixth years, and union takes place in the fourteenth to seventeenth year—i.e., earlier than the corresponding epiphyses in the fingers. The union occurs earlier in females than in males. The primary centers for the third phalanges appear at the distal extremities of the bones.

SESAMOID BONES

As previously mentioned, the patella is in reality a large sesamoid bone. In the foot a pair of sesamoid bones is constant over the metatarsophalangeal joint of the great toe in the tendons of the flexor hallucis brevis. One sometimes occurs over the interphalangeal joint of the same toe and over the metatarsophalangeal joints of the second and fifth and rarely of the third and fourth toes.

A sesamoid also occurs in the tendon of the peroneus longus, where it glides over the groove in the cuboid; another may be found, especially in later life, in the tendon of the tibialis anterior over the first cuneiform bone, and another in the tendon of the tibialis posterior over the medial

ce of the head of the talus. Further a sesamoid, the *fabella*, sometimes occurs in the al head of the gastrocnemius, and another may be found in the tendon of the iliopsoas the pubis.

BONES OF THE FOOT AS A WHOLE

Arches of the foot.—Although the foot is constructed on the same general plan he hand, there is a marked difference in its architecture to qualify it for the erent functions which it is called upon to perform. When in the erect posture, foot forms a firm basis of support for the rest of the body, and the bones are anged in an elliptical arch, supported on two pillars, a posterior or *calcaneal* ar and an anterior or *metatarsal* pillar. It is convenient, however, to regard anterior part of the arch as consisting of two segments, corresponding to the dial and lateral borders of the foot respectively. The medial segment is made of the three metatarsal bones, the three cuneiform, the navicular, and talus; lateral segment is made up of the fourth and fifth metatarsal bones, the oid, and the calcaneus, and both segments are supported behind on a common *aneal* pillar.

The division corresponds to a difference in function of the two *longitudinal arches*. Both intimately concerned in ordinary locomotion. In addition, the medial, characterized by its t curvature and remarkable elasticity, sustains the more violent concussions in jumping and lar actions, whereas the lateral, less curved, more rigid, and less elastic arch forms, with the rs in front and behind, a firm basis of support in the upright posture.

Both arches are completed and maintained by strong ligaments and tendons. The weakest is the joint between the talus and navicular bone, but this appears to be strengthened by trong calcaneonavicular ligament, for the support of the head of the talus. This ligament is rn supported by its union with the deltoid ligament of the ankle, and by the tendon of the *lis posterior* which passes beneath it to its insertion.

Besides being arched longitudinally, the foot presents a *transverse arch* formed he metatarsal bones in front and the distal row of the tarsus behind. It is luced by the marked elevation of the central portion of the medial longitudinal above the ground, whereas the lateral longitudinal arch is much less raised, at its anterior end becomes almost horizontal. Both the longitudinal and sverse arches serve the double purpose of increasing the strength and elasticity e foot and of providing a hollow in which the muscles, nerves, and vessels of ole may lie protected from pressure.

Homology of the Bones of the Extremities

at there is a general correspondence in the plan of construction of the two extremities is ent to a superficial observer, and this becomes more marked when a detailed examination individual bones, their forms and relations, their embryonic and adult peculiarities, is natically carried out. In each limb there are four segments, the shoulder girdle corre- ing to the pelvic girdle, the arm to the thigh, the forearm to the leg, and the hand to the These parts have been variously modified, in adaptation to the different functions of the mbs. particularly in regard to the deviations or changes from what is considered as their ive position, and as a knowledge of these changes is essential to a clear understanding of mologous bones, it will be advantageous to refer briefly to the relations of the limbs in the t stages of development.

e limbs first appear as flattened, bud-like outgrowths from the sides of the trunk. Each ts a *dorsal* or *extensor* surface, and a *ventral* or *flexor* surface, as well as two borders, *erior*, or *cephalic*, directed toward the head end of the embryo, and a *posterior* or *caudal*, ed toward the tail end. In reference to the axis of the limb itself, the borders have alled *preaxial* and *postaxial*, respectively. When, somewhat later, the various divisions limb make their appearance, it is seen that the greater tuberosity, the lateral epicondyle, dius, and the thumb lie on the preaxial border of the forelimb, and the small trochanter, dial condyle, the tibia, and the great toe on the preaxial border of the hind limb. Further postaxial border of the forelimb are seen the lesser tuberosity, the medial epicondyle, the nd little finger, whilst on the corresponding border of the hind limb are the great trochan- e lateral condyle, the fibula, and the little toe. The parts enumerated on the correspond- orders of the two limbs have been regarded as serially homologous (fig. 287). The pmental flexures and rotation by which the limbs are shifted from their primitive onic to their adult positions have been mentioned (p. 20).

rthermore, as shown in fig. 287, it is evident that the shoulder-girdle and the pelvic- are comparable structures. The scapula probably corresponds to the ilium, and the id process to the ischium. The clavicle (corresponding to the reptilian precoracoid) e the homolog of the clavicle, but this is doubtful.

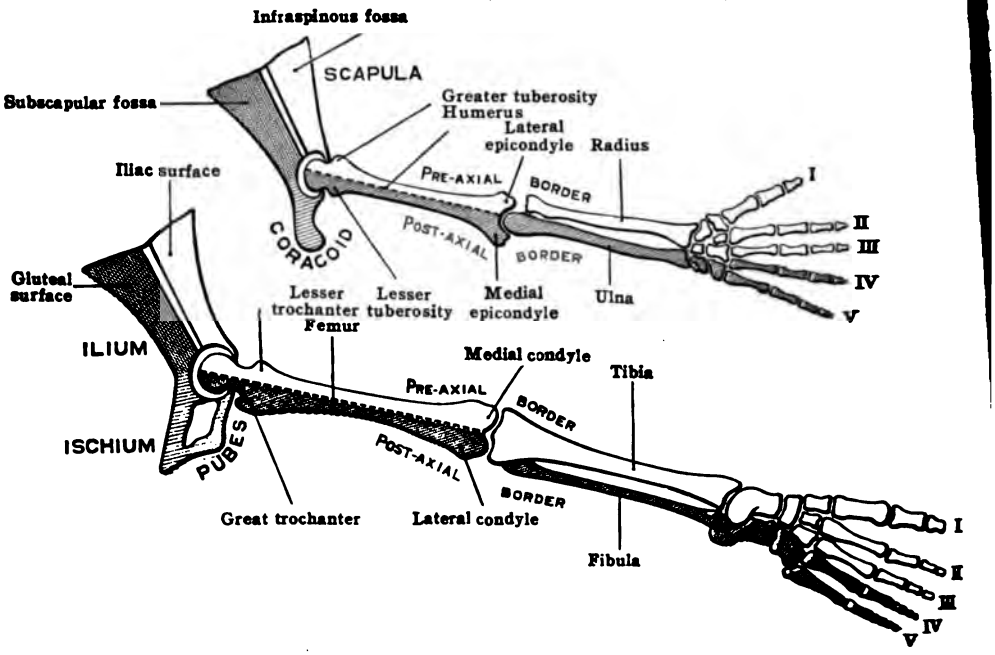
nes of the hand and foot.—The carpus and tarsus, the metacarpus and metatarsus, and rious digits, commencing at the thumb, in the hand, and at the great toe, in the foot, are ed as serially homologous.

order to trace the correspondence between the various elements of the carpus and tarsus nvenient to refer in the first place to a simple type of hand and foot as found in the

water-tortoise and the lizard (fig. 288). In each segment nine elements may be recognised, arranged in a proximal row of three, named respectively *radiale* or *tibiale*, *intermedium*, and *ulnare*, or *fibulare*, a distal row of five *carpalia*, or *tarsalia*, numbered from one to five, commencing at the preaxial border, and between the two rows an *os centrale*.

In man the carpus may be compared with the simple type in the following manner: The radiale forms the navicular, intermedium the lunate, and the ulnare, the triquetral; carpale

FIG. 287.—DIAGRAMMATIC REPRESENTATION OF THE BONES OF THE TWO LIMBS, TO SHOW HOMOLOGOUS PARTS. (Modified from Flower.)



I forms the greater multangular, carpale II the lesser multangular, carpale III the capitate, while carpalia IV and V coalesce to form the hamate. The os centrale is present in the human carpus at an early stage, but in the second month it joins the navicular. It is occasionally separate—a normal arrangement in most of the primates.

In the tarsus, the tibiale and intermedium coalesce to form the talus, and the fibulare becomes the calcaneus. It is interesting to note that although in the human subject there are

FIG. 288.—DORSAL SURFACE OF THE RIGHT MANUS OF A WATER-TORTOISE, *Chelydra serpentina*. (After Gegenbaur.)

three bones in the first row of the carpus and two in the first row of the tarsus, in carnivores the navicular and lunate are united to form a naviculo-lunate bone—the homologue of the talus. In the human tarsus the intermedium occasionally remains distinct as the *os trigonum*.

Tarsale I forms the first cuneiform, tarsale II the second cuneiform, tarsale III the third cuneiform, and tarsale IV and V are joined to form the cuboid. The os centrale forms the navicular.

In addition to the carpal and tarsal elements enumerated above, brief mention must now be made of the sesamoid bones of the two segments, which are regarded by many anatomists

iges of suppressed digits. In the hand are the **ulnar** and **radial sesamoids**, the ulnar epresented by the pisiform and the radial probably by the tuberosity of the navicular mole and other allied species with fossorial habits, the radial sesamoid is greatly de- l to form a sickle-shaped bone which has received the name of *os falciforme*.
corresponding structures in the foot are the **tibial** and **fibular sesamoids**, the tibial nost nearly represented by the tuberosity of the navicular and the fibular by the tuber calcaneus.

erences.—For the *development* of the skeleton, consult the bibliography in Bardeen's in Keibel and Mall's 'Human Embryology,' Vol. 1; for *ossification*, Mall, Am. Jour. of v. V, 1906; Pryor, Bull. State College, Kentucky, 1906 and 1908; Macewen, Growth of 1912. For further references concerning the *adult structure* and *morphology* of the skele- sections on osteology in the larger works on human anatomy by Quain, Poirier-Charpy, ardeleben, etc., should be consulted. For *variation* (axial skeleton) LeDouble, 1903, 912. On *anthropology*, Cunningham, (lumbar curve). Proc. Roy. Soc., 1887; Hrdlicka *pometry)*, 1920. *Cranium*, Macklin, Am. Jour. Anat. v. 16, 1914; Noordenbos, in Petrus r, 1905; Shaeffer, Nose and Accessory Sinuses, 1920; Terry, Jour. Morph. 1917. Refer- the most recent literature may be found in Schwalbe's Jahresbericht, the Index Medicus the various anatomical journals.

SECTION IV

THE ARTICULATIONS

REVISED FOR THE SIXTH EDITION

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section devoted to the Articulations or Joints deals with the union of the rious parts of the human skeleton. The following structures enter to the formation of joints.

s constitute the basis of most joints. The long bones articulate by their flat by their edges, and the short at various parts on their surfaces. The ends of long bones are expanded, and are composed of cancellous tissue, led by a dense and strong shell of compact tissue.

cartilage which covers the articular ends of the bones is called **articular,** the **hyaline variety.** It is firmly implanted on the bone by one surface, other is smooth, polished, and free, thus reducing friction to a minimum, slight elasticity tends to break jars. It ends abruptly at the edge of the ion, and is thickest over the areas of greatest pressure.

r form of cartilage, the **white fibrous**, is also found in joints:—
interarticular cartilage in diarthrodial joints—viz., in the knee, mandibular, sterno-radiocarpal, and occasionally in the acromioclavicular joint. It is interposed he ends of the bones, partially or completely dividing the synovial cavity into two. o adjust dissimilar bony surfaces, adding to the security of, while it increases the notion at, the joint; it also acts as a buffer to break shocks.
circumferential or marginal fibrocartilages, which serve to deepen the sockets for ion of the heads of bones—e. g., the glenoid ligaments of the shoulder and hip.
r form of marginal plate is seen in the accessory volar ligaments of the fingers and deepen the articulations of the phalanges and add to their security.
connecting fibrocartilage. The more pliant and elastic is the more cellular form, id in the intervertebral disks; while the less yielding and more fibrous form is seen in iac and pubic articulations, where there is little or no movement.

igaments which bind the bones together are strong bands of white fibrous those joints having an articular cavity, they form a more or less perfect capsula articularis], round the articulation. They are pliant but inex- arying in shape, strength, and thickness according to the kind of articu- o which they enter. They are closely connected with the periosteum ones they unite. In some cases—as the ligamenta flava which unite t in contact—they are formed of yellow elastic tissue. Besides the ous structure serving to maintain the bones in apposition, security is in tances brought about by the conformation of articular surfaces, as for at the humeroulnar articulation. Strength is given also by muscles, ndons frequently are in the closest relations with the ligaments. Finally, eric pressure must be taken into consideration as an important factor in ing to the stability of the articulations.

ynovial membrane [stratum synoviale] lines the interior of the fibrous ligaments, thus excluding them, as well as the cushions or pads of fatty uated within and the tendons which perforate the fibrous capsule, from **lar cavity.** It is a thin delicate membrane, frequently forming folds [plicæ] es which project into the cavity of the joint; or, as in the knee, it across the cavity, forming a so-called synovial ligament. In these folds found pads of fatty tissue, which fill up interstices, and form soft between the contiguous bones. The amount of fat that is mormally

present within a joint varies greatly. It is an old observation that although there is always fat in the hip- and knee-joints, there is usually none within the shoulder-joint. Sometimes these fringes become villous and pedunculated, and cause pain on movement of the joints. They contain fibrous tissue and fat, with isolated cartilage cells. The synovial membrane is well supplied with blood, especially near the margins of the articular cartilages and in the fringes. It secretes a thick, glairy fluid (94 per cent. water, albumin, salts, oil) like the white of egg, called **synovia**, which lubricates the joint. Another variety of synovial membrane is seen in the bursæ, which are interposed between various moving surfaces. In some instances bursæ in the neighborhood of a joint may communicate with the synovial cavity of that joint.

Vascular and nervous supply.—Articular cartilage contains neither vessels nor nerves, vessels are present in the perichondrium and the cartilage is nourished by imbibition. Both vessels and nerves are distributed to the ligaments of a joint after the manner of supply to tendons. The nerves are vasomotor and sensory, terminal twigs of the latter being provided with lamellar corpuscles in the case of diarthrodial joints. Frequently a rich anastomatic network of blood-vessels is present over the surface of the articular capsule. The synovial membrane is very vascular in adaptation to the secretion of synovial fluid. Lymphatic vessels are also present. Nerves penetrate to the synovial layer from the ligamentous capsule.

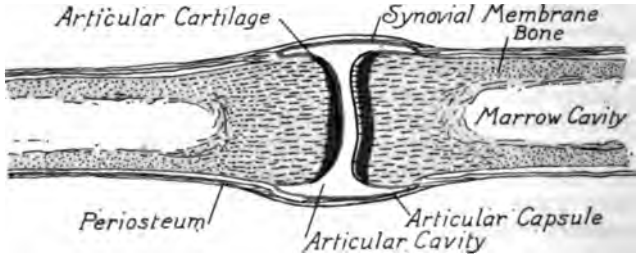
CLASSIFICATION OF ARTICULATIONS

Joints may be classified:—(*a*) From an anatomical point of view, with regard to the substances and the arrangement of the substances by which the constituent parts are united. (*b*) From a physiological standpoint, with regard to the greater or smaller mobility at the seat of union. (*c*) From a physical standpoint, either the shapes of the portions in contact being mainly considered or the axes round which movement can occur. Or again (*d*) a combination of the preceding methods may be adopted, and this is the plan most generally followed. None of the classifications hitherto used is quite satisfactory; that suggested by Macalister with slight modification is utilized here.

There are three chief groups of joints:—

1. *Synarthroses.* In joints of this class the bones are united by fibrous tissue.
2. *Synchondroses.* Joints in which the uniting substance intervening between the bones is cartilage.
3. *Diarthroses.* The constituent parts of joints of this class are (*a*) two or more bones each covered by articular hyaline cartilage; (*b*) a fibrous capsule

FIG. 289.—DIAGRAM OF A DIARTHROSIS.



uniting the bones, and (*c*) a synovial membrane which lines the fibrous capsule and covers any part of bone enclosed in the capsule and not covered with articular cartilage. An interarticular plate of cartilage may or may not be present.

I. **Synarthroses.**—
- (*a*) *Sutures* or immovable joints, in which the fibrous tissue between the bones is small in amount and movement is not permitted.
  - (1) *Harmonic.* The edges of the bones are comparatively smooth and are in even apposition, e.g., vertical plate of palate and maxilla.
  - (2) *Squamous.* The margin of one bone overlaps the other, e. g., temporal and parietal.
  - (3) *Serrate.* The opposed edges interlock by processes tapering to a point.
  - (4) *Dentate.* The opposed edges are dovetailed, e. g., occipital and parietal.
  - (5) *Limbous.* The opposed edges alternately overlap, e. g., parietal and frontal.
  - (6) *Schindylesis.* A ridge or flattened process is received into a corresponding socket, e. g., rostrum of sphenoid and vomer.

(7) *Gomphosis.* A peg-like process is lodged in a corresponding socket, e. g., the fangs of the teeth.

(*b*) *Syndesmoses.* Movable joints in which the fibrous tissue between bones or cartilages is sufficiently lax to allow movement between the connected parts, e.g., thyrohyoid membrane. Interosseous membranes of forearm and leg.

II. **Synchondroses.**—In all synchrondroses a certain amount of movement is possible, and they are often called amphiarthroses.

(1) *True synchondroses.* The cartilage connecting the bones is derived from the bar in which the bones were ossified, e. g., occipitosphenoidal joint.

(2) *False synchondroses.* The plate of cartilage intervening between and connecting the bones is fibrocartilage and is not part of the cartilage in which the bones were ossified, but is developed separately, e. g., intervertebral joint and pubic symphysis. The articular end of each bone may be covered with hyaline cartilage and there may be a more or less well-marked cavity in the intervening plate of fibrocartilage.

III. **Diarthroses.**—In diarthrodial joints the surfaces in contact may be equal and similar or unequal and dissimilar. In the former case the joints are homomorphic; in the latter, heteromorphic.

(*a*) *Homomorphic.*

(1) *Plane or arthrodial.* Flat surfaces, admitting gliding movement, e. g., intercarpal and acromioclavicular joints.

(2) *Ephippial.* Saddle-shaped surfaces, admitting free movement in all directions (except rotation), e. g., carpometacarpal joint of thumb.

(*b*) *Heteromorphic.*

(1) *Enarthrodial.* Ball-and-socket, allowing the most free movement, e. g., hip- and shoulder-joints.

(2) *Condylarthroses.* The convex surface is ellipsoidal, and fits into a corresponding concavity, e.g., wrist and metacarpophalangeal joints.

(3) *Ginglymi.* One surface consists of two conjoined condyles or of a segment of a cone or cylinder, and the opposite surface has a reciprocal contour. In these joints movement is permitted round only one axis, which may be transverse; e. g., elbow, ankle; or it may be vertical, in which case the joint is trochoid; e. g., dens epistrophei with atlas, radius with ulna.

Such a classification should be considered as being purely academic and the student must always remember that it is not enough to discuss a joint by assigning it to a particular class in any scheme; for he must be familiar with the actual conditions present in every joint. No classification, however perfect, must be taken as final, and each joint should be studied as a separate thing altogether apart from any general systematic arrangement.

The movements which may take place at a joint are either gliding, angular, rotatory, or circumductory.

The **gliding** motion is the simplest, and is characteristic of the plane or arthrodial joints; it consists of a simple sliding of the apposed surfaces of the bones upon one another, without angular or rotatory motion. It is the only kind of motion permitted in the carpal and tarsal joints, and in those between the articular processes of the vertebræ.

The **angular** motion is more elaborate, and increases or diminishes the angle between different parts. There are four varieties, viz., *flexion* and *extension*, which bend or straighten the various joints, and take place in a forward and backward direction (in a perfect hinge-joint this is the only motion permitted); and *adduction* and *abduction*, which, except in the case of the fingers and toes, signifies an approach to, or deviation from, the median plane of the body. In the case of the hand, the line to or from which adduction and abduction are made is drawn through the middle finger, while in the foot it is through the second toe.

Rotation is the revolution of a bone about its own axis without much change of position. It is only seen in enarthrodial and trochoidal joints. The knee also permits of slight rotation in certain positions, which is a distinctive feature of this articulation.

Circumduction is the movement compounded of all angular movements in succession, by which the moving bone describes a cone, the proximal end of the bone forming the apex, while the distal end describes the base of the cone. It is seen in the hip and shoulder, as well as in in the carpometacarpal joint of the thumb, which thus approximates to the ball-and-socket joint.

In some situations where a variety of motion is required, strength, security, and celerity are obtained by the combination of two or more joints, each allowing a different class of action, as in the case of the wrist, the ankle, and the head with the spine. Many of the long muscles, which pass over two or more joints, act on all, so tending to co-ordinate their movements and enabling them to be produced with the least expenditure of power. Muscles also act as elastic ligaments to the joints; and when acting as such, are diffusers and combiners, not producers of movement.

Muscles are so disposed at their attachments near the joints as never to strain the ligaments by tending to pull the bones apart; but, on the contrary, they add to the security of the joint by bracing the bones firmly together during their action.

The articulations may be divided for convenience of description into those: (1) of the SKULL; (2) of the TRUNK; (3) of the UPPER LIMB; and (4) of the LOWER LIMB.

THE ARTICULATIONS OF THE SKULL

The movable articulations of the skull comprise (1) the mandibular; and (2) those between the skull and the vertebral column, namely (*a*) between the occiput and atlas; (*b*) between the atlas and epistropheus (axis); and (*c*) the ligaments which connect the occiput and epistropheus. The form of the sutures will be found described in the section on OSTEOLOGY.

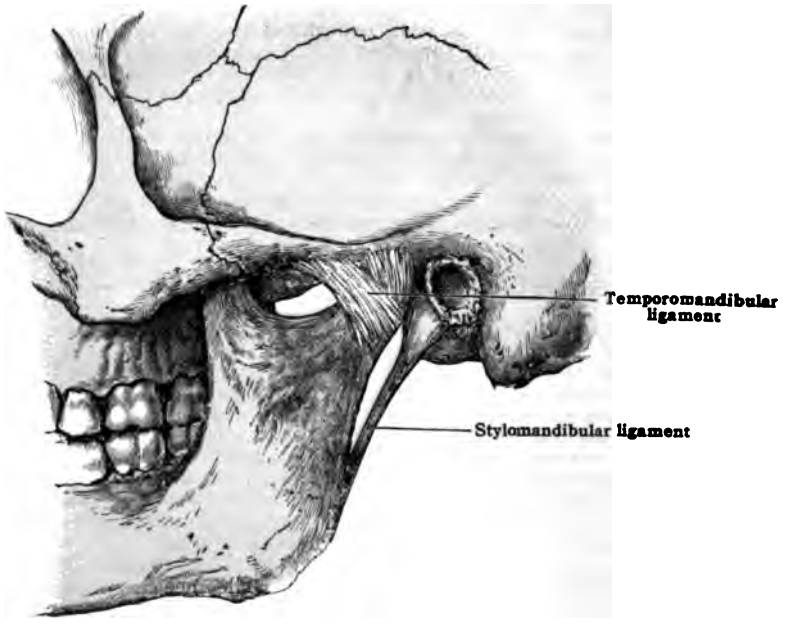
The union of the atlas and epistropheus is described in this section because, (1) there is often a direct communication between the synovial cavity of the transverse epistrophic and the occipitoatlantal joints; (2) the rotatory movements of the head take place around the dens (odontoid process); and (3) important ligaments from the dens pass over the atlas to the occiput.

(1) THE MANDIBULAR ARTICULATION

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

The parts entering into the formation of this joint (figs. 290, 291) are:—the anterior portion of the mandibular fossa and articular tubercle [tuberculum articulare] constituting the articular surface of the temporal bone above, and the condyle of the lower jaw below. Both are covered with fibrocartilage, which approximates pure fibrous tissue on the back of the capitulum. The ligaments which unite the bones are:

FIG. 290.—LATERAL VIEW OF THE MANDIBULAR JOINT.



1. Articular capsule.
2. Articular disk.
3. Sphenomandibular.
4. Stylomandibular.

The **articular capsule** is often described as consisting of four portions, anterior, posterior, lateral and medial, which are, however, continuous with one another around the articulation.

1. The **anterior portion** consists of a few stray fibers connected with the anterior margin of the articular disk, and attached below to the anterior edge of the condyle, and above to the front of the articular tubercle. Some fibers of insertion of the external pterygoid muscle pass between them to be inserted into the margin of the articular disk.

2. The **posterior portion** is attached above, just in front of the petrotympanic (Glaserian) fissure, and is inserted into the back of the jaw just below its neck.

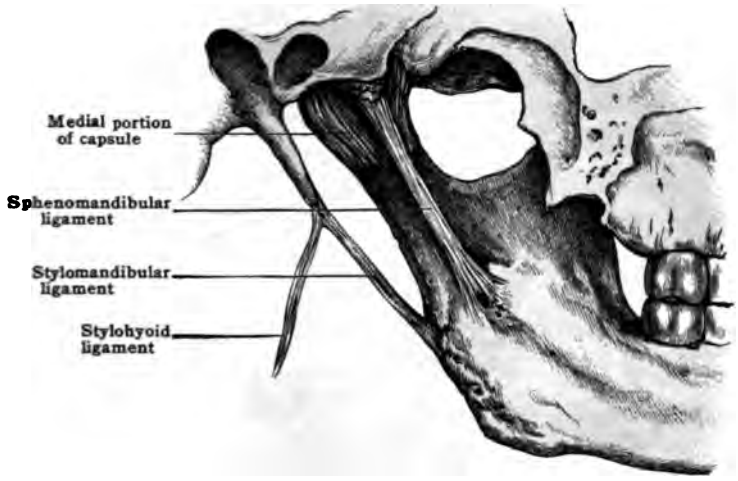
3. The **lateral portion** or **temporomandibular** (external lateral) **ligament** (fig. 290) is the strongest part of the capsule. It is broader above, where it is attached to the lower edge of the zygoma, as well as to the tubercle at the point where the two roots of the zygoma meet. It is inclined downward and backward, to be inserted into the condyle and neck of the mandible laterally. Its fibers diminish in obliquity and strength from before backward, those coming from the tubercle being short and nearly vertical.

4. The **medial portion** (or short internal lateral ligament) (fig. 291) consists of well-defined fibers, having a broad attachment, above to the lateral side of the spine of the sphenoid and medial edge of the mandibular fossa; and below, a narrow insertion to the medial side of the neck of the condyle. Fatty and cellular tissue separate it from the sphenomandibular ligament which is medial to it.

The **articular disk** (fig. 292) is an oval plate of fibrocartilage interposed between and adapted to the two articular surfaces. It is thinner at the center than at the circumference, and is thicker behind, where it covers the thin bone at the bottom of the mandibular fossa which separates it from the dura mater, than in front, where it covers the articular tubercle.

Its *inferior surface* is concave and fits on to the condyle of the lower jaw; while its *superior surface* is concavoconvex from before backward, and is in contact with the articular surface of the temporal bone. It divides the joint into two separate synovial cavities, but is occasion-

FIG. 291.—MEDIAL VIEW OF THE MANDIBULAR JOINT.



ally perforated in the center, and thus allows them to communicate. It is connected with the articular capsule at its circumference, and has some fibers of the external pterygoid muscle inserted into its anterior margin.

There are usually two **synovial membranes** (fig. 292), the superior being the larger and looser, passing down from the margin of the articular surface above, to the upper surface of the articular disk below; the lower and smaller one passes from the articular disk above to the condyle of the jaw below, extending somewhat further down behind than in front. When the disk is perforated, the two sacs communicate.

The **sphenomandibular ligament** (long internal lateral) (fig. 291) is a thin, loose band, situated some little distance from the joint. It is attached above to the spine of the sphenoid and contiguous part of the temporal bone, and below to the lingula of the lower jaw.

It covers the upper end of the mylohyoid groove, and is here pierced by the mylohyoid nerve. Its origin is a little medial to, and immediately behind, the origin of the medial portion of the capsule. It is separated from the joint and ramus of the jaw by the external pterygoid muscle, the internal maxillary artery and vein, the inferior alveolar (dental) nerve and artery, the auriculotemporal nerve, and the middle meningeal artery. It is really the fibrous remnant of a part of the mandibular (Meckelian) bar.

The **stylomandibular ligament** (stylomaxillary) (figs 290, 291) is a process of the deep cervical fascia extending from near the tip of the styloid process

to the angle and posterior border of the ramus of the jaw, between the masseter and internal pterygoid muscles. It separates the parotid from the submaxillary gland, and gives origin to some fibers of the styloglossus muscle.

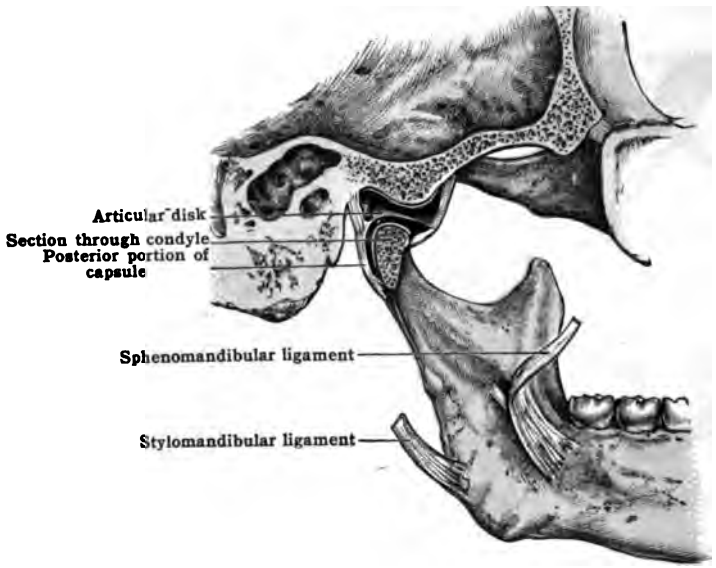
The **arterial supply** of the mandibular joint is derived from the temporal, middle meningeal and ascending pharyngeal arteries, and from the latter by its branches to the Eustachian tube.

The **nerves** are derived from the masseteric and auriculotemporal.

Movements.—(1) The chief movement of this joint is of a **ginglymoid or hinge character**, accompanied by a slight gliding action, as in opening or shutting the mouth. In the opening movement the condyle turns like a hinge on the articular disk, while at the same time the articular disk, together with the condyle, glides forward so as to rise upon the **tuberculum articulare**, reaching as far as the anterior edge of the tubercle; but the condyle never reaches quite so far as the summit of the tubercle. Should the condyle, however, by excessive movement (as in a convulsive yawn), glide over the summit, it slips into the zygomatic fossa, the mandible is dislocated, and the posterior portion of the capsule is torn. In the shutting movement the condyle revolves back again, and the articular disk glides back, carrying the condyle with it. This combination of the hinge and gliding motions gives a tearing as well as a cutting action to the incisor teeth, without any extra muscular exertion.

There is (2) a **horizontal gliding action** in an anteroposterior direction, by which the lower teeth are thrust forward and drawn back again: this takes place almost entirely in the upper compartment, because of the closer connection of the articular disk with the condyle than with

FIG. 292.—SAGITTAL SECTION THROUGH THE CONDYLE OF JAW TO SHOW THE TWO SYNOVIAL SACS AND THE ARTICULAR DISK.



the squamosal bone, and also because of the insertion of the external pterygoid into both bone and cartilage. In these two sets of movements the joints of both sides are simultaneously and similarly engaged.

(3) The form of movement called the **oblique rotatory** is that by which the grinding and chewing actions are performed. It consists in a rotation of the condyle about the vertical axis of its neck in the lower compartment, while the cartilage glides obliquely forward and inward on one side, and backward and inward on the other, upon the articular surface of the squamosal bones, each side acting alternately. If the symphysis be simply moved from the center to one side and back again, and not from side to side as in grinding, the condyle of that side moved round the vertical axis of its neck, and the opposite condyle and cartilage glide forward and inward upon the mandibular fossa. But in the ordinary grinding movement, one condyle advances and the other recedes, and then the first recedes while the other advances, slight rotation taking place in each joint meanwhile. For further details on the movements of the mandibular joint see p. 533.

Relations.—The chief relations are: Behind, and overlapping the lateral side, the parotid gland. Laterally, the superficial temporal artery. Medially, the internal maxillary artery and auriculotemporal nerve. In front, the nerve to the masseter muscle.

Muscles acting on the joint (cf. also p. 373).—*Elevators of the mandible.*—**Temporals, masseters**, internal pterygoids.

Depressors.—Mylohyoid, digastric, geniohyoid, muscles connecting the hyoid bone to lower points. External pterygoid. The weight of the jaw.

Protractors.—External pterygoids, superficial layer of masseter, anterior fibers of temporal.

Retractors.—Posterior fibers of temporal, slightly by the internal pterygoid and deep layer of the masseters.

(2) THE LIGAMENTS AND JOINTS BETWEEN THE SKULL AND VERTEBRAL COLUMN, AND BETWEEN THE ATLAS AND EPISTROPHEUS

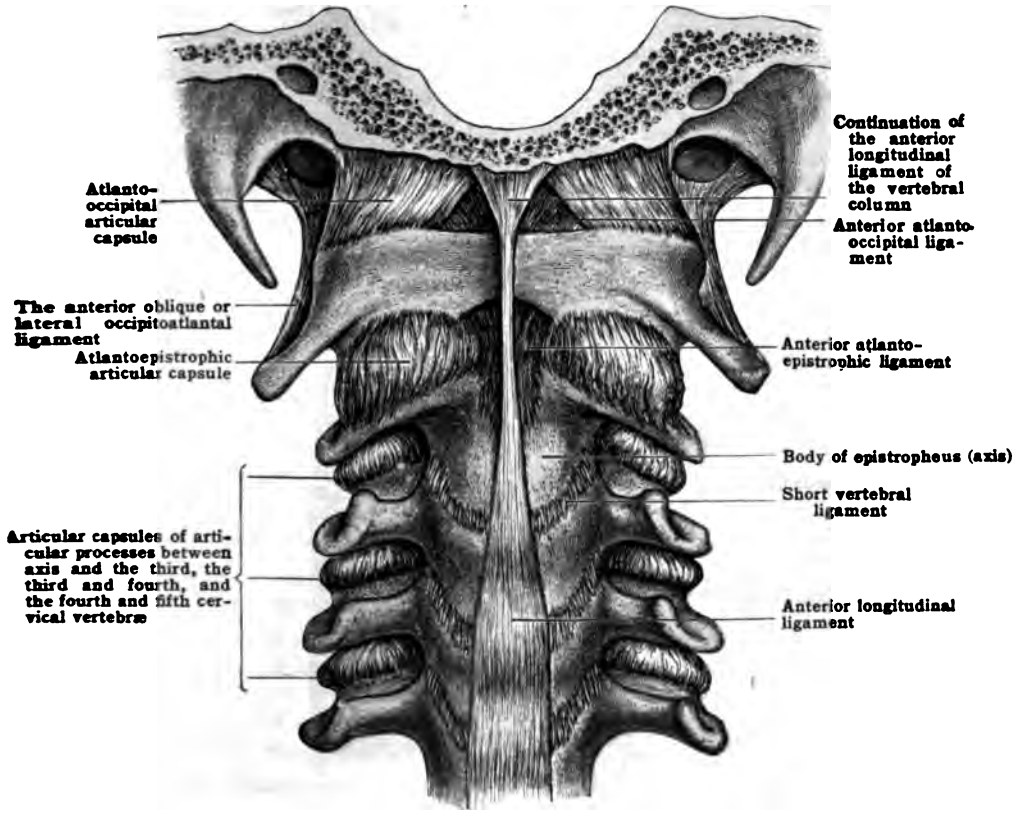
(*a*) The Articulation of the Atlas With the Occiput

Class.—*Diarthrosis.* **Subdivision.**—*Double Condylarthrosis.*

This articulation [articulatio atlantooccipitalis] consists of a pair of joints symmetrically situated on either side of the middle line. The parts entering into their formation are the cup-shaped superior articular processes of the atlas and the condyles of the occipital bone. They are united by the following ligaments:—

1. Anterior atlanto-occipital.
2. Posterior atlanto-occipital.
3. Two articular capsules.
4. Two anterior oblique.

Fig. 293.—Anterior View of the Upper End of the Vertebral Column.


Continuation of the anterior longitudinal ligament of the vertebral column
Atlanto-occipital articular capsule
Anterior atlanto-occipital ligament
The anterior oblique or lateral occipitoatlantal ligament
Atlantoepistrophic articular capsule
Anterior atlanto-epistrophic ligament
Body of epistropheus (axis)
Short vertebral ligament
Articular capsules of articular processes between axis and the third, the third and fourth, and the fourth and fifth cervical vertebræ
Anterior longitudinal ligament

The **anterior atlanto-occipital ligament** [membrana atlantooccipitalis anterior] (fig. 293) is about 2 cm. wide, and is composed of densely woven fibers most of which radiate slightly lateralward as they ascend from the front surface and upper margin of the anterior arch of the atlas to the anterior border of the foramen magnum; it is continuous at the sides with the articular capsules, the fibers of which overlap its edges, and take an opposite direction medially and upward.

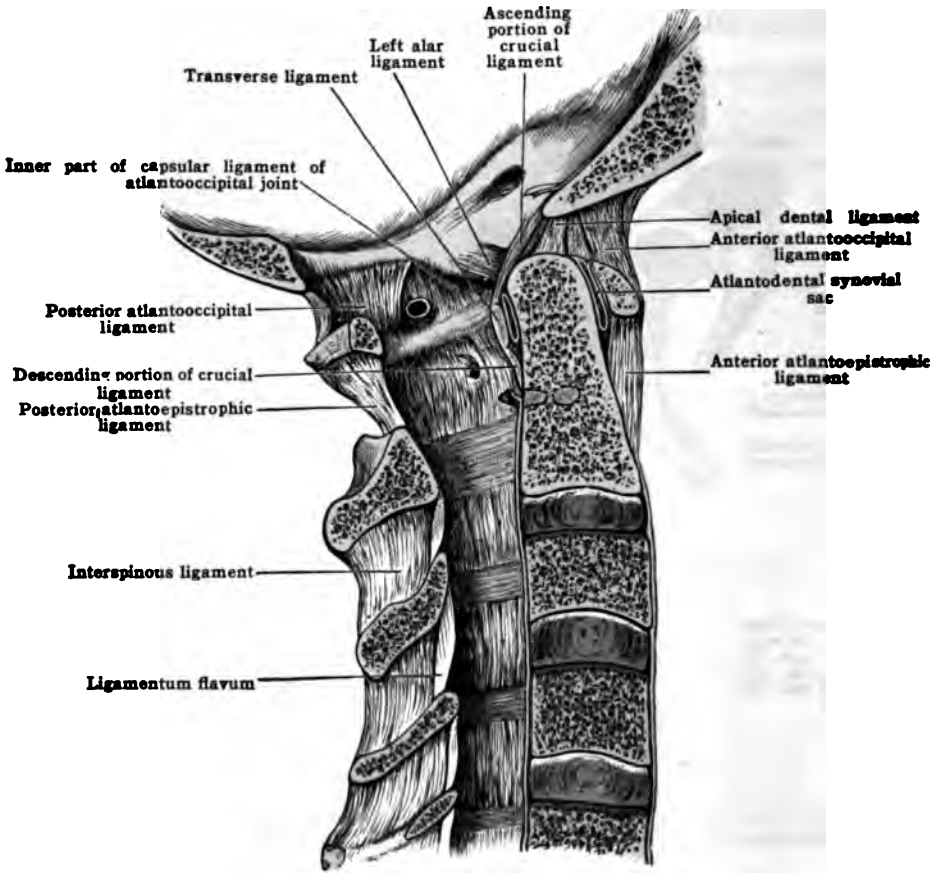
The central fibers ascend vertically from the anterior tubercle of the atlas to the pharyngeal tubercle on the occipital bone; they are thicker than the lateral fibers,and are continuous below with the superficial part of the anterior atlantoepistrophic ligament, and through it with the anterior longitudinal ligament of the vertebral column. It is in relation, in front, with the recti capitis anteriores; and behind, with the apical dental or suspensory ligament.

The **posterior atlanto-occipital ligament** (fig. 294) is broader, more membranous, and not so strong as the anterior. It extends from the posterior surface and upper border of the posterior arch of the atlas to the posterior margin of the foramen magnum from condyle to condyle; being incomplete on either side for the

passage of the vertebral artery into, and suboccipital nerve out of, the canal. It is somewhat thickened in the middle line by fibers, which pass from the posterior tubercle of the atlas to the lower end of the occipital crest.

It is not tightly stretched between the bones, nor does it limit their movements; it corresponds with the position of the ligamenta flava, but has no elastic tissue in its composition. It is in relation in front with the dura mater, which is firmly attached to it; and behind with the recti capitis posteriores minores and enters into the floor of the suboccipital triangle. Its lateral margins, which do not reach the occipital bone but terminate on the posterior end of the superior articular processes of the atlas, form the so-called *oblique ligaments of the atlas*. The lateral margins of these ligaments are free and they form the posterior boundaries of the apertures through which the vertebral arteries enter and the suboccipital nerves leave the vertebral canal.

FIG. 294.—MEDIAN SAGITTAL SECTION OF VERTEBRAL COLUMN SHOWING LIGAMENTS.



The **atlanto-occipital articular capsules** (figs. 293 and 294) are very distinct and strongly marked, except on the medial side, where they are thin and formed only of short membranous fibers. They are lax, and do not add much to the security of the joint.

In front, the capsule descends upon the atlas, to be attached, some distance below the articular margin, to the front surface of the lateral mass and to the base of the transverse process; these fibers take an oblique course upward and medialward, overlapping the anterior atlanto-occipital. At the sides and behind, the capsule is attached above to the margins of the occipital condyles; below, it skirts the medial edge of the foramen for the vertebral artery, and behind is attached to the prominent tubercle overhanging the groove for that vessel; these latter fibers are strengthened by a band running obliquely upward and medialward to the posterior margin of the foramen magnum.

The **anterior oblique** or **lateral occipito-atlantal ligament** is an accessory band which strengthens the capsule laterally (fig. 293). It is an oblique, thick band of fibers, sometimes quite separate and distinct from the rest, passing upward and medialward from the upper surface of the transverse process beyond the costo-transverse foramen to the jugular process of the occipital bone.

The **synovial membrane** of these joints occasionally communicates with the synovial sac between the dens (odontoid process) and the transverse ligament.

The **arterial** supply is derived from twigs of the vertebral, and occasionally from twigs from the meningeal branches of the ascending pharyngeal.

The **nerve-supply** comes from the anterior division of the suboccipital nerve.

Movements (Cf. p. 535).—By the symmetrical and bilateral arrangement of these joints, security and strength are gained at the expense of a very small amount of actual articular surface; the basis of support and the area of action being equal to the width between the most distant borders of the joint.

The principal movement permitted at these joints is of a ginglymoid character, producing flexion and extension upon a transverse axis drawn across the condyles at their slightly constricted parts. In flexion, the forehead and chin drop, and what is called the nodding movement is made; in extension, the chin is elevated and the forehead recedes.

There is also a slight amount of gliding movement, which may be directly lateral, the lateral edge of one condyle sinking a little within the lateral edge of the socket of the atlas, and that of the opposite condyle projecting to a corresponding degree. The head is thus tilted to one side, and it is even possible that the weight of the skull may be borne almost entirely on one joint, the articular surfaces of the other being thrown partly out of contact.

Or the movement may be obliquely lateral, when the lower side of the head will be a trifle in advance of the elevated side. In this motion, which takes place on the anteroposterior axis, one condyle advances slightly and approaches the middle line, while the other recedes. This is of the nature of rotation, though there is no true rotation round a vertical axis possible between the occiput and atlas.

These lateral movements are checked by the alar ligaments and the lateral part of the capsules; extension is checked by the anterior atlanto-occipital and anterior oblique ligaments, and flexion by the posterior part of the capsule and the tectorial membrane.

Muscles acting upon the occipitoatlantal joint (Cf. p. 535).—Flexion whereby the chin is approximated toward the sternum is produced by the weight of the anterior part of the head and by all muscles which are attached to the hyoid bone or to the bones of the skull in front of a transverse axis between the two condyles. These muscles take their fixed point below either from the vertebral column, the sternum, or the bones of the shoulder girdle. Before those connected with the mandible can act that bone must be fixed by the muscles of mastication which, therefore, also take part in the movements.

Extension is due to the action of muscles or portions of muscles inserted into the skull behind the transverse axis above mentioned, and connected below either with the vertebral column, shoulder girdle, or sternum. The sternomastoid muscles are chiefly extensors, although their most anterior portions may serve as flexors of the joint.

Lateral movement is produced by the anterior and posterior groups of muscles on the same side acting simultaneously and aided by the rectus capitis lateralis of that side.

(*b*) The Articulations between the Atlas and Epistropheus (Axis).

1. The Lateral Atlantoepistrophic Joints. { **Class.**—*Diarthrosis.* / **Subdivision.**—*Arthrodia.*
2. The Central Atlantoepistrophic Joint or The Atlantodental. { **Class.**—*Diarthrosis.* / **Subdivision.**—*Trochoides*

The bones that enter into the formation of the lateral joints are the inferior articular processes of the atlas and the superior of the epistropheus (axis); the central joint is formed by the dens (odontoid process) articulating in front with the atlas, and behind with the transverse ligament.

The ligaments which unite the epistropheus and atlas are:—

1. The anterior atlantoepistrophic.
2. The posterior atlantoepistrophic.
3. Two articular capsules (for lateral joints).
4. The transverse ligament.
5. The atlantodental articular capsule.

The **anterior atlantoepistrophic ligament** (figs. 293 and 294) is a narrow but strong membrane filling up the interval between the lateral joints. It is attached above to the front surface and lower border of the anterior arch of the atlas, and below to the transverse ridge on the front of the body of the epistropheus. Its fibers are vertical, and are thickened in the median line by a dense band which is a continuation upward of the anterior longitudinal ligament of the vertebral column.

This band is fixed above to the anterior tubercle of the atlas, where it becomes continuous with the central part of the anterior atlanto-occipital ligament (fig. 293); it is sometimes separated by an interval from the deeper ligament, and is often described as the superficial atlantoepistrophic ligament. It is in relation with the longus colli muscle.

The **posterior atlantoepistrophic ligament** (fig. 294) is a deeper, but thinner and looser membrane than the anterior. It extends from the posterior root of the

transverse process of one side to that of the other, projecting laterally beyond the posterior part of the capsules which are connected with it. It is attached above to the posterior surface and lower edge of the posterior arch of the atlas, and below to the superior edge of the laminæ of the epistropheus on their dorsal aspect.

It is denser and stronger in the median line, and has a layer of elastic tissue on its anterior surface like the ligamenta flava, to which it corresponds in position. It is connected in front with the dura mater; behind, it is in relation with the inferior oblique muscles, and is perforated at each side by the second cervical nerve.

1. The Lateral Atlantoepistrophic Joints are provided with short, ligamentous fibers, forming **articular capsules** (fig. 293), which completely surround the lateral articular facets. Lateral to the canal they are attached some little distance from the articular margins, extending along the roots of the transverse processes of the epistropheus nearly to the tips, but between the roots they skirt the medial edge of the costotransverse foramina. They are strengthened in front and behind by the atlantoepistrophic ligaments. There is a **synovial membrane** for each joint.

Medially each capsule is thinner, and attached close to the articular margins, being strengthened behind by a strong band of slightly oblique fibers passing upward along the lateral edge of the tectorial membrane from the body of the epistropheus to the lateral mass of the atlas behind the transverse ligament; some of these fibers pass on, thickening and blending with the atlantooccipital capsule, to be inserted into the margin of the foramen magnum. This band is sometimes called the **accessory band** (fig. 297).

Fig. 295.—Horizontal Section Through the Lateral Masses of the Atlas and the Top of the Dens (Odontoid Process).

2. The Central Atlantoepistrophic Joint, although usually described as one, is composed of two articulations, which are quite separate from each other: an anterior between the dens and the arch of the atlas, and a posterior between the dens and the transverse ligament.

The **transverse ligament** (figs. 294, 295, 297) is one of the most important structures in the body, for on its integrity and that of the **alar ligaments** our lives largely depend. It is a thick and very strong band, as dense and closely woven as fibrocartilage, about 6 mm. deep at the sides, and somewhat more in the midline. Attached at each end to a tubercle on the inner side of the lateral mass of the atlas, it crosses the ring of this bone in a curved manner, so as to have the concavity forward; thus dividing the ring into a smaller anterior portion for the dens and a larger posterior part for the spinal cord and its membranes, and the spinal accessory nerves.

It is flattened from before backward, [illegible] and covered by synovial membrane to allow it to glide [illegible]. Where it is attached to the atlas it is smooth and [illegible] communication between the transverse and [illegible]

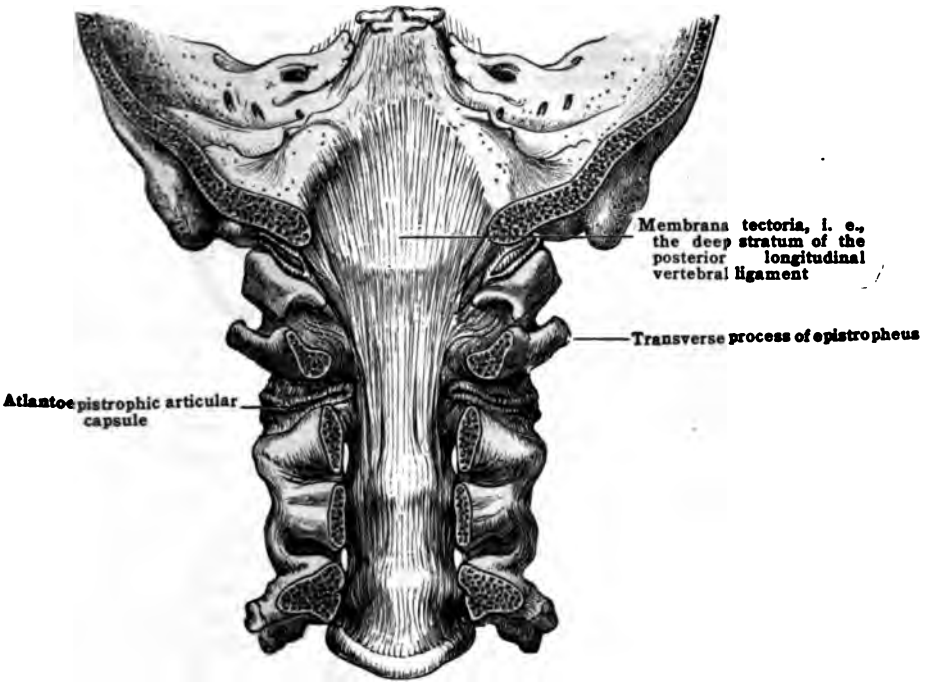
To its posterior surface is added in the middle a strong fasciculus of vertical fibers passing upward from the [illegible] to the basilar border of the foramen magnum, in its [illegible]. Some of these fibers are derived from the transverse ligament. These vertical fibers give the transverse ligament a cruciform appearance, and the whole the **crucial ligament** (figs. 294 and 297) applied to the whole.

The **atlantodental articular capsule** (fig. 295) is a tough, loose membrane, completely surrounding the apposed articular surfaces of the atlas and dens.

At the dens it blends above with the front of the alar and central occipitodental ligaments, and arises also along the sides of the articular facet as far as the neck of the dens; the fibers are thick, and blend with the capsules of the lateral joint. At the atlas they are attached to the nonarticular part of the anterior arch in front of the tubercles for the transverse ligament, blending, above and below the borders of the bone, with the anterior atlanto-occipital and atlantoepistrophic ligaments, as well as with the medial portion of the articular capsules. It holds the dens to the anterior arch of the atlas after all the other ligaments have been divided.

The **synovial membranes** (figs. 294, 295) are two in number:—one for the joint between the dens and atlas; and another (transversodental) for that between the transverse liagment and the dens. This last often communicates with the atlanto-occipital articulations; it is closed in by membranous tissue between the borders of the transverse ligament and the margin of the facet on the dens, and is separated from the front sac by the atlantodental articular capsule.

FIG. 296.—THE TECTORIAL MEMBRANE. DEEP STRATUM OF THE POSTERIOR LONGITUDINAL VERTEBRAL LIGAMENT. SUPERFICIAL LAYER REMOVED. POSTERIOR VIEW.


Membrana tectoria, i. e., the deep stratum of the posterior longitudinal vertebral ligament
Transverse process of epistropheus
Atlantoepistrophic articular capsule

The **arterial supply** is from the vertebral artery, and the **nerve-supply** from the loop between the first and second cervical nerves.

Movements (Cf. p. 536).—The chief and characteristic movement at these joints is the rotation, in a nearly horizontal plane, of the collar formed by the atlas and transverse ligament, round the dens as a pivot, which is extensive enough to allow of an all-round view without twisting the trunk. Partly on account of its ligamentous attachments, and partly on account of the shape of the articular surfaces, the cranium must be carried with the atlas in these movements. The rotation is checked by the ligaments passing from the dens to the occiput (alar ligaments), and also by the atlantoepistrophic. Owing to the fact that the facets of both atlas and epistropheus, which enter into the formation of the lateral atlantoepitrophic articulations, are convex from before backward, and have the articular cartilage thicker in the center than at the circumference, the motion is not quite horizontal but slightly curvilinear. In the erect position, with the face looking directly forward, the most convex portions of the articular surfaces are alone in contact, there being a considerable interval between the edges; during rotation, therefore, the prominent portions of the condyles of the atlas descend upon those of the epistropheus, diminishing the space between the bones, slackening the ligaments, and thus increasing the amount of rotation, without sacrificing the security of the joint in the central position.

Besides rotation, forward and backward movements and some lateral flexion are permitted between the atlas and epistropheus, even to a greater extent than in most of the other vertebral joints.

The muscles acting upon the atlantoepistrophic joints (Cf. p. 536).—The muscles capable of producing rotation at the atlantoepistrophic joints are those which take origin from near the mesial plane, either in front or behind and which are attached above either to the atlas or

the skull, lateral to the atlantoepistrophic joints. When the muscles which lie at the back of the joint on one side act they will turn the head to the same side and will be aided by the muscles in front on the opposite side. If the muscles in front and behind on the same side act simultaneously, they will pull down the head to that side and will be aided by muscles which pass more or less vertically from the transverse process of the atlas to points below.

(*c*) The Ligaments uniting the Occiput and Epistropheus

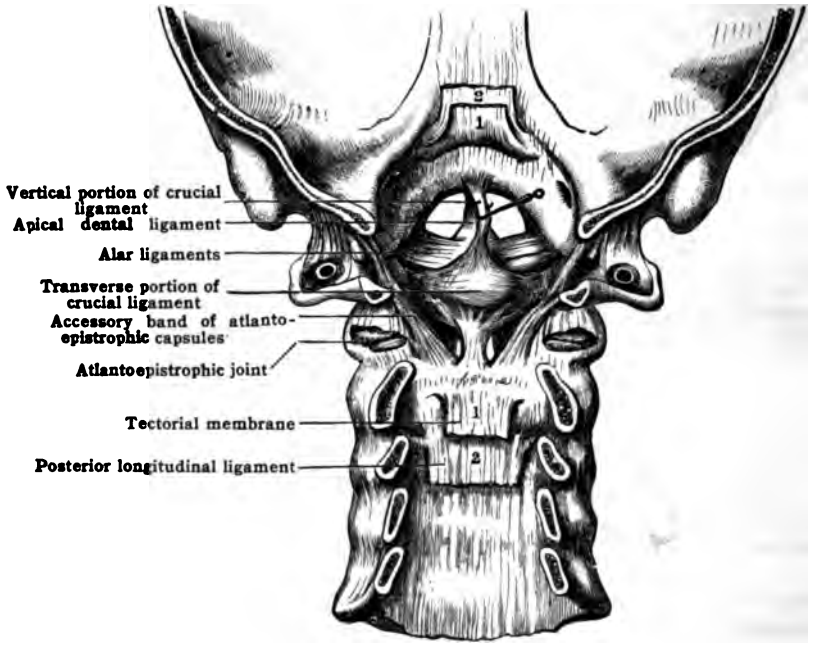
The following ligaments unite bones not in contact, and are to be seen from the interior of the canal after removing the posterior arches of the epistropheus and atlas and posterior ring of the foramen magnum:—

1. The tectorial membrane.
2. The crucial ligament.
3. Two alar (or check) ligaments.
4. The apical dental ligament.

The **tectorial membrane** (occipitocervical ligament) (figs. 295, 297) consists of a very strong band of fibers, connected below to the upper part of the body

Fig. 297.—Coronal Section of the Vertebral Column and the Occipital Bone to show Ligaments.

The tectorial membrane (1), though shown as a distinct stratum, is really the deeper part of the posterior longitudinal ligament (2). The upper ends have been reflected upward, the lower downward. Viewed from behind.)



of the third vertebra and lower part of the body of the epistropheus as far as the root of the dens. It is narrow below, but widens out as it ascends, to be fastened to the basilar groove of the occiput. Laterally, it is connected with the accessory fibers of the atlantoepistrophic capsule. It is really only the upward prolongation of the deep stratum of the posterior longitudinal ligament, the superficial fibers of which run on to the occipital bone without touching the the epistropheus, thus giving rise to two strata. It is in relation in front with the crucial ligament.

The **crucial ligament** has been already described (see p. 264).

The **alar** (or check) **ligaments** (figs. 294, 297) are two strong rounded cords, which extend from the sides of the apex of the dens, transversely lateralward to the medial edge of the anterior portion of the occipital condyles.

They are to be seen immediately above the upper border of the transverse ligament, which they cross obliquely owing to its forward curve at its attachments to the atlas. Some of their fibers occasionally run across the middle line from one alar ligament to the other. At the dens they are connected with the atlantodental capsule, and at the condyles they strengthen the atlanto-occipital articular capsule.

The **apical dental** (or suspensory) ligament (figs. 294, 297) consists of a slender band of fibers ascending from the summit of the dens to the lower surface of the occipital bone, close to the foramen magnum. It is best seen from the front after removing the anterior atlanto-occipital ligament, or from behind by drawing aside the crucial ligament.

The apical ligament is tightened by extension and relaxed by flexion or nodding; the alar ligaments not only limit the rotatory movements of the head and atlas upon the epistropheus, but by binding the occiput to the pivot, round which rotation occurs, they steady the head and prevent its undue lateral inclination upon the vertebral column. (See TRANSVERSE LIGAMENT, p. 264.)

By experiments, it has been proved that the head, when placed so that the orbits look a little upward, is poised upon the occipital condyles in a line drawn a little in front of their middle; the amount of elevation varies slightly in different cases, but the balance is always to be obtained in the human body—it is one of the characteristics of the human figure. It serves to maintain the head erect without undue muscular effort, or a strong ligamentum nuchæ and prominent dorsal spines such as are seen in the lower animals. Disturb this balance, and let the muscles cease to act, the head will either drop forward or backward according as the center of gravity is in front or behind the balance line. The ligaments which pass over the dens to the occiput are not quite tight when the head is erect, and only become so when the head is flexed; if this were not so, no flexion would be allowed; thus, muscular action, and not ligamentous tension, is employed to steady the head in the erect position. It is through the combination of the joints of the atlas and epistropheus, and occiput and epistropheus (consisting of two pairs of joints placed symmetrically on either side of the median line, while through the median line there passes a pivot, also with a pair of joints), that the head enjoys such freedom and celerity of action, remarkable strength, and almost absolute security against violence, which could only be obtained by a ball-and-socket joint; but the ordinary ball-and-socket joints are too prone to dislocations by even moderate twists to be reliable enough when the life of the individual depends on the perfection of the articulation: hence the importance of this combination of joints.

THE ARTICULATIONS OF THE TRUNK

These may be divided into the following sets:—

1. Those of the vertebral column. Joints and ligaments connecting:
   - (*a*) The bodies.
   - (*b*) The articular processes.
   - (*c*) The laminæ.
   - (*d*) The spinous processes.
   - (*e*) The transverse processes.
2. Vertebral column with the pelvis.
3. Pelvis.
   - (*a*) Sacroiliac
   - (*b*) Sacrococcygeal.
   - (*c*) Intercoccygeal.
   - (*d*) Symphysis pubis.
4. Ribs with the vertebral column.
5. The articulations at the front of the thorax.
   - (*a*) Costal cartilages with the sternum.
   - (*b*) Costal cartilages with the ribs.
   - (*c*) Sternal.
   - (*d*) Certain costal cartilages with each other.

1. THE ARTICULATIONS OF THE VERTEBRAL COLUMN

There are two distinct sets of articulations in the vertebral column:—

- (*a*) Those between the bodies and intervertebral disks which form synchondroses and which are amphiarthrodial as regards movement.
- (*b*) Those between the articular processes which form arthroidal joints.

The ligaments which unite the various parts may also be divided into two sets, viz.—**immediate,** or those that bind together parts which are in contact; and **intermediate,** or those that bind together parts which are not in contact.

Immediate.

- (*a*) Those between the bodies and disks.
- (*b*) Those between the articular processes.

Intermediate.

- (*c*) Those between the laminæ.
- (*d*) Those between the spinous processes.
- (*e*) Those between the transverse processes.

(*a*) The Articulations of the Bodies of the Vertebræ

Class.—*False Synchondrosis.*

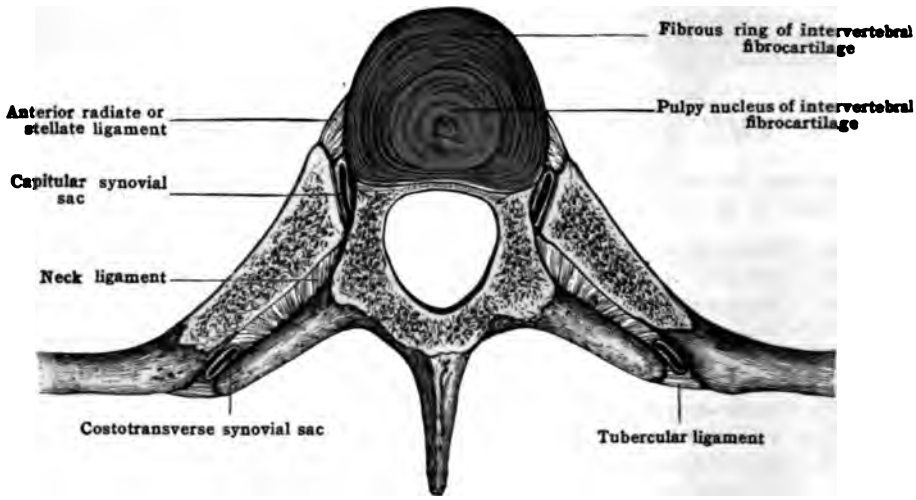
The ligaments which unite the bodies of the vertebræ are:—

Intervertebral fibrocartilages.	Anterior longitudinal.
Short lateral ligaments.	Posterior longitudinal.

The **intervertebral fibrocartilages** (figs. 294, 298) are tough, but elastic and compressible disks of composite structure, which serve as the chief bond of union between the vertebræ. They are twenty-three in number, and are interposed between the bodies of all the vertebræ from the epistropheus to the sacrum (figs. 294 and 304). Similar disks are found between the segments of the sacrum and coccyx in the younger stages of life, but they undergo ossification at their surfaces and often throughout their whole extent.

Each disk is composed of two portions—a circumferential laminar, and a central pulpy portion; the former tightly surrounds and braces in the latter, and forms somewhat more than half the disk. The **fibrous ring** [annulus fibrosus] or laminar portion consists of layers of fibrous tissue and fibrocartilage; the component fibers of these layers are firmly connected with two vertebræ, those of one passing obliquely down and to the right, those of the next down and to the left, making an X-shaped arrangement of the alternate layers. A few of the superficial

Fig. 298.—Horizontal Section Through an Intervertebral Fibrocartilage.



lamellæ project beyond the edges of the bodies, their fibers being connected with the edges of the anterior and lateral surfaces; and some do not completely surround the rest, but terminate at the intervertebral foramina, so that on horizontal section the circumferential portion is seen to be thinner posteriorly. The more central lamellæ are incomplete, less firm, and not so distinct as the rest; and as they near the pulp they gradually assume its characters, becoming more fibrocartilaginous and less fibrous, and have cartilage cells in their structure.

The **pulpy nucleus** [nucleus pulposus] or central portion is situated somewhat behind the center of the disk, forming a ball of very elastic and tightly compressed material, which bulges freely when the confining pressure of the laminar portion is removed by either horizontal or vertical section. Thus, it has a constant tendency to spring out of its confinement in the direction of least resistance, and constitutes a pivot round which the bodies of the vertebræ can twist, tilt, or incline. It is yellowish in color, and is composed of fine white and elastic fibers amidst which are ordinary connective-tissue cells, and peculiar cells of various sizes which contain one or more nuclei. Together with the most central laminæ, it is separated from immediate contact with the bone by a thin plate of articular cartilage. The central pulp of the intervertebral substance is the persistent part of the notochord.

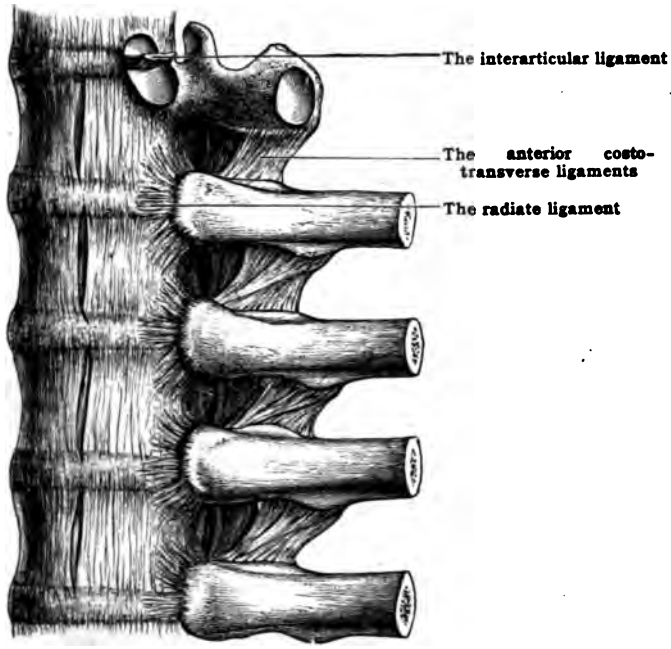
The intervertebral substances vary in shape with the bodies of the vertebræ they unite, and are widest and thickest in the lumbar region. In the cervical and lumbar regions they are thicker in front than behind, thus causing the convexity forward of the cervical, and increasing that of the lumbar region. The curve in the thoracic region, almost entirely due to the shape of the bodies, is, however, somewhat increased by the disks. Without the disks the column loses, a quarter of its length, and assumes a curve with the concavity forward, most marked a little below the midthoracic region. Such is the curve of old age, which is due to the shrinking and drying up of the intervertebral substances. The disk between the epistropheus and third cervical is the thinnest of all (fig. 294); that between the fifth lumbar and sacrum is the thickest, and is much thicker in front than behind (fig. 304). The intervertebral disks are in relation, in

front with the anterior longitudinal ligament; behind, with the posterior longitudinal ligament; laterally, with the short lateral; and in the thoracic region, with the interarticular and radiate ligaments.

In the cervical region lateral diarthrodial joints are placed one on each side of the intervertebral disks. They are of small extent and are confined to the intervals between the prominent lateral lips of the upper surface of the body below and the bevelled lateral edges of the lower surface of the body above.

The **anterior longitudinal ligament** (figs. 293, 299) commences as a narrow band attached to the inferior surface of the occipital bone in the median line, just in front of the atlanto-occipital ligament, of which it forms the thickened central portion. Attached firmly to the tubercle of the atlas, it passes down as the central portion of the atlantoepistrophic ligament, in the midline, to the front of the body of the epistropheus. It now begins to widen out as it descends, until it is nearly 5 cm. wide in the lumbar region. Below, it is fixed to the upper segment of the sacrum, becoming lost in periosteum about the middle of that bone; but is again distinguishable in front of the sacrococcygeal joint, as the anterior sacrococcygeal ligament.

FIG. 299.—THE ANTERIOR LONGITUDINAL LIGAMENT, THE RADIATE, THE INTERARTICULAR, AND THE ANTERIOR COSTOTRANSVERSE LIGAMENTS.



Its structure is bright, pearly-white, and glistening. Its lateral borders are separated from the lateral bands by clefts through which blood-vessels pass; they are frequently indistinct and are best marked in the thoracic region. It is thickest in the thoracic region, and thicker in the lumbar than the cervical. It is firmly connected with the bodies of the vertebræ, and is composed of longitudinal fibers, of which the superficial extend over several, while the deeper pass over only two or three vertebræ. It is connected with the tendinous expansion of the prevertebral muscles in the cervical, and the crura of the diaphragm are closely attached to it in the lumbar region.

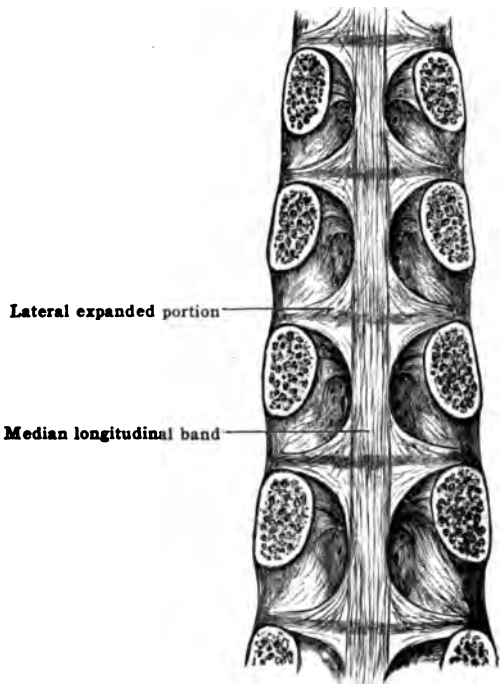
The **posterior longitudinal ligament** (figs. 297, 300, 307) extends from the occipital bone to the coccyx. It is wider above than below, and commences by a broad attachment to the cranial surface of the basioccipital. In the cervical region it is of nearly uniform width, and extends completely across the bodies of the vertebræ, upon which it rests quite flat. It does, however, extend slightly further laterally on each side opposite the intervertebral disks. In the thoracic and lumbar regions it is distinctly dentated, being broader over the intervertebral substances and the edges of the bones than over the middle of the bodies, where it is a narrow band stretched over the bones without resting on them, the anterior internal vertebral venous plexus being interposed. The narrow median portion consists of longitudinal fibers, some of which are super-

ficial and pass over several vertebræ; and others are deeper, and extend only from one vertebra to the next but one below.

The dentated or broader portions (fig. 307) are formed by oblique fibers which, springing from the bodies near the intervertebral foramina, take a curved course downward and backward over an intervertebral fibrocartilage, and reach the narrow portion of the ligament on the center of the vertebra next below; they then diverge to pass over another intervertebral disk to end on the body of the vertebra beyond, near the intervertebral notch. They thus pass over two disks and three vertebræ. Deeper still are other fibers thickening these expansions of the longitudinal ligament, and extending from one bone to the next.

The last well-marked expansion is situated between the first two segments of the sacrum: below this, the ligament becomes a delicate central band with rudimentary expansions, being more pronounced again over the sacrococcygeal joint, and losing itself in the ligamentous tissue at the back of the coccyx. The dura mater is tightly attached to it at the margin of the foramen magnum and behind the bodies of the upper cervical vertebræ, but is separated from it in the rest of its extent by loose cellular tissue which becomes condensed in the sacral region to form the sacrodural ligament. The filum terminale becomes blended with it at the lower part of the sacrum and back of the coccyx.

FIG. 300.—POSTERIOR LONGITUDINAL LIGAMENT. (Thoracic region.)
(Pedicles cut through, and posterior arches of vertebræ removed.)



The **lateral** (or short) **vertebral ligaments** (fig. 299) consist of numerous short fibers situated between the anterior and posterior longitudinal ligaments, and passing from one vertebra over the intervertebral disk, to which it is firmly adherent, to the next vertebra below.

The more superficial fibers are more or less vertical, but the deeper decussate and have a crucial arrangement. They are connected with the deep surface of the anterior longitudinal ligament, and so tie it to the edges of the bodies of the vertebræ and to the intervertebral disks. They blend behind with the expansions of the posterior longitudinal ligament, and so complete the casing round each amphiarthrodial joint. In the thoracic region, they overlie the radiate ligament, and in the lumbar they radiate toward the transverse processes. In the cervical region they are less well marked.

(*b*) THE LIGAMENTS CONNECTING THE ARTICULAR PROCESSES

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The **articular capsules** (fig. 293) which unite these processes are composed partly of yellow elastic tissue and partly of white fibrous tissue. In the cervical

region only the medial side of the capsule is formed by the ligamenta flava, which in the thoracic and lumbar regions, however, extend anteriorly to the margins of the intervertebral foramina.

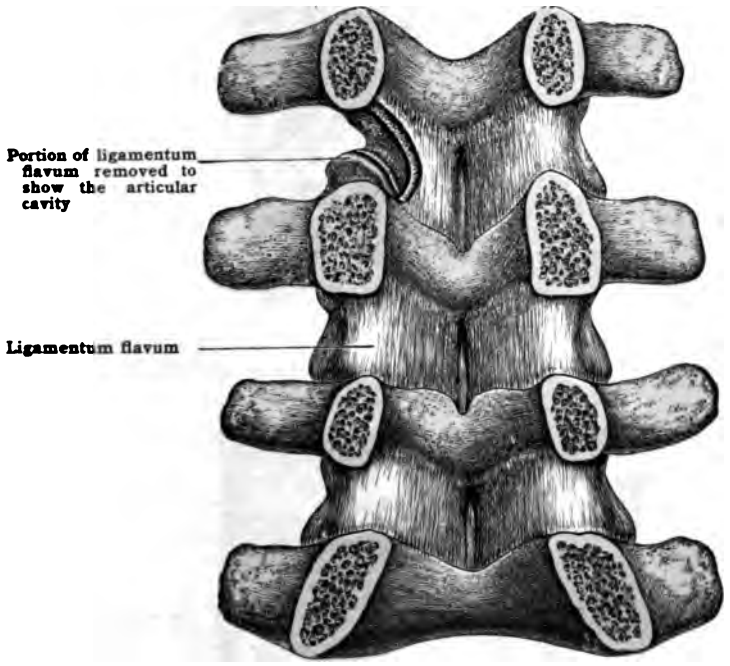
The part formed of white fibrous tissue consists of short, well-marked fibers, which in the cervical region pass obliquely downward and forward over the joint, between the articular processes and the posterior roots of the transverse processes of two contiguous vertebræ. In the thoracic region the fibers are shorter, and vertical in direction, and are attached to the bases of the transverse processes; in the lumbar, they are obliquely transverse. The articular capsules in the cervical region are the most lax, those in the lumbar region are rather tighter and those in the thoracic region are the tightest.

There is one **synovial membrane** to each capsule.

(*c*) The Ligaments uniting the Laminæ

The **ligamenta flava** (fig. 301) are thick plates of closely woven yellow elastic tissue, interposed between the laminæ of two adjacent vertebræ. The first connects the epistropheus with the third cervical, and the last the fifth lumbar with the sacrum. Each ligament extends from the medial and posterior edge of the

Fig. 301.—Ligamenta Flava in the Lumbar Region seen from within the vertebral Canal.



intervertebral foramen on one side to a corresponding point on the other; above, it is attached close to the inner margin of the inferior articular process and to a well-marked ridge on the inner surface of the lamina as far as the root of the spine; below, it is fixed close to the inner margin of the superior articular process and to the dorsal aspect of the upper edge of the lamina.

Thus each ligamentum flavum, besides filling up the interlaminar space, enters into the formation of two articular capsules; they do so to a greater extent in the thoracic and lumbar regions than in the cervical, where the articular processes are placed wider apart. When seen from the front after removing the bodies of the vertebræ, they are concave from side to side, but convex from above downward; they make a more decided transverse curve than the arches between which they are placed. This concavity is more marked in the thoracic, and still more in the lumbar region than in the cervical; in the lumbar region the ligamenta flava extend a short distance between the roots of the spinous process, blending with the interspinous ligament, and making a median sulcus when seen from the front; there is, however, no separation between the two parts. In the cervical region, where the spines are bifid, there is a median fissure in the yellow tissue which is filled up by fibroareolar tissue. The ligaments are thickest and strongest in the lumbar region; narrow but strong in the thoracic; thinner, broader, and more membranous in the cervical region.

(*d*) The Ligaments connecting the Spinous Processes

These include the supraspinous ligament, interspinous ligaments, and the li
mentum nuchæ.

Fig. 302.—Side View of Ligamentum Nuchæ.

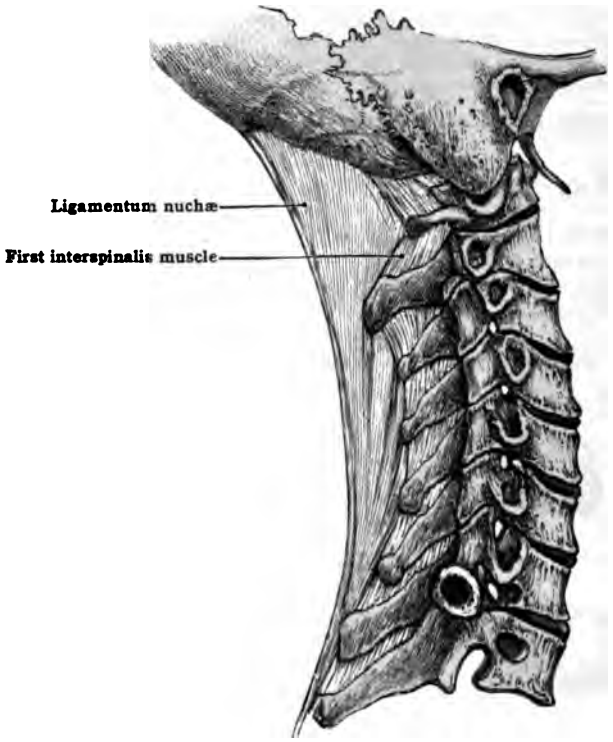
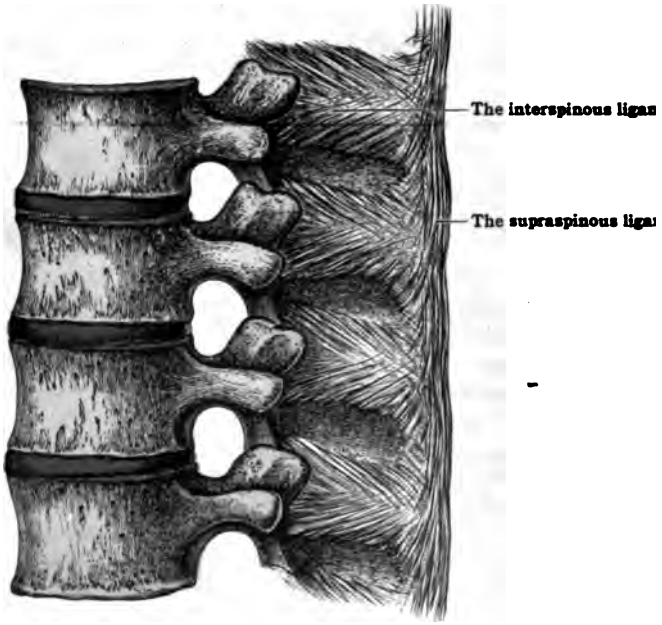


Fig. 303.—The Interspinous and Supraspinous Ligaments in the Lumbar Re



The **supraspinous ligament** (fig. 303) extends without interruption
well-marked band of longitudinal fibers along the tips of the spines of the vert
from that of the seventh cervical downward till it ends on the median sacral c

Its more superficial fibers are much longer than the deep. The deeper fibers pass over adjacent spines only, while the superficial overlie several. It is connected laterally with the aponeurotic structures of the back; indeed, in the lumbar region, where it is well marked, it appears to result from the interweaving of the tendinous fibers of the several muscles which are attached to the tips of the spinous processes. In the dorsal region it is a round slender cord which is put on the stretch in flexion and relaxed in extension of the back.

The **ligamentum nuchæ**, or the posterior cervical ligament (fig. 302), is the continuation in the neck of the supraspinous ligament, from which, however, it differs considerably. It is a slender vertical septum of an elongated triangular form, extending from the seventh cervical vertebra to the external protuberance and the crest of the occipital bone. Its anterior border is firmly attached to the tips of the spines of all the cervical vertebræ, including the posterior tubercle of the atlas, as well as to the occiput. Its posterior border gives origin to the trapezii, with the tendinous fibers of which muscle it blends. Its lateral, triangular surfaces afford numerous points of attachment for the posterior muscles of the head and neck.

In man it is rudimentary, and consists of elastic and white fibrous tissues. As seen in the horse, elephant, ox, and other pronograde mammals, it is a great and important elastic ligament, which even reaches along the thoracic part of the spinal column. In these animals it serves to support the head and neck, which otherwise from their own weight would hang down. Its rudimentary state in man is probably correlated with his erect position.

The **interspinous ligaments** (fig. 303) are thin membranous structures which extend between the spines, and are connected with the ligamenta flava in front, and the supraspinous ligament behind.

The fibers pass obliquely from the root of one spine to the tip of the next; they thus decussate. They are best marked in the lumbar region, and are replaced by the well-developed interspinales muscles in the cervical region.

(*e*) The Ligaments connecting the Transverse Processes

The **intertransverse ligaments** are but poorly developed.

In the thoracic region they form small rounded bundles, and in the lumbar they are flat membranous bands, unimportant as bonds of union. They consist of fibers passing between the apices of the transverse processes. In the cervical region they are replaced by the intertransversarii muscles.

Vessels, Nerves and Movements

The **arterial supply** for the articulations of the vertebral column comes from twigs of the vertebral, ascending pharyngeal, ascending cervical, superior and aortic intercostals, lumbar, iliolumbar, and lateral sacral.

The **nerve-supply** comes from the spinal nerves of each region.

Movements (Cf. p. 536).—The vertebral column is so formed of a number of bones and intervertebral disks as to serve many purposes. It is the axis of the skeleton; upon it the skull is supported; and with it the walls and viscera of the trunk and the limbs are connected. As a fixed column it is capable of bearing great weight, and, through the elastic intervertebral substances, of resisting and breaking the transmission of shocks. Moreover, it is flexible. While the movements between any two vertebræ are slight, the range of movements for the column as a whole is very considerable.

The amount of motion is everywhere limited by the common vertebral ligaments, but depends partly upon the width of the bodies of the vertebræ, and partly upon the depth of the disks, so that in the loins, where the bodies are large and wide, and the disks very thick, free motion is permitted; in the cervical region, though the disks are thinner, yet, as the bodies are smaller, almost equally free motion is allowed. The influence of the articular processes in limiting the direction of inclination will appear from a study of the movements in the three regions of the spine. Were it not for these processes, the column, instead of being steady, endowed with the capacity of movement by muscular agency, would be tottering, requiring muscles to steady it.

In the **neck** all movements are permitted and are free, except between the second and third cervical vertebræ, where they are slight, owing to the shallow intervertebral disk and the great prolongation of the anterior lip of the inferior surface of the body of the epistropheus, which checks forward flexion considerably. On the whole, however, extension and lateral inclination are more free than in any other region of the column, whilst flexion is more limited than in the lumbar region. Rotatory movements are also free, but take place, on account of the position and inclination of the articular facets, not, as in the thoracic region, round a vertical axis, but round an oblique axis, the articular process of one side gliding upward and forward and that of the opposite side downward and backward.

In the **thoracic region**, especially near its middle, anteroposterior flexion and extension are very slight; and, as the concavity of the curve here is forward, the flat and nearly vertical surfaces of the articular processes prevent anything like sliding in a curvilinear manner of the

ocesses over the sharp upper edges of the other, whi
on. A fair amount of lateral inclination would be per
by the ribs; while the position and direction of the artic
vertical axis which passes through the centers of the bod
t very great, and is freer in the upper than in the lower p
nbar region, extension and flexion are very free, especial
ourth and fifth vertebræ, where the lumbar curve is sha
ee between these same vertebræ. It has been stated tha
ar processes of the lumbar and the lower two or three dors
in these regions; but, owing to the fact that the inferior ar
ced by the superior, so that the two sets of articular proc
of the bodies at the same time, there is always some spa
ccur round an axis drawn through the central part of the
t it is very slight. Thus, the motions are most free in thos
convex curve forward, due to the shape of the intervertel
walls surrounding solid viscera, where the spinal canal is la
y attached, and where the pedicles and articular processes
rel with the posterior surface of the bodies of the vertebræ.
the uses of the ligamenta flava be forgotten. These useful
fing-in of the vertebral canal, and yet at the same time perm
he width of the interlaminar spaces in flexion and extension;
ng surfaces to their normal position with regard to each oth
n; (3) and by forming the medial portion of each articular cap
cle in preventing it from being nipped between the articul

which take part in the movements of the vertebral column (Cf. p
with their fellows of the opposite side. Rectus abdominis, s
nomastoid, external oblique, internal oblique, intercostals, scalen
inor, longus colli, longus capitis (rectus capitis anterior major).
: When acting with their fellows of the opposite side. Sacrosp
emispinalis, multifidus, rotatores, interspinales, serrati posterior
scapula fixed the levator scapulæ and the upper fibers of the trap
which help to incline the column to their own side.—Sacrospi
emispinalis, multifidus, the intercostals helping to fix the ribs, th
que muscles, levatores costarum, serrati posteriores, the scalenes, sp
oblique part), rotatores, intertransversales, psoas, and with the sc
ulæ and the upper and lower fibers of the trapezius.
which rotate the column and turn the body to their own side.—Spl
que (the ribs being fixed), serratus posterior inferior, and with the
ers of the trapezius.
which rotate the column and turn the body to the opposite side.—
external oblique, the lower oblique fibers of the longus colli, and with
fixed the latissimus dorsi and trapezius.

2. THE SACROVERTEBRAL ARTICULATIONS

(*a*) **Class.**—*False Synchondrosis.*

(*b*) **Class.**—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

ie intervertebral articulations, so in the union of the first portio
ih the last lumbar vertebra, there are two sets of joints—viz.
osis, between the bodies and intervertebral disk; and (*b*) a p
joints, between the articular processes. The union is effected l
igaments, which are common to the vertebral column:—(1) ant
osterior longitudinal; (3) lateral or short vertebral; (4) capsular
flava; (6) supraspinous and (7) interspinous ligaments. Two sp
ligaments on either side, viz., the sacrolumbar and the iliolum
e pelvis with the fourth and fifth lumbar vertebræ.
crolumbar ligament (fig. 304) is strong, and triangular in shape.
ove and medial, being attached to the whole of the lower border a
ce of the transverse process of the fifth lumbar vertebra, as well as
and body. It is intimately blended with the iliolumbar ligamen
as a wide, fan-shaped attachment, extending from the edge of the ili
ament forward to the brim of the minor (true) pelvis; blending with th
on the base of the sacrum and in the iliac fossa, and with the superio
igament.

arp medial border it limits laterally the foramen for the last lumbar nerve. It
wo large foramina, which transmit arteries to the sacroiliac synchondrosis. Thi
n series with the intertransverse ligaments of the spinal column. It is sometime
a part of the iliolumbar ligament.

disk here than elsewhere, the movements permitted at this joint are very free, being freer than those between any two lumbar vertebræ. As the diameter of the two contiguous bones is less in the sagittal than in the frontal plane, the forward and backward motions are much freer than those from side to side. The backward and forward motions take place every time the sitting is exchanged for the standing position, and the standing for the sitting posture; in rising, the back is extended on the sacrum at the sacrolumbar union; in sitting down it is flexed.

The articular processes provide for the gliding movement incidental to the extension, flexion, and lateral movements; they also allow some horizontal movement, necessary for the rotation of the vertebral column on the pelvis, or pelvis on the column. The inferior articular processes of the fifth differ considerably from the inferior processes in the rest of the lumbar vertebræ, and in direction they resemble somewhat those of the cervical vertebræ; while the superior articular processes of the sacrum differ in a similar degree from the superior processes of the lumbar vertebræ. This difference allows for the freer rotation which occurs at this joint.

The sacrovertebral angle averages 117° in the male, and 130° in the female; while the pelvic inclination averages 155° in the male, and 150° in the female.

As already stated, the movements at the sacrovertebral joint are the same as those in other parts of the spinal column, but more extensive, and the muscles which produce the movements are those mentioned in the preceding groups which cross the plane of the articulation.

3. THE ARTICULATIONS OF THE PELVIS

This group may again be subdivided into—

(*a*) The **sacroiliac articulation** and **sacrosciatic ligaments.**
(*b*) The **sacrococcygeal.**
(*c*) The **intercoccygeal.**
(*d*) The **symphysis pubis** and **obturator membrane.**

(*a*) The Sacroiliac Articulation and Sacrosciatic Ligaments

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

It is now generally admitted that the sacroiliac joint is a diarthrosis, the articular surface of each bone being covered with a layer of cartilage, whilst the cavity of the joint is a narrow cleft and the capsule is extremely thick posteriorly. The cartilage on the sacrum is much thicker than that on the ilium and the cartilages are sometimes bound together here and there by fibrous strands. The different character of the joint in the two sexes should be noted. Briefly, the female joint has strong ligamentous bonds with but little bony apposition, while the male joint gains its strength by virtue of extensive areas of bony contact and a slighter development of ligaments. This difference is, of course, a physiological one; for some laxity of the joint is demanded during pregnancy and labour. The bones which enter the joint are the sacrum and ilium, and they are bound together by the following ligaments:—

Anterior sacroiliac.
Posterior sacroiliac.
Interosseous.

The **anterior sacroiliac ligament** (figs. 304, 305) consists of well-marked glistening fibers which unite the ala and the first three bones of the sacrum to the ilium, blending with the periosteum of the sacrum and ilium as it passes away from the united edges of the bones.

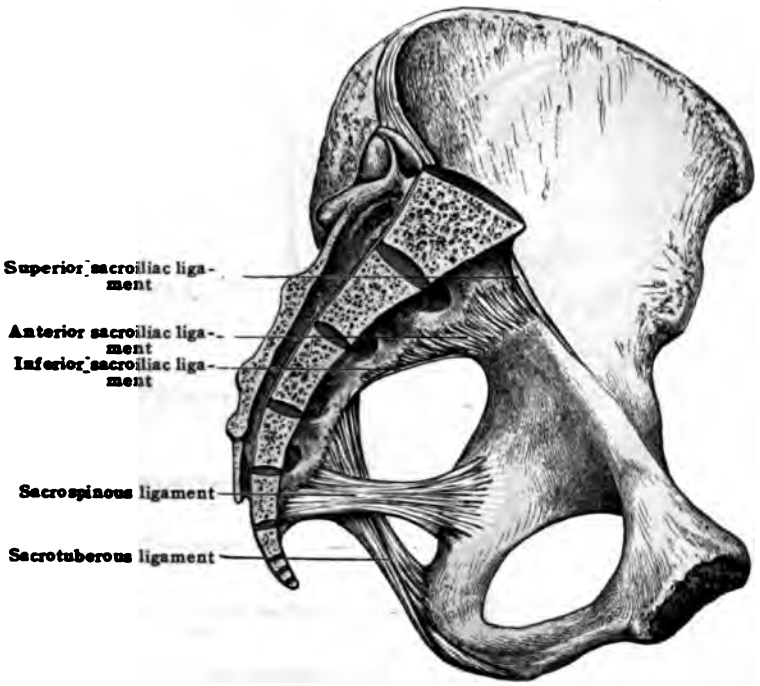
The upper anterior portion of the sacroiliac ligament, extending from the ala to the iliac fossa, is sometimes called the *superior sacroiliac ligament.* A band of fibers from the lateral part of the ala and adjacent ilium to the transverse process of the fifth lumbar vertebra forms the *sacrolumbar ligament* (fig. 304). The lowermost fibers of the anterior sacroiliac ligament, adjacent to the great sciatic notch, are sometimes termed the *inferior sacroiliac ligament* (fig. 305).

The **posterior sacroiliac ligament** (fig. 306) is extremely strong and consists essentially of two sets of fibers, deep and superficial, forming the short and long *posterior sacroiliac ligament* respectively. The *short posterior sacroiliac ligament* [lig. sacroiliacum posterius breve] passes downward and medialward from the rough area of the ilium behind the auricular surface to the back of the lateral mass of the sacrum, and to the upper sacral articular process, and the area between it and the first sacral foramen. The *long posterior sacroiliac ligament* [lig. sacroiliacum posterius longum] passes downward from the posterior superior iliac spine to the second third, and fourth tubercles on the back of the sacrum, and is continuous below with the sacrotuberous ligament.

The **interosseous ligament** is the strongest of all, and consists of fibers of different lengths passing in various directions between the two bones. It extends from the rough surface of the iliac tuberosity to the corresponding surface on the lateral aspect of the sacrum above and behind the auricular surface. Immediately above the interspinous notch of the ilium the fibers of this ligament are very strong, and form an open network, in the interstices of which is a quantity of fat in which the articular vessels ramify.

The ear-shaped **cartilaginous plate,** which unites the bones firmly, is accurately applied to the auricular surfaces of the sacrum and ilium. It is about 2 mm. thick in the center, but becomes thinner toward the edges. Though closely adherent to the bones, it tears away from one entirely, or from both partially, on the application of violence, sometimes breaking irregularly so that the greater portion remains connected with one bone, leaving the other bone rough and bare. It consists of two layers of fibrocartilage, separated by a more or less extensive imperfect synovial cavity. Testut mentions certain folds of synovial membrane filling up gaps which here and there occur at the margin of the fibrocartilage but they are not usually seen.

FIG. 305.—MEDIAN SAGITTAL SECTION OF THE PELVIS, SHOWING LIGAMENTS.



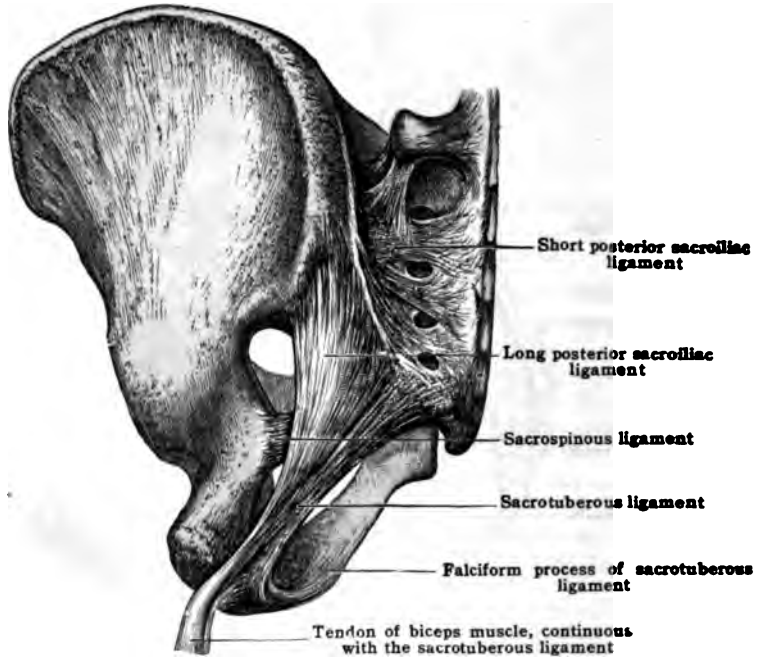
The **sacrotuberous** (great sciatic) **ligament** (figs. 304–306) is attached above to the posterior extremity of the crest of the ilium and the lateral aspect of the posterior iliac spines, in common with the long posterior sacroiliac ligament. From this attachment some of its fibers pass downward and backward to be attached to the lateral borders and posterior surfaces of the lower three sacral vertebræ and upper two segments of the coccyx; while others, after passing for a certain distance backward, curve forward and downward to the ischium, forming the anterior free margin of the ligament where it limits posteriorly the sciatic foramina. These fibers are joined by others which arise from the posterior surfaces of the lower three sacral vertebræ and upper pieces of the coccyx. At the ischium it is fixed to the medial border of the tuberosity, and sends a thin sharp process upward along the ramus of the ischium which is called the **falciform process** (fig. 306), and is a prolongation of the posterior edge of the ligament.

A great many fibers pass on directly into the tendon of the biceps muscle, so that traction on this muscle braces up the whole ligament, and the coccyx is thus made to move on the sacrum. The ligament may not unfairly be described as a tendinous expansion of the muscle, whereby its action is extended and a more advantageous leverage given. It is broad and flat at its attached ends, but narrower and thicker in the center, looking like two triangular expansions joined by a flat band, the larger triangle being at the ilium, and the smaller at the ischium. The fibers of the ligament are twisted upon its axis at the narrow part, so that some of the superior fibers pass to the lower border.

The posterior surface gives origin to the gluteus maximus muscle, and on it ramify the loops from the posterior branches of the sacral nerves; its anterior surface is closely connected at its origin with the sacrospinous ligament, and some fibers of the piriformis muscle arise from it; below, the obturator internus passes out of the pelvis under its cover, and the internal pudic vessels and nerve pass into the perineum. At the ilium, its posterior edge is continuous with the vertebral aponeurosis; while to the anterior edge is attached the thick fascia covering the gluteus medius. The obturator fascia is attached to its falciform edge. It is pierced by the coccygeal branches of the inferior gluteal (sciatic) artery and the inferior clunial (perforating cutaneous) nerve from the second and third sacral.

The **sacrospinous** (small sciatic) **ligament** (figs. 304–306) is triangular and thin, springing by a broad base from the lateral border of the sacrum and coccyx, from the front of the sacrum both above and below the level of the fourth sacral foramen, and from the coccyx nearly as far as its tip. By its apex it is attached to the front surface and the borders of the ischial spine as far outward as its base. Its fibers decussate so that the lower ones at the coccyx become the highest at the ischial spine; muscular fibers are often seen intermingled with the ligamentous.

FIG. 306.—POSTERIOR SACROILIAC, SACROTUBEROUS AND SACROSPINOUS LIGAMENTS.


Short posterior sacroiliac ligament
Long posterior sacroiliac ligament
Sacrospinous ligament
Sacrotuberous ligament
Falciform process of sacrotuberous ligament
Tendon of biceps muscle, continuous with the sacrotuberous ligament

The sacrospinous ligament is situated in front of the sacrotuberous ligament, with which it is closely connected at the sacrum, and separates the greater from the lesser sciatic foramen [foramen ischiadicum majus; foramen ischiadicum minus]. These are subdivisions of a large space intervening between the sacrotuberous ligament and the hip-bone. The piriformis muscle passes out of the pelvis into the thigh by way of the greater sciatic foramen, and is accompanied by the gluteal and sciatic vessels and nerves. The internal pudendal vessels and nerve and the nerve to the obturator internus muscle also leave the pelvis by this foramen to enter the perineal region through the lesser sciatic opening, by which also the obturator internus muscle passes from the pelvis to its insertion on the femur.

Anteriorly, the sacrospinous ligament gives attachment to the coccygeus muscle, which overlies it. Behind, it is connected with, and hidden by, the sacrotuberous ligament, so that only the lateral inch or less (2 cm.) and a small part of its attachment to the coccyx can be seen; the internal pudic nerve also passes over the posterior surface.

The **arterial supply** of the sacroiliac joint comes from the superior gluteal, iliolumbar, and lateral sacral.

The **nerve supply** is from the superior gluteal, sacral plexus, and external twigs of the posterior divisions of the first and second sacral nerves.

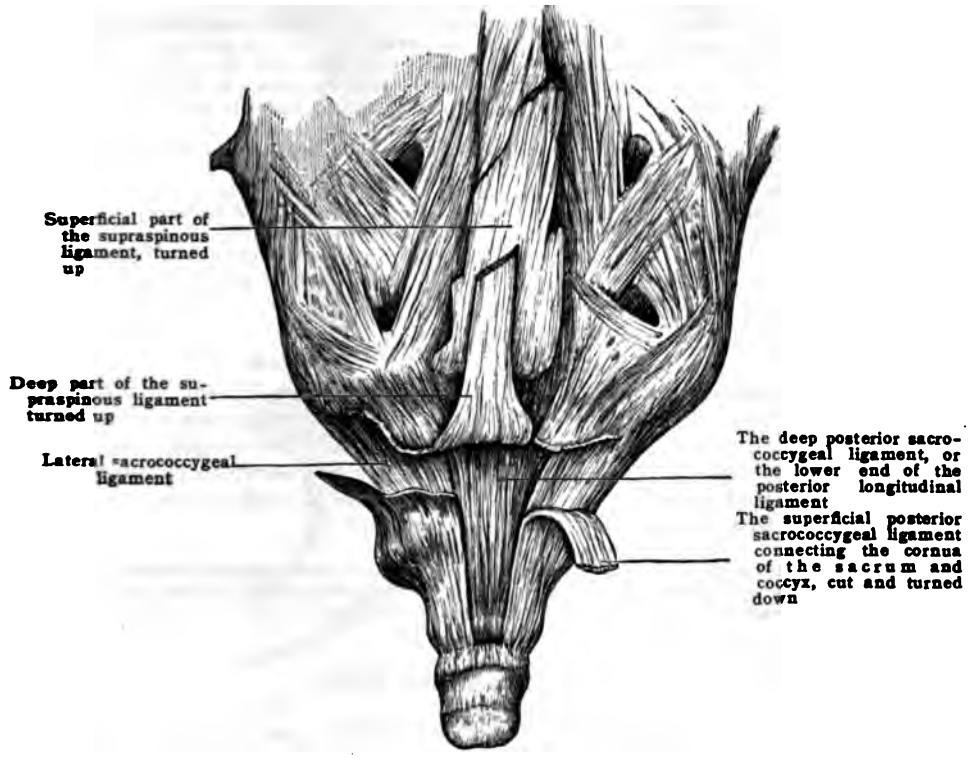
Movements.—Investigations have shown that in spite of the interlocking of the articular surfaces and the strong ligaments connecting the bones together a slight amount of movement, both a gliding and rotatory, does occur at the sacroiliac joint. The gliding movement is both up and down, and forward and backward, and the latter is associated with a slight rotation round a transverse axis which passes through the upper tubercles on the back of the sacrum. The movement is but small in extent, nevertheless as the base of the sacrum moves downward and forward the conjugate (anteroposterior) diameter of the pelvic inlet is diminished and at

the same time, as the coccyx moves up and back, the conjugate diameter of the outlet is increased. This rotatory movement is limited principally by the sacrosciatic (sacrotuberous and sacrospinous) ligaments which prevent any extensive upward and backward movement of the coccyx and lower part of the sacrum.

Downward displacement of the sacrum when the body is in the sitting posture is prevented not only by the surrounding ligaments, but also by the wedge-like character of the sacrum, which is broader above than below. Downward and forward displacement of the sacrum in the erect posture is prevented by the ligaments and more particularly by the posterior sacroiliac bands, while backward displacement would be hindered by the breadth of the anterior as contrasted with the posterior part of the sacrum as well as by the anterior ligaments.

Relations.—The sacroiliac joint is in relation above with psoas and iliacus. In front it is in relation at its upper part with the hypogastric vessels and obturator nerve, and at its lower part with the piriformis muscle.

FIG. 307.—LIGAMENTS CONNECTING SACRUM AND COCCYX POSTERIORLY.


Superficial part of the supraspinous ligament, turned up
Deep part of the supraspinous ligament turned up
Lateral sacrococcygeal ligament
The deep posterior sacrococcygeal ligament, or the lower end of the posterior longitudinal ligament
The superficial posterior sacrococcygeal ligament connecting the cornua of the sacrum and coccyx, cut and turned down

(*b*) THE SACROCOCCYGEAL ARTICULATION

Class.—*False Synchondrosis*

The last piece of the sacrum and first piece of the coccyx enter into this union [symphysis sacrococcygea] and are bound together by the following ligaments:–

Anterior sacrococcygeal. Deep posterior sacrococcygeal.
Superficial posterior sacrococcygeal. Lateral sacrococcygeal.
Intervertebral fibrocartilage.

The **intervertebral fibrocartilage** is a small oval disk, about 2 cm. wide, and a little less from before backward, closely connected with the surrounding ligaments. It resembles the other disks in structure, but is softer and more jelly-like, though the laminæ of the fibrous portion are well marked.

The **anterior sacrococcygeal ligament** is a prolongation of the glistening fibrous structure on the front of the sacrum. It is really the lower extremity of the anterior longitudinal ligament, which is thicker over this joint than over the central part of either of the bones.

The **posterior sacrococcygeal ligament** (fig. 307) is divided into two layers of which one (the **deep**) is a direct continuation of the posterior longitudinal ligament of the column, consisting of a narrow band of closely packed fibers,

which become blended at the lower border of the first segment of the coccyx with the filum terminale and deep posterior ligament.

The **superficial layer** of the posterior sacrococcygeal ligament (or supracornual ligament), (fig. 307) is the prolongation of the supraspinous which becomes inseparably blended with the aponeurosis of the sacrospinalis (erector spinæ) opposite the laminæ of the third sacral vertebra, and is thus prolonged downward upon the back of the coccyx, passing over and roofing in the lower end of the spinal canal where the laminæ are deficient.

The median fibers (the **supraspinous ligament**) extend over the back of the coccyx to its tip, blending with the deep fibers of the posterior sacrococcygeal ligament and filum terminale; the deeper fibers run across from the stunted laminæ on one side to the next below on the opposite side, and from the sacral cornu on one side to the coccygeal on the opposite, some passing between the two cornu of the same side, and bridging the aperture through which the fifth sacral nerve passes. Its posterior surface gives origin to the gluteus maximus muscle.

The **lateral sacrococcygeal** or **intertransverse ligament** (fig. 307) is merely a quantity of fibrous tissue which passes from the transverse process of the coccyx to the lateral edge of the sacrum below its angle. It is connected with the sacrosciatic ligaments at their attachments, and the fifth sacral nerve escapes behind it. It is perforated by twigs from the lateral sacral artery and the coccygeal nerve.

The **arterial supply** of the sacrococcygeal joint is from the lateral sacral and middle sacral arteries.

The **nerves** come from the fourth and fifth sacral and coccygeal nerves.

The **movements** permitted at this joint are of a simple forward and backward, or hinge-like character. In the act of defecation, the bone is pushed back by the fecal mass, and, in parturition, by the fetus; but this backward movement is controlled by the upward and forward pull of the levator ani and coccygeus. The external sphincter also tends to pull the coccyx forward.

(*c*) Intercoccygeal Joints

The several segments of the coccyx are held together by the anterior and posterior longitudinal ligaments, which completely cover the bony nodules on their anterior and posterior aspects. Laterally, the sacrosciatic ligaments, being attached to nearly the whole length of the coccyx, serve to connect them. Between the first and second pieces of the coccyx there is a very perfect amphiarthrodial joint, with a well-marked intervertebral disk.

Movements.—But little movement occurs as a rule at the sacrococcygeal and intercoccygeal joints, but when the head of the child is passing through the pelvic outlet at birth, the tip of the coccyx is displaced backward, it may be to the extent of one inch.

(*d*) The Symphysis Pubis

Class.—*False Synchondrosis*

The bones entering into this joint are the pubic portions of the hip-bones. This joint is shorter and broader in the female than in the male. The ligaments, which completely surround the articulation, are:—

Superior.	Anterior.
Arcuate.	Interpubic cartilage.

The **superior ligament** (figs. 308, 309) is a well-marked stratum of yellowish fibers which extends lateralward along the crest of the pubis on each side, blending in the middle line with the interosseous cartilage. It gives origin to the rectus abdominis tendon.

The **anterior ligament** (figs. 308, 309) is thick and strong, and is closely connected with the fascial covering of the muscles arising from the body of the pubis. It consists of several strata of thick, decussating fibers of different degrees of obliquity, the superficial being the most oblique, and extending lowest over the joint.

The most superficial descending fibers extend from the upper border of the pubis, cross others from the opposite side about the middle of the symphysis, and are attached to the ramus of the opposite bone. The most superficial ascending fibers come from the arcuate ligament, arch upward, and decussate with other fibers across the middle line, and are lost on the opposite side beneath the descending set. There is another deeper set of descending fibers which arise below the angle, but do not descend so far as the superficial; and a deeper set of ascending, which decussate, and reach higher than the superficial set, and are connected with the arcuate

ligament. Some few transverse fibers pass from side to side, especially above and below the points of decussation.

The **arcuate** (inferior or subpubic) **ligament** (figs. 308, 310) is a thick, arch-like band of closely packed fibers which fills up the angle between the pubic rami, and forms a smooth, rounded summit to the pubic arch. It is yellowish in color and is inseparably connected with the interpubic cartilage.

FIG. 308.—ANTERIOR VIEW OF THE MALE SYMPHYSIS PUBIS, SHOWING THE DECUSSATION OF THE FIBERS OF THE ANTERIOR LIGAMENT.

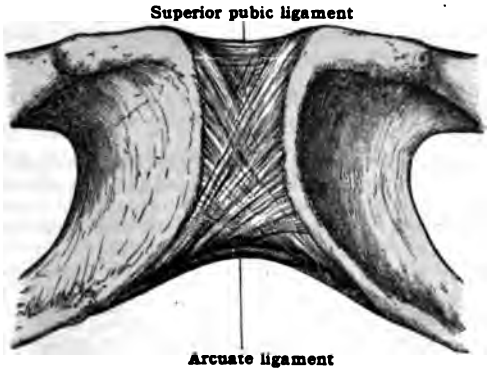


FIG. 309.—ANTERIOR VIEW OF THE FEMALE SYMPHYSIS PUBIS, SHOWING GREATER WIDTH.

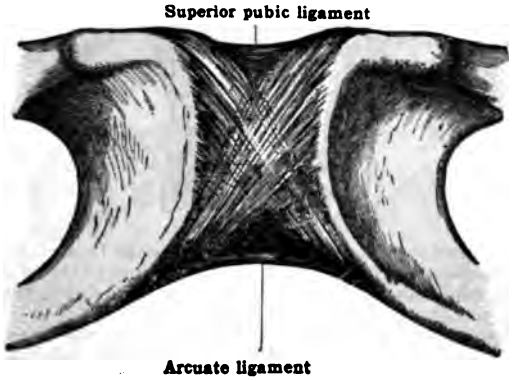
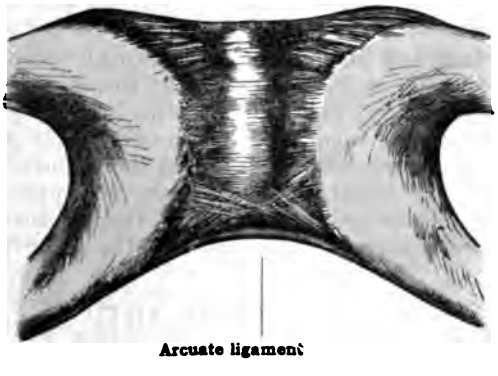


FIG. 310.—POSTERIOR VIEW OF THE SYMPHYSIS PUBIS, SHOWING THE DECUSSATION OF THE FIBERS FROM THE ARCUATE LIGAMENT.



Both on the front and back aspects of the joint it gives off decussating fibers, which, by their interlacement add very materially to the strength of the joint. In fact, the ligament may be said to split superiorly into two layers, one passing over the front, and the other over the back, of the articulation.

The interpubic fibrocartilage [lamina fibrocartilaginea interpubica] varies in different subjects, but is thicker in the female than in the male. It is thicker in front than behind, and projects beyond the edges of the bones, especially

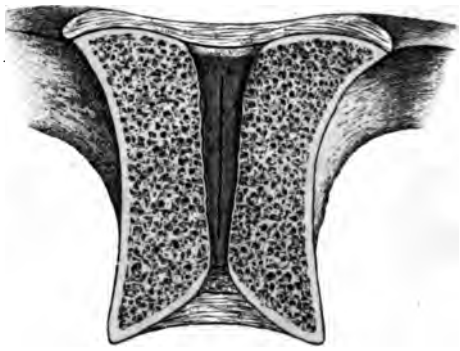
posteriorly (see fig. 310), blending intimately with the ligaments at its margins. It is sometimes uninterruptedly woven throughout, but often presents an elongated narrow fissure, partially dividing the cartilage into two plates, with a little fluid in the interspace (fig. 311). This rudimentary synovial cavity generally extends about half the length of the cartilage.

When this cavity is large, especially if it reaches or approaches very near to the circumference of the cartilage (which, however, it very rarely does), it is thought by some anatomists that it more nearly resembles a diarthrodial than an amphiarthrodial joint, and it is then classed with the sacroiliac joint under similar conditions, as 'diarthroamphiarthrosis.' The interosseous cartilage is intimately adherent to the layer of hyaline cartilage which covers the medial surface of each pubic bone; the osseous surface is ridged to give a firmer attachment; and, on forcing the bones apart, it does not frequently split into two plates, but is torn from the bone on one side or the other.

The **arterial supply** of the interpubic joint is from twigs of the internal pudic, pubic branches of the obturator and epigastric, and ascending branches of the internal circumflex and superficial external pudic.

The **movements** amount only to a slight yielding of the cartilage; neither muscular force nor extrinsic forces produce any appreciable movement in the ordinary condition. Occasionally, as the result of child-bearing, the joint becomes unnaturally loose, and then walking and standing are painfully unsteady. It is known that, during pregnancy and parturition, the

FIG. 311.—SECTION OF SYMPHYSIS TO SHOW THE RUDIMENTARY SYNOVIAL CAVITY.



symphyseal cartilage becomes softer and more vascular, so as to permit the temporary enlargement of the pelvis; but it must be remembered that the fibers of the oblique muscles decussate and thus, during labor, while they force the head of the fetus down, they strengthen the joint by bracing the bones more tightly together.

Relations.—The interpubic joint is in relation above with the linea alba; behind with the prostate and the anterior border of the bladder; in front with the suspensory ligament of the penis or clitoris; and below with the dorsal vein of the penis or clitoris and the upper border of the urogenital diaphragm (triangular ligament).

OBTURATOR MEMBRANE

The **obturator membrane** [membrana obturatoria], composed of fibers having various directions, fills the thyroid (obturator) foramen, its attachment being upon the pelvic side of the bony margin of the opening. Superiorly, it is deficient and a notch remains, which, together with the obturator groove forms a canal traversed by the obturator vessels and nerve in their course from the pelvis into the thigh. Through this canal, the membrane is continuous with the pelvic fascia covering the obturator internus muscle. Both obturator muscles in large part arise from the membrane, one from its outer, the other from its inner surface.

4. THE COSTOVERTEBRAL ARTICULATIONS

These consist of two sets, viz.:—

(*a*) The **capitular** (costocentral): i. e., the articulation of the head of the rib with the vertebræ.

(*b*) The **costotransverse,** or the articulation of the tubercle (of each of the first ten ribs) with the transverse process of the lower of the two vertebræ, with which the head of the rib articulates: i. e., the one bearing its own number, as the first rib with the first thoracic vertebra, the second rib with the second thoracic vertebra, and so on.

(*a*) The Capitular Articulation

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

It is a very perfect joint, into the formation of which the head of the rib and two vertebræ, with the intervertebral disk between them, enter. The articular surfaces of the bones are covered with cartilage. In the case of the first, tenth, eleventh, and twelfth ribs, the capitular joint is formed by the head of the rib articulating with a single vertebra.

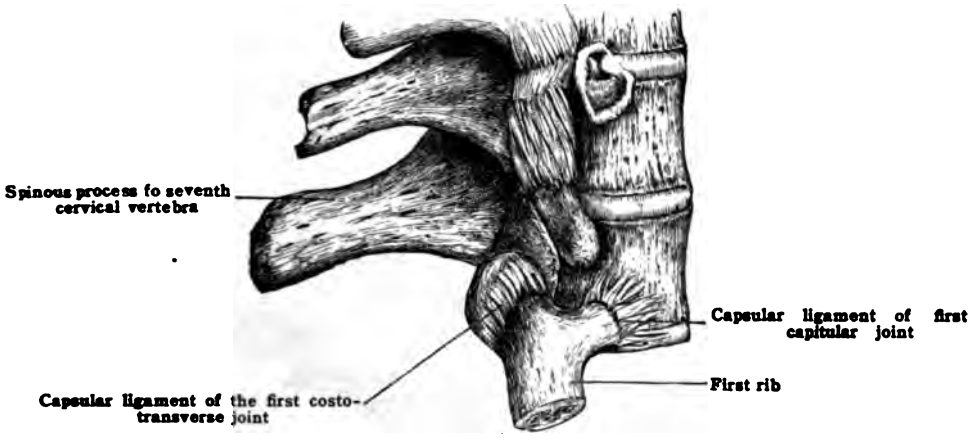
The ligaments are:—

Articular capsule. Interarticular.
Radiate.

The articular capsule (fig. 312) consists of short, strong fibers, completely surrounding the joint, which are attached to the bones and intervertebral disks, a little beyond their articular margins.

At its upper part it reaches through the intervertebral foramen toward the back of the bodies of the vertebræ, being strengthened here by fibers which at intervals connect the anterior with the posterior longitudinal ligaments. The lower fibers extend downward nearly to the demifacet (costal pit) of the rib below; behind, it is continuous with the neck ligament, and in front is overlaid by the radiate.

Fig. 312.—The Capsular Ligaments of the Costovertebral Joints.


Spinous process to seventh cervical vertebra
Capsular ligament of first capitular joint
First rib
Capsular ligament of the first costo-transverse joint

The interarticular ligament (fig. 313) consists of short, strong fibers, closely interwoven with the outermost ring of the intervertebral disk, and attached to the transverse ridge separating the articular facets on the head of the rib. It completely divides the articulation into two parts, but does not brace the rib tightly to the spine, being loose enough to allow a moderate amount of rotation on its own axis. There is no interarticular ligament in the costovertebral joints of the first, tenth, eleventh, and twelfth ribs.

The radiate (or stellate) **ligament** [lig. capituli costæ radiatum], a thickening of the anterior part of the capsule (figs. 313, 314), is the most striking of all, and consists of bright, pearly-white fibers attached to the anterior surface, and upper and lower borders of the neck of the rib, a little way beyond the articular facet; from this they radiate upward, forward, and downward, so as to form a continuous layer of distinct and sharply defined fibers.

The middle fibers run straight forward to be attached to the intervertebral disk, the upper ascend to the lower half of the lateral surface of the vertebra above, and the lower descend to the upper half of the vertebra below. The radiate ligament is overlapped on the vertebral bodies by the lateral (short) vertebral ligaments.

In the case of the first, tenth, eleventh, and twelfth ribs, each of which articulates with one vertebra, the ligament is not quite so distinctly radiate, but even in these the ascending fibers reach the vertebra above that with which the rib articulates.

The synovial membranes of the capitular articulation (fig. 314) consist of two closed sacs which do not communicate: one above, and the other below, the interarticular ligament. In the case of the first, tenth, eleventh, and twelfth

articulations, there is but one synovial membrane, as these joints have no interarticular ligament.

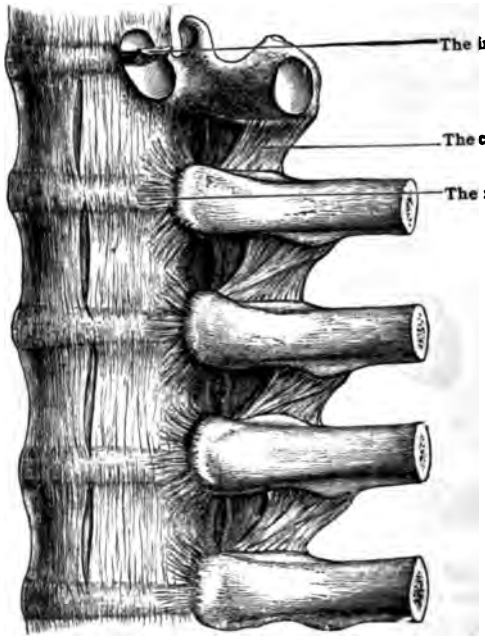
The **arterial supply** of the capitular articulations is from the intercostal arteries, the twigs piercing the radiate and capsular ligaments.

The **nerve-supply** comes from the anterior primary branches of the intercostal nerves.

Movements (Cf. p. 538).—These joints approach most nearly in their movements to the condylarthroses. The movements are ginglymoid in character, consisting of a slight degree of elevation and depression around an obliquely horizontal axis corresponding with the interarticular ligament; there is also a slight amount of forward and backward gliding; and a slight degree of screwing or rotatory movement is also possible. There is a considerable difference in the degree of mobility of the different ribs, for while the first rib is almost immobile except in a very deep inspiration, the mobility of the others increases from the second to the last; the two floating ribs being the most mobile of all. The head of the rib is the most fixed point of the costal arch, and upon it the whole arch rotates; the interarticular ligament allows only a very limited amount of flexion and extension (i. e., elevation and depression), and of gliding. Gliding is checked by the radiate ligament.

In inspiration, the rib is elevated, and glides forward in its socket, too great elevation being checked not only by the ligaments, but also by the overhanging upper edge of the cavity itself. In expiration, the rib is depressed, and glides backward in its cavity.

FIG. 313.—ANTERIOR LONGITUDINAL LIGAMENT, AND THE CONNECTION OF THE RIBS WITH THE VERTEBRÆ.



(*b*) THE COSTOTRANSVERSE ARTICULATION

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

This joint is formed by the tubercle of the rib articulating with the anterior part of the tip of the transverse process. The eleventh and twelfth ribs are devoid of these joints, for the tubercles of these ribs are absent, and the transverse processes of the eleventh and twelfth thoracic vertebræ are rudimentary.

The ligaments of the union are:—

Articular capsule.	Tubercular ligament.
Neck ligament.	Costotransverse ligaments.

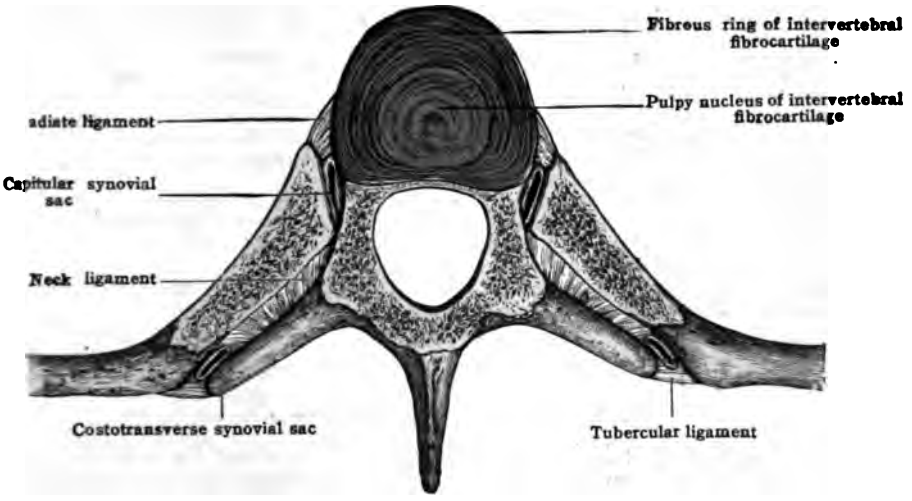
The **articular capsule** (figs. 312, 314) forms a thin, loose, fibrous envelope to the synovial membrane. Its fibers are attached to the bones just beyond the articular margins, and are thickest below, where they are not strengthened by any other structure. It is connected medially with the neck ligament, above with the costotransverse, and laterally with the tubercular (posterior costotransverse) ligaments. The eleventh and twelfth ribs are unprovided with costotransverse capsules.

The neck ligament [lig. colli costæ] (middle costotransverse, or interosseous ligament) (fig. 314), consists of short fibers passing between the back of the neck of the rib and front of the transverse process, with which the tubercle articulates. It extends from the capsule of the capitular joint to that of the costotransverse. It is best seen on horizontal section through the bones filling the costotransverse foramen. In the **eleventh** and **twelfth** ribs this ligament is rudimentary.

The **tubercular ligament** [lig. tuberculi costæ] (fig. 314) is a short but thick, strong, and broad ligament, which extends laterally and upward from the extremity of the transverse process to the non-articular surface of the tubercle of the corresponding rib. The **eleventh** and **twelfth** ribs have no posterior ligament.

The **costotransverse ligament** (fig. 313) is a strong, broad band of fibers which ascends laterally from the crest on the upper border of the neck of the rib, to the lower border of the transverse process above. A few scattered posterior fibers pass upward and medially from the neck to the transverse process. The costotransverse ligament is subdivided into a stronger anterior portion, **anterior costotransverse ligament,** best seen from the front (fig. 313), and a weaker posterior portion, **posterior costotransverse ligament.** Its medial border bounds the foramen through which the posterior branches of the intercostal vessels and nerves

FIG. 314.—HORIZONTAL SECTION THROUGH THE INTERVERTEBRAL DISK AND RIBS.



pass. To the lateral border is attached the thin aponeurosis covering the external intercostals. Its anterior surface is in relation with the intercostal vessels and nerve; the posterior with the longissimus dorsi. The **first** rib has no costotransverse ligament. The twelfth rib is firmly bound down by the **lumbocostal ligament,** a specially strong mass of fibers in the anterior layer of the lumbodorsal fascia connected medially with the tips of the transverse processes of the first two lumbar vertebræ.

The **synovial membrane** (fig. 314) of the costotransverse articulation is a single sac.

The **arterial** and **nerve supplies** come from the posterior branches of the intercostal arteries and nerves.

The **movements** which take place at these joints are limited to a gliding of the tubercle of the rib upon the transverse process. The exact position of the facet on the transverse process varies slightly from above downward, being placed higher on the processes of the lower vertebræ. The plane of movement in most of the costotransverse joints is inclined upward and backward in inspiration, and downward and forward in expiration. The point round which these movements occur is the head of the rib, so that the tubercle of the rib glides upon the transverse process in the circumference of a circle, the center of which is at the capitular joint.

5. THE ARTICULATIONS AT THE FRONT OF THE THORAX

These may be divided into four sets, viz.:—

(*a*) The **intersternal joints,** or the union of the several parts of the sternum with one another.

(*b*) The **costochondral joints,** or the union of the ribs with their costal cartilages.

(*c*) The **chondrosternal joints,** or the junction of the costal cartilages with the sternum.

(*d*) The **interchondral joints,** or the union of five costal cartilages (sixth, seventh, eighth, ninth, and tenth) with one another.

(*a*) The Intersternal Joints

The sternum being composed, in the adult, of three distinct pieces—the manubrium, body, and the xiphoid process—has two articulations, viz., the superior, which unites the manubrium with the body (gladiolus), and the inferior, which unites the body with the xiphoid.

1. The Superior Intersternal Articulation

Class.—*False Synchondrosis.*

The lower border of the manubrium and the upper border of the body of the sternum present oval-shaped, flat surfaces, with their long axes transverse, and covered with a thin layer of hyaline cartilage. An **interosseous fibrocartilage** is interposed between the bony surfaces; it corresponds exactly in shape and intimately adheres to them. At each lateral border this fibrocartilage enters into the formation of the second chondrosternal articulation (fig. 315).

In consistence it varies, being in some cases uniform throughout, in others softer in the center than at the circumference, and in others again an oval-shaped synovial cavity is found toward its anterior part. When such a cavity exists in the fibrocartilage this joint has a remote resemblance to the diarthroses, and is classed, with the sacroiliac joint and the symphysis pubis under similar conditions, as 'diarthroamphiarthrosis.'

The periosteum passes uninterruptedly over the joint from one segment of the sternum to the other, forming a kind of capsular ligament [membrana sterni]. This capsule is strengthened, especially on its posterior aspect, by longitudinal ligamentous fibers as well as by the radiating and decussating fibers of the chondrosternal ligaments.

In some instances the fibrocartilage is replaced by short bundles of fibrous tissue which unite the cartilage-coated articular bone surfaces.

2. The Inferior Intersternal Articulation

Class.—*False Synchondrosis*

The body (gladiolus) is joined to the xiphoid cartilage by a thick investing membrane, by anterior and posterior longitudinal fibers, and by radiating fibers of the sixth and seventh chondrosternal ligaments. The **costoxiphoid ligament** also connects the xiphoid with the anterior surface of the sixth and seventh costal cartilages, and thus indirectly with the gladiolus; and some fine fibroareolar tissue also connects the xiphoid with the back of the seventh costal cartilage.

The junction of the xiphoid with the sternum is on a level somewhat posterior to the junction of the seventh costal cartilage with the sternum. The union is a synchondrosis, each bone being covered by hyaline cartilage which is connected with the intervening fibrocartilage plate.

(*b*) The Costochondral Joints

Class.—*Synarthrosis.*

The extremity of the costal cartilage is received into a cup-shaped depression at the end of the rib, which is somewhat larger than the cartilage. The two are joined together by the continuity of the investing membranes, the periosteum of the rib being continuous with the perichondrium of the cartilage.

(*c*) The Sternocostal Articulations

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

These articulations are between the lateral borders of the sternum and the ends of the costal cartilages. The union of the first rib with the sternum is *synchondrodial*, and therefore forms an exception to the others. From the second

the seventh inclusive, the articulations have the following ligaments, which gether form a complete capsule:—

Radiate (anterior) sternocostal. Posterior sternocostal.

The **radiate** (anterior) **sternocostal ligament** (fig. 315) is a triangular band omposed of strong fibers which cover the medial one centimeter of the front of the ostal cartilage, and radiate upward and downward upon the front of the sternum. Some of the fibers decussate across the middle line with fibers of the opposite ligament.

The **posterior sternocostal ligament** consists of little more than a thickening of the fibrous envelopes of the bone and cartilage, the joint being completed behind by a continuity of perichondrium with periosteum. The periosteum of the sternum, augmented by the fibers of the anterior and posterior ligaments forms a dense layer enveloping the sternum and has been termed the **membrana sterni.**

Deeper than the fibers of these ligaments are short fibers passing from the margins of the sternal facets to the edges of the facets on the cartilages; they are most distinct in the front and lower part of the joint, and may encroach so much upon the synovial cavity as to reduce it to a very small size, or almost obliterate it. This occurs mostly in the case of the sixth and seventh joints, especially the latter.

The interarticular ligament (fig. 315) is by no means constant, but is usually resent in the second joint on one, if not on both sides of the same subject. It onsists of a strong transverse bundle of fibers passing from the ridge on the facet n the cartilage to the fibrous substance between the manubrium and body; ometimes the upper part of the synovial cavity is partially or entirely obliterated y short, fine, ligamentous fibers.

The costoxiphoid ligament (fig. 315) is a strong flat band of fibers passing bliquely upward and laterally from the front surface of the xiphoid cartilage to he anterior surface of the sternal end of the seventh costal cartilage, and most requently to that of the sixth also. It is not always present.

Synovial membranes.—The union of the first cartilage with the sternum, being synchondroal, has no synovial membrane; the second has usually two, separated by the interarticular pament. The rest usually have one synovial membrane, which may occasionally be subivided into two (fig. 315).

The arterial supply is derived from perforating branches of the internal mammary; and ie **nerves** come from the anterior branches of the intercostals.

Movements.—Excepting the first, the chondrosternal joints are ginglymoid, but the motion which they are capable is very limited. It consists of a hinge-like action in two directions: rst, there is a slight amount of elevation and depression which takes place round a transverse cis, and, secondly, there is some forward and backward movement round an obliquely vertical cis. In inspiration the cartilage is elevated, the lowest part of its articular facet is pressed to the sternal socket, and the sternum is thrust forward so that the upper and front edges the articular surfaces separate a little; in expiration the reverse movement takes place. Thus e two extremities of the costal arches move in their respective sockets in opposite directions. This difference results necessarily from the fact that the costal arch moves upon the vertebral column, and, having been elevated, it in its turn raises the sternum by pushing it upward id forward.

The costoxiphoid ligament tends to prevent the xiphoid cartilage from being drawn backard by the action of the diaphragm.

(*d*) The Interchondral Articulations

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

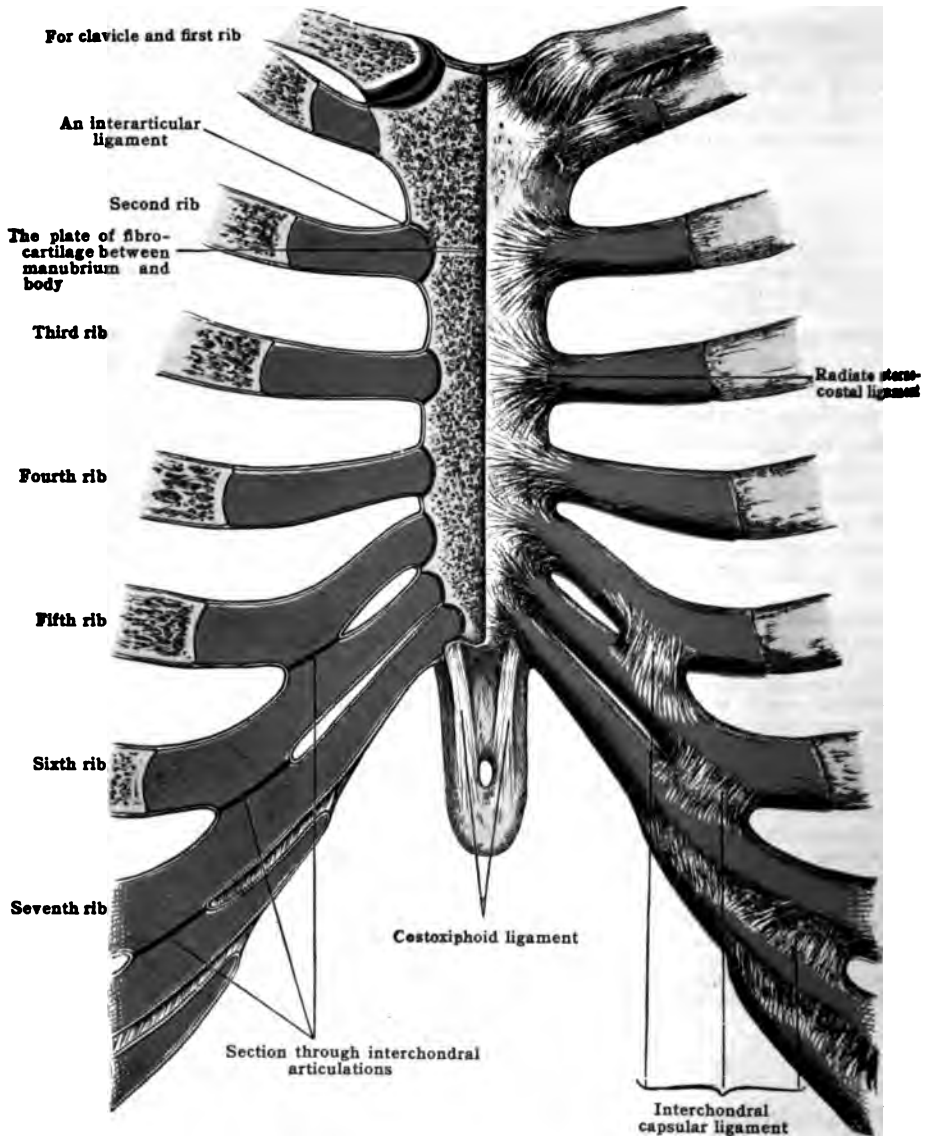
A little in front of the point where the costal cartilages bend upward toward ie median line (fig. 315) the sixth is united with the seventh, the seventh with the ghth, the eighth with the ninth, and the ninth with the tenth.

At this point each of the cartilages from the sixth to the ninth inclusive is deeper than sewhere, owing to the projection downward from its lower edge, of a broad blunt process, hich comes into contact with the cartilage next below. Each of the apposed surfaces is nooth, and they are connected at their margins by ligamentous tissue, which forms a complete psule for the articulation, and is lined by a synovial membrane (fig. 315). The largest of ese cavities is between the seventh and eighth; those between the eighth and ninth, and ninth id tenth are smaller, and are not free to play upon each other in the whole of their extent, being eld together by ligamentous tissue at their anterior margins. Sometimes this fibrous tissue mpletely obliterates the synovial cavity.

The arteries are derived from the musculophrenic, and the nerves from the intercostals.

Movements.—By means of the costal cartilages and interchondral joints, strength with elasticity is given to the wall of the trunk at a part where the cartilages are the only firm structures in its composition; while a slight gliding movement is permitted between the costal cartilages themselves, which takes place round an axis corresponding to the long axis of the cartilages. By this means, the outward projection of the lower part of the thoracic wall is increased by deep inspiration.

FIG. 315.—THE ARTICULATIONS AT THE FRONT OF THE THORAX.
(Left side, showing ligaments; right side, the articular cavities.)

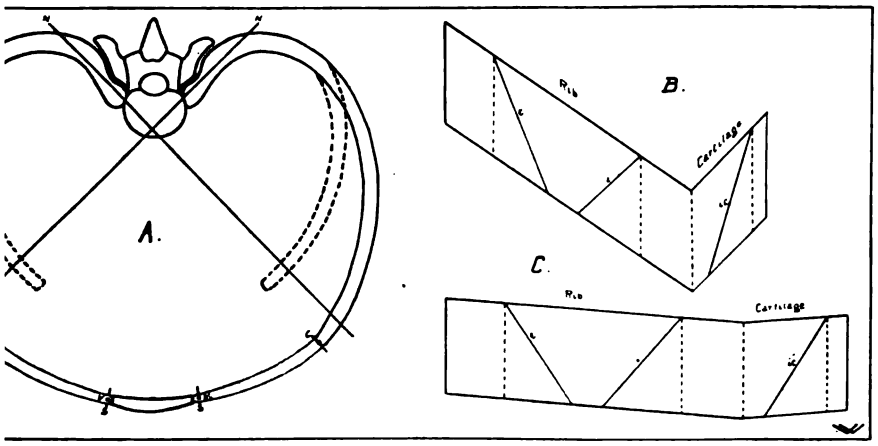


MOVEMENTS OF THE THORAX AS A WHOLE

Each rib above the tenth moves on an axis which passes through the costotransverse and capitular articulations approximately parallel with the direction of the neck of the rib, fig. 316. The axes of rotation of the pairs of ribs converge in front to intersect in the mid-plane, in angles which diminish from above downward, following the differences in form of rib and vertebra in the upper and lower ends of the series. The movements which take place in the upper ribs for the same cause differ from those occurring in the pairs of lower ribs. During inspiration and expiration, the anterior extremities of the first pair of costal arches play up and down, the tubercles and the heads of the ribs acting in a hinge-like manner, around an axis whose direction tends to approach a right angle with the sagittal plane. By this movement the anterior ends of these costal arches are simply raised or depressed, and the sternum pushed a little forward (Cf. p. 538).

ovements of the other ribs, particularly in the midregion of the thorax, are more
the axes of rotation tending to pass in a sagittal direction; for, besides the elevation
erior extremities, the bodies and angles of the ribs rise nearly as much as the extremities
s. In this movement the tubercles of the ribs glide upward and backward in inspira-
downward and forward in expiration.
g inspiration the cavity of the thorax is increased in every direction. The **antero-**
diameter is increased by the thrusting forward of the sternum, caused by the eleva-
e costal cartilages and fore part of the ribs, whereby they are brought to nearly the
l as the heads of the ribs. The **transverse diameter** is increased: (1) Behind, by the
of the middle part of the ribs; for when at rest the midpart of the rib is on a lower
l either the costovertebral or chondrosternal articulations. Owing to this obliquity
verse diameter is increased when the rib is raised, and the increase is proportionate
gree of obliquity. (2) By the eversion of the lower border of the costal arch, which
ward as the arch is raised. (3) The transverse diameter is increased in front by the
l of the anterior extremity of the rib at the same time as it is elevated and thrust

—Horizontal Projection of the Costal Ring Formed by the Fifth Ribs (After Luciani.)



crease in the vertical diameter of the thorax is due to the elevation of the ribs, espe-
l **upper ones**, and the consequent widening of the intercostal spaces; but the chief
n **this direction** is due to the descent of the diaphragm.
reatest increase both in the anteroposterior and transverse diameters takes place
ribs are longest, most oblique, and most curved at their angles, and where the bulkiest
e **lung is enclosed**. This is on a level with the sixth, seventh, and eighth ribs.
lower part of the thorax, where the ribs have no relation to the lungs, and do not
piration directly by their movements, it is important that the costal arches should
well outward in order to counteract the compression of the abdominal viscera by the
on of the diaphragm.
dening and steadying the lower part of the thorax during inspiration, the attachments
scular fibers of the diaphragm are widened, and their power increased.
les which take part in the movement of inspiration (cf. p. 538).—(*a*) ***Ordinary inspira-***
scalenes, serratus posterior superior, the external and internal (?) intercostals, the
n; the quadratus lumborum and serratus posterior inferior fixing the lower ribs,
the posterior fibers of the external oblique also helping to fix the lower ribs. (*b*)
nary inspiration: The superior extremities are raised and fixed. The cervical part of
bral column and the head are extended, and in addition to the muscles of ordinary
n, the following muscles also come into play: The pectoralis minor, the muscles which
e head and the cervical part of the vertebral column, the sternomastoid and the supra-
hyoid muscles, the lower fibers of the pectoralis major, some of the lower fibers of the
nterior, and, when the clavicle is fixed, the subclavius.
tion is produced by the elasticity of the lungs and the weight of the thorax, aided
stic reaction and contraction of the external (?) and internal oblique **muscles**, the recti
midales, the transversus abdominis, and the levatores ani and coccygei. In forcible
l all muscles which depress the ribs and reduce the dimensions of the abdomen are
to action. The internal intercostals probably tend to contract the thorax, excepting
chondral parts, which tend to expand the thorax.

THE ARTICULATIONS OF THE UPPER EXTREMITY

The articulations of the upper extremity are the following:—

1. The **sternocostoclavicular.**
2. The **scapuloclavicular union.**
3. The **shoulder-joint.**
4. The **elbow-joint.**
5. The **radioulnar union.**
6. The **radiocarpal** or **wrist-joint.**
7. The **carpal joints.**
8. The **carpometacarpal joints.**
9. The **intermetacarpal joints.**
10. The **metacarpophalangeal joints.**
11. The **interphalangeal joints.**

1. THE STERNOCOSTOCLAVICULAR ARTICULATION

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

At this joint (figs. 315, 317, 318) the large medial end of the clavicle is united to the superior angle of the manubrium sterni, the first costal cartilage also assisting to support the clavicle. It is the only joint between the upper extremity and the trunk, and takes part in all the movements of the pectoral girdle. Looking at the bones, one would say that they were in no way adapted to articulate with one another, and yet they assist in constructing a joint of security, strength, and freedom of movement. The bones are nowhere in actual contact, being completely separated by an articular disk. The interval between the joints of the two sides varies from 2.5 to 4 cm. The ligaments of this joint are:—

Articular capsule.	Articular disk.
Interclavicular.	Costoclavicular.

The **articular capsule** (fig. 317) consists of fibers, having varying directions and being of various strength and thickness, which completely surround the articulation, and are firmly connected with the edges of the articular disk.

The fibers at the back of the joint, sometimes styled the **posterior sternoclavicular ligament,** are stronger than those in front or below, and consist of two sets: a superficial, passing upward and laterally from the manubrium sterni, to the projecting posterior edge of the end of the clavicle, a few being prolonged onward upon the posterior surface of the bone. A deeper set of fibers, especially thick and numerous below the clavicle, connect the interarticular cartilage with the clavicle and with the sternum, but do not extend from one bone to the other. The fibers in front, the **anterior sternoclavicular ligament,** are well marked, but more lax and less tough than the posterior, and are overlaid by the tendinous sternal origin of the sternomastoid, the fibers of which run parallel to those of the ligament. They extend obliquely upward and laterally from the margin of the sternal facet to the anterior surface of the clavicle some little distance from the articular margin. The fibers which cover in the joint below are short, and consist more of fibroareolar tissue than true fibrous tissue; they extend from the upper border of the first costal cartilage to the lower border of the clavicle just lateral to the articular margin, and fill up the gap between it and the costoclavicular ligament. The superior portion consists of short tough fibers passing from the sternum to the articular disk and of others binding the fibrocartilage to the upper edge of the clavicle, only a few of them passing from the clavicle direct to the sternum.

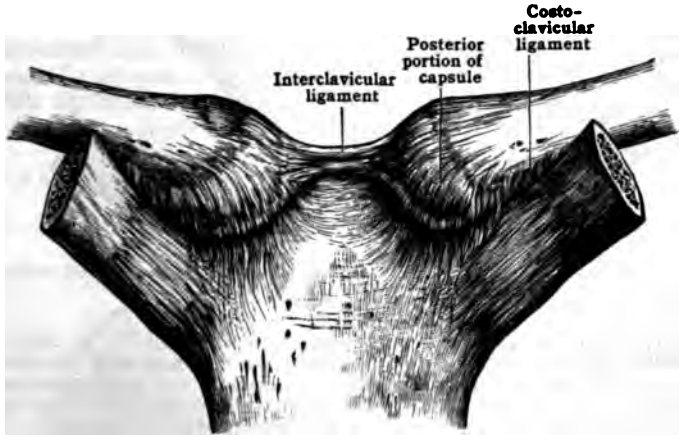
The **interclavicular ligament** (fig. 317) is a strong, concave band, materially strengthening the superior portion of the capsule. It is about 6 mm. deep with a concavity upward, its upper border tapering to a narrow, almost sharp edge. It is connected with the posterior superior angle of the sternal extremity of each clavicle, and with the fibers which bind the articular disk to the clavicle; and then passes across from clavicle to clavicle along the posterior aspect of the upper border of the manubrium sterni. The lowest fibers are attached to the sternum, and join the posterior fibers of the capsule of each joint. In the midline, between the ligament and the sternum, there is an aperture for the passage of a small artery and vein.

In addition to the interclavicular ligament, Carwardine (Journal of Anatomy and Physiology, vol. 7, n.s., p. 232) has described a special band of the upper portion of the sternoclavicular capsule which he proposes to name the 'suprasternal ligament.' It descends from the upper border of the sternal end of the clavicle to the upper border of the sternum, and is of special importance as it encloses the suprasternal bones, when these rudiments are present.

The **costoclavicular** (or rhomboid) **ligament** (fig. 317) is a strong dense band, composed of fine fibers massed together into a membranous structure. It extends from the upper (medial) border of the first costal cartilage (and rib), upward, backward, and distinctly laterally to the costal tuberosity on the under surface of the medial extremity of the clavicle, to which it is attached just lateral to the lower part of the capsule. Frequently some of the lateral fibers pass upward and medially behind the rest, and give the appearance of decussating. It is from 1.5 to 2 cm. broad.

The **articular disk** (fig. 318) is a flattened disk of nearly the same size and outline as the medial articular end of the clavicle, which it fairly accurately fits. It is attached above to the upper border of the posterior edge of the clavicle; and below to the cartilage of the first rib at its union with the sternum, where it assists in forming the socket for the clavicle. At its circumference it is connected with the articular capsule, and this connection is very strong behind, and still stronger above, where it is blended with the interclavicular ligament.

FIG. 317.—POSTERIOR VIEW OF THE STERNOCLAVICULAR JOINT.



The disk is usually thinnest below, where it is connected with the costal cartilage. It varies in thickness in different parts, sometimes being thinner in the center than at the circumference, sometimes the reverse, and is occasionally perforated in the center. It divides the joint into two compartments.

There are two **synovial membranes** (fig. 318); a lateral one, which is reflected from the clavicle and capsule over the lateral aspect of the disk and is looser than the medial one; the medial is reflected from the sternum over the medial side of the articular disk, costal cartilage, and capsule. Occasionally a communication takes place between them.

The arterial supply of the sternoclavicular joint is derived from branches—(1) from the internal mammary; (2) from the superior thoracic branch of the axillary; (3) twigs of a muscular branch often arising from the subclavian artery pass over the interclavicular notch; (4) twigs of the transverse scapular (suprascapular) artery.

The nerve-supply is derived from the nerve to the subclavius and sternal descending branch of the cervical plexus.

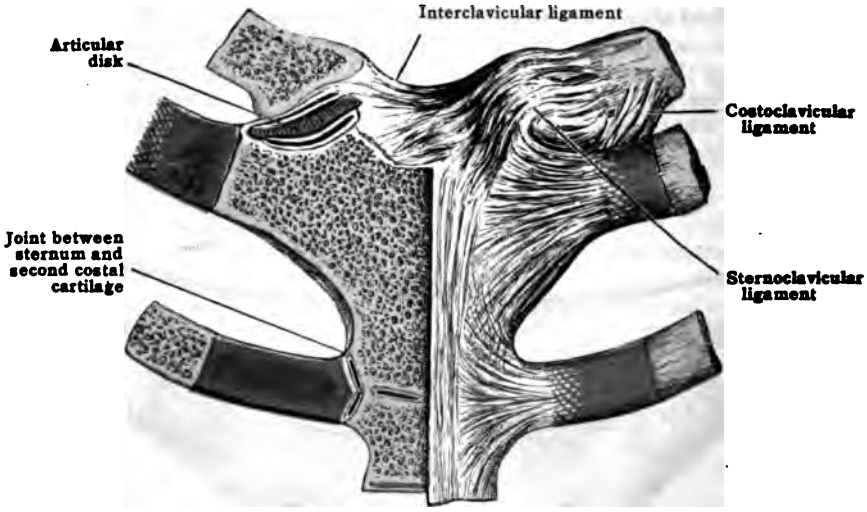
Relations.—In front of the joint is the sternal head of the sternomastoid. Behind it are the sternohyoid and sternothyroid muscles. Still further back, on the right side, are the innominate and internal mammary arteries, and, on the left side, the left common carotid, the left subclavian, and the internal mammary arteries. Above and behind, between the sternomastoid and sternohyoid muscles, the anterior jugular vein passes back and laterally toward the posterior triangle.

The movements (cf. p. 539) permitted at this joint are various though limited, owing to the capsular ligament being moderatly tense in every position of the clavicle. Motion takes place in nearly every direction—viz., upward, downward, forward, backward, and in a circumductory path. The upward and downward motions occur between the clavicle and the articular disk; during elevation of the corner, the upper edge of the clavicle with its attached articular disk

is pressed into the sternal socket, and the lower edge glides away from the disk; during depression of the limb, the lower edge of the clavicle presses on to the disk, while the rest of the articular surface of the clavicle inclines laterally, bringing with it to a slight degree the upper edge of the articular disk. These movements occur on an anteroposterior axis drawn through the outer compartment of the joint. The forward and backward motions take place between the articular disk and sternum, the clavicle with the disk gliding backward upon the sternum when the shoulder is brought forward, and forward when the shoulder is forced backward; these movements occur round an axis drawn nearly vertically through the sternal socket.

The articular disk serves materially to bind the bones together, and to prevent the medial and upward displacements of the clavicle. It also forms an elastic buffer which tends to break shocks. The capsule, by being moderately tight, tends to limit movements in all directions, while the interclavicular ligament is a safeguard against upward displacement during depression of the arm. The costoclavicular ligament prevents dislocation upward during elevation of the arm, and resists displacements backward.

FIG. 318.—ANTERIOR VIEW OF STERNOCOSTOCLAVICULAR JOINT, WITH SECTION SHOWING CAVITIES OPENED ON THE RIGHT SIDE.



Muscles which move the clavicle at the sternoclavicular joint (cf. p. 539).—*Elevators.*—Trapezius, clavicular part of sternomastoid, levator scapulæ, omohyoid, rhomboids. *Depressors.*—Subclavius, pectoralis minor, lower fibers of trapezius and serratus anterior (magnus). Depression is aided by the weight of the upper extremity. *Protractors.*—Pectoralis major and minor, serratus anterior (magnus). *Retractors.*—Latissimus dorsi, trapezius.

2. THE SCAPULOCLAVICULAR UNION

The scapula is connected with the clavicle by a synovial joint with its ligaments at the acromioclavicular articulation; and also by a set of ligaments passing between the coracoid process and the clavicle. So that we have to consider—

(*a*) The **acromioclavicular articulation.**

(*b*) The **coracoclavicular ligaments.**

(*c*) The **proper scapular ligaments** are also best described in this section—viz., the **coracoacromial** and **transverse.**

(*a*) THE ACROMIOCLAVICULAR JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The acromioclavicular joint is surrounded by an articular capsule and frequently contains an articular disk.

The **articular capsule** (figs. 320, 323) completely surrounds the articular margins and is composed of strong, coarse fibers arranged in parallel fasciculi, of fairly uniform thickness, which are attached to the borders as well as the surfaces of the bones. It is somewhat lax in all positions of the joint, so that the clavicle is not tightly braced to the acromion. The fibers extend about 2 cm. along the clavicle posteriorly, but only 6 mm. anteriorly. Superiorly, they are attached to an oblique line joining these two points, while inferiorly they reach to the ridge for the trapezoid ligament with which they blend.

At the acromion they extend half way across the upper and lower surfaces, but at the anterior and posterior limits of the joint they are attached close to the articular facet. The anterior fibers become blended with the insertion of the coracoacromial ligament. The fibers are strengthened above by the aponeuroses of the trapezius and deltoid muscles; and all run from the acromion to the clavicle medially and backward. The upper portion of the capsule has been designated the acromioclavicular ligament.

The **articular disk** is occasionally present, but is usually imperfect, only occupying the upper part of the joint; it may completely divide the joint into two cavities, or be perforated in the center. It is usually thicker at the edge than in the center, and some of the fibers of the articular capsule are blended with its edges. The **synovial membrane** lining the joint is accordingly either partially or entirely divided into two by the articular disk.

Relations.—Superiorly skin and fascia and the tendinous intersection between the deltoid and the trapezius. Inferiorly, the coracoacromial ligament and supraspinatus. Anteriorly, part of the origin of the deltoid. Posteriorly, part of the insertion of the trapezius.

Movements.—A certain amount of gliding movement occurs at this joint, but the most important movement is a rotation of the scapula whereby the glenoid cavity is turned forward and upward, or downward. As these movements occur the inferior angle of the scapula moves forward as the glenoid cavity turns upward and the superior angle recedes.

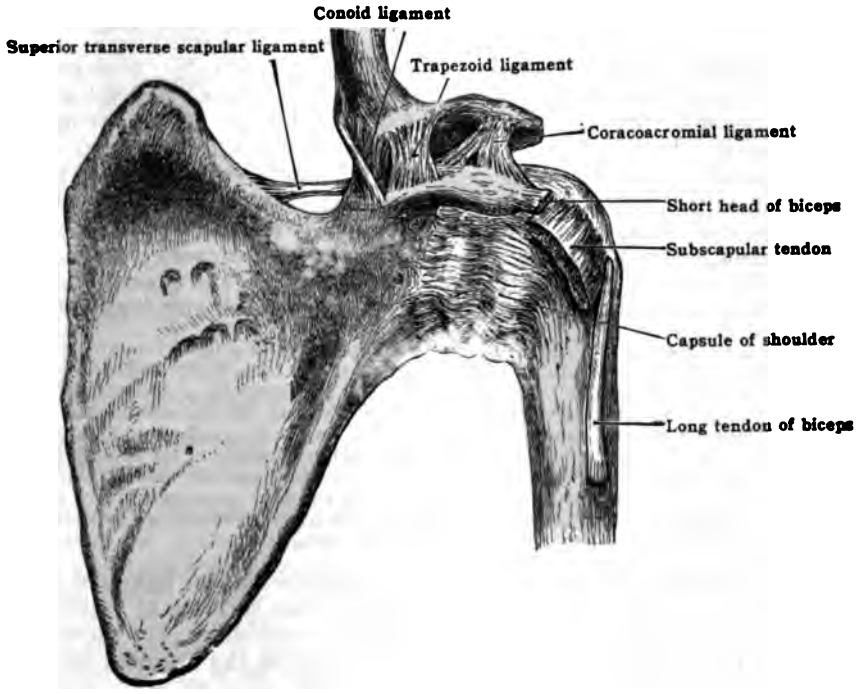
The forward movement of the inferior angle is produced mainly by the inferior fibers of the serratus anterior (magnus), aided by the inferior fibers of the trapezius, and it is by this movement that the arm is raised above the level of the shoulder. The reverse movement is produced mainly by the rhomboideus major aided by the latissmus dorsi.

(*b*) The Coracoclavicular Union

The **coracoclavicular ligament** (figs. 319, 320, 323) consists of two parts, the conoid and the trapezoid ligaments.

The **conoid ligament** is the medial and posterior portion, and passes upward and laterally from the coracoid process to the clavicle.

Fig. 319.—Anterior View of Shoulder, showing also Coracoclavicular and Coracoacromial Ligaments.



It is a very strong and coarsely fasciculated band of triangular shape, the apex being fixed to the medial and posterior edge of the root of the coracoid process just in front of the scapular notch, some fibers joining the transverse ligament. Its base is at the clavicle, where it widens out, to be attached to the posterior edge of the inferior surface, as well as to the coracoid tubercle. It is easily separated from the trapezoid, without being absolutely distinct. A small bursa often exists between it and the coracoid process; medially, some of the fibers of the subclavius muscle are often attached to it.

The **trapezoid ligament** is the anterior and lateral portion of the coraco-clavicular ligament. It is a strong, flat, quadrilateral plane of closely woven fibers, the surfaces of which look upward and medially toward the clavicle, and downward and laterally over the upper surface of the coracoid process.

At the coracoid it is attached for about 2.5 cm. to a rough ridge which runs forward from the angle, along the anterior border of the process. At the clavicle it is attached to the oblique ridge which runs laterally and forward from the coracoid tubercle, reaching as far as, and blending with the inferior part of the acromioclavicular ligament. Its anterior edge is free, and overlies the coracoacromial ligament; the posterior edge is shorter than the anterior, and is in contact with the posterior and lateral portions of the conoid ligament.

The **arterial supply** is derived from the transverse scapular (suprascapular), acromial branches of the thoracoacromial, and the anterior circumflex.

The **nerve-supply** is derived from the suprascapular and axillary (circumflex) nerves.

Movements (cf. p. 539).—In the movements of the shoulder girdle, the scapula moves upon the lateral end of the clavicle, and the clavicle, in turn, carried by the uniting ligaments, moves upon the sternum; so that the entire scapula moves in the arc of a circle whose center is at the sternoclavicular joint, and whose radius is the clavicle. The scapula, in moving upon the clavicle, also moves upon the thorax forward and backward, upward and downward, and also in a rotatory direction upon an axis drawn at right angles to the center of the bone. Throughout these movements the inferior angle and base of the scapula are kept in contact with the ribs by the latissimus dorsi, which straps down the former, and the rhomboids and serratus anterior (magnus), which brace down the latter. By means of the acromioclavicular joint, the scapula can be forcibly advanced upon the thorax, the glenoid cavity all the time keeping its face duly forward. Thus the muscles of the shoulder and forearm can be with advantage combined, as, for example, in giving a direct blow. The acromioclavicular joint also permits the lower angle of the scapula to be retained in contact with the chest wall during the rising and falling of the shoulder, the scapula turning in a hinge-like manner round the horizontal axis of the joint.

There are no actions in which the scapula moves on a fixed clavicle, or the clavicle on a fixed scapula; the two bones, bound together by their connecting ligament, must move in unison

(*c*) The Proper Scapular Ligaments

There are three proper ligaments of the scapula, which pass between different portions of the bone, viz.—

Coracoacromial. Superior transverse.
Inferior transverse.

The **coracoacromial ligament** (figs. 319, 323) is a flat, triangular band with a broad base, attached to the lateral border of the coracoid process, and a blunt apex which is fixed to the tip of the acromion. It is made up of two broad marginal bands, and a smaller and thinner intervening portion. The **anterior band,** which arises from the anterior portion of the coracoid process, is the stronger, and some of its marginal fibers can often be traced into the short head of the biceps, which can then make tense this edge of the ligament. The **posterior band,** coming from the posterior part of the coracoid process, is also strong. The intermediate part, of variable extent, is thin and membranous; it is often incomplete near the coracoid process, leaving a small gap (fig. 319).

The superior surface of the ligament looks upward and a little forward, and is covered by the deltoid muscle; the inferior looks downward and a little backward, and is separated from the capsule of the shoulder-joint by a bursa and the tendons of the supraspinatus and subscapularis muscles. At the coracoid process it overlies the coracohumeral ligament. It is barely 8 mm. above the capsule of the shoulder, and in the undissected state there is scarcely a 6 mm. interval. The anterior band projects over the center of the head of the humerus, and is continued into a tough fascia under the deltoid; the posterior band is continuous with the fascia over the supraspinatus muscle. It binds the two processes firmly together, and so strengthens each; it holds the deltoid off the capsule of the shoulder, and protects the joint from slight injuries directed downward and backward against it.

The **superior transverse** (coracoid, or suprascapular) **ligament** (figs. 319, 321) is a small triangular band of fibrous tissue, the surfaces of which look forward and backward; and its edges, which are thin and sharp, are turned upward and downward. It continues the superior border of the scapula, bridging over the scapular notch.

It is broader medially, where it springs from the upper border of the scapula on its dorsal surface; and narrow laterally, where it is attached to the base of the coracoid process; some of its fibers are inserted under the edge of the trapezoid ligament, and others pass upward with the conoid to reach the clavicle. The transverse scapular (suprascapular) artery passes over it, and the suprascapular nerve beneath it. Medially, some fibers of the omohyoid muscle arise from it.

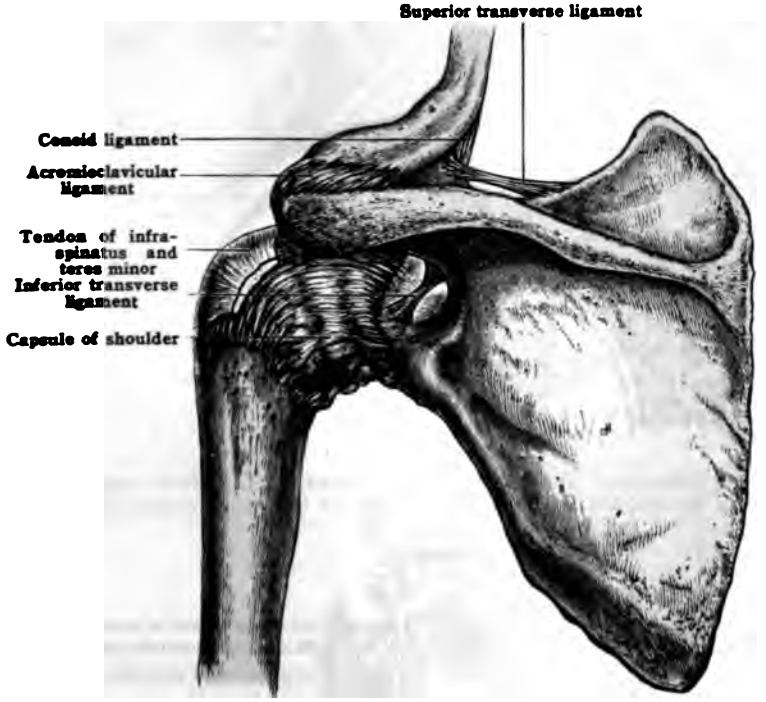
The inferior transverse (spinoglenoid) **ligament** (fig. 320) reaches from the lateral border of the spine of the scapula to the margin of the glenoid cavity, and so forms a foramen under which the transverse scapular (suprascapular) vessels and suprascapular nerve gain the infraspinous fossa. It is usually a weak membranous structure.

3. THE SHOULDER-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Enarthrodia.*

The shoulder-joint [articulatio humeri] is one of the most perfect and most movable of joints, the large upper end of the humerus playing upon the shallow glenoid cavity. Like the hip, it is a ball-and-socket joint. It is retained in position much less by ligaments than by muscles, and, owing to the looseness of its capsule, as well as to all the other conditions of its construction and position, it is exceedingly liable to be displaced; on the other hand, it is sheltered from violence by the two projecting processes—the acromion and coracoid.

FIG. 320.—POSTERIOR VIEW OF THE SHOULDER-JOINT, SHOWING ALSO THE ACROMIOCLAVICULAR JOINT AND THE SPECIAL LIGAMENTS OF THE SCAPULA.



The ligaments of the shoulder-joint are:—

Articular capsule.	Coracohumeral.
Glenohumeral.	Glenoid.

The articular capsule (figs. 319–321, also 1118) is a loose sac, insufficient in itself to maintain the bones in contact. It consists of fairly distinct but not coarse fibers, closely woven together, and directed, some straight, others obliquely, between the two bones, a few circular ones being interwoven amongst them. At the scapula, it is fixed on the dorsal aspect to the prominent rough surface around the margin of the glenoid cavity, reaching as far as the neck of the bone. Superiorly, it is attached to the root of the coracoid process; anteriorly, to the ventral surface, at a variable distance from the articular margin, often reaching 12 mm. upon the neck of the bone, and thus allowing the formation of a pouch; it may not, however, extend for more than 6 mm. beyond the articular margin; inferiorly, it blends with the origin of the long head of the triceps. At the humerus, the superior half is fixed to the anatomical neck, sending a prolongation downward between the two tuberosities which attenuates as it descends, and

covers the transverse humeral ligament. The lower half of the capsule descends upon the humerus further from the articular margin, some of the deeper fibers being reflected upward so as to be attached close to the articular edge, thus forming a kind of fibrous investment for the neck of the humerus. This ligament is more uniform in thickness than that of the hip.

Glenohumeral bands of the capsule (figs. 321, 322).—There are three accessory bands, known as the *superior*, *middle* and *inferior glenohumeral bands*, which project toward the interior of the joint from the fore part of the capsule and are consequently best seen when the joint is opened from behind.

FIG. 321.—VERTICAL SECTION THROUGH THE SHOULDER-JOINT TO SHOW THE GLENOHUMERAL LIGAMENT.
(The joint is opened from behind.)

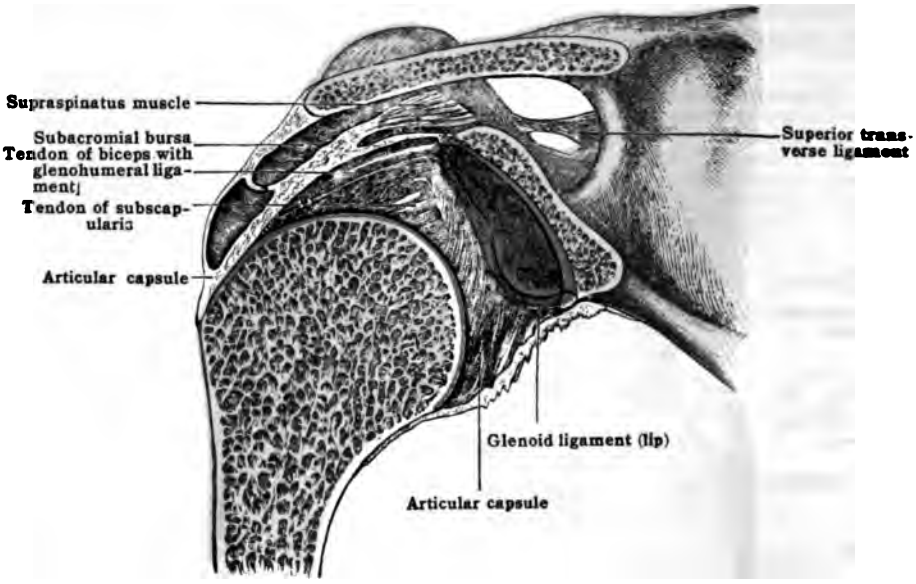


FIG. 322.—FETAL SHOULDER-JOINT, SHOWING THE GLENOHUMERAL LIGAMENT, AND ALSO THE SHORT HEAD OF THE BICEPS, BEING CONTINUOUS WITH THE CORACOACROMIAL LIGAMENT.

Short tendon of biceps running on into anterior band of coracoacromial ligament
Long tendon of biceps
Glenohumeral ligament
Capsule of shoulder, turned back
Subscapularis tendon, cut and turned laterally

The middle band reaches from the anterior margin of the glenoid cavity along the lower border of the subscapularis tendon to the lower border of the lesser tuberosity, and the inferior band from the inferior part of the glenoid cavity to the inferior part of the neck of the humerus. The superior band, known also as the glenohumeral ligament, runs from the edge of the glenoid cavity at the root of the coracoid process, just medial to the origin of the long tendon of the biceps, and, passing laterally and downward at an acute angle to the tendon, for which it forms a slight groove or sulcus, is fixed to a depression, the fovea capitis humeri, above the lesser tuberosity of the humerus. It is a thin, ribbon-like band, of which the superior surface is attached to the capsule, while the inferior is free and turned toward the joint. In the fetus it is often, and in the adult occasionally, quite free from the capsule, and may be as thick as the long tendon of the biceps (fig. 322).

The tendons of the supra- and infraspinatus, teres minor, and subscapularis muscles strengthen and support the capsule, especially near their points of insertion, and can be with difficulty dissected off from it. The long head of the triceps supports and strengthens the

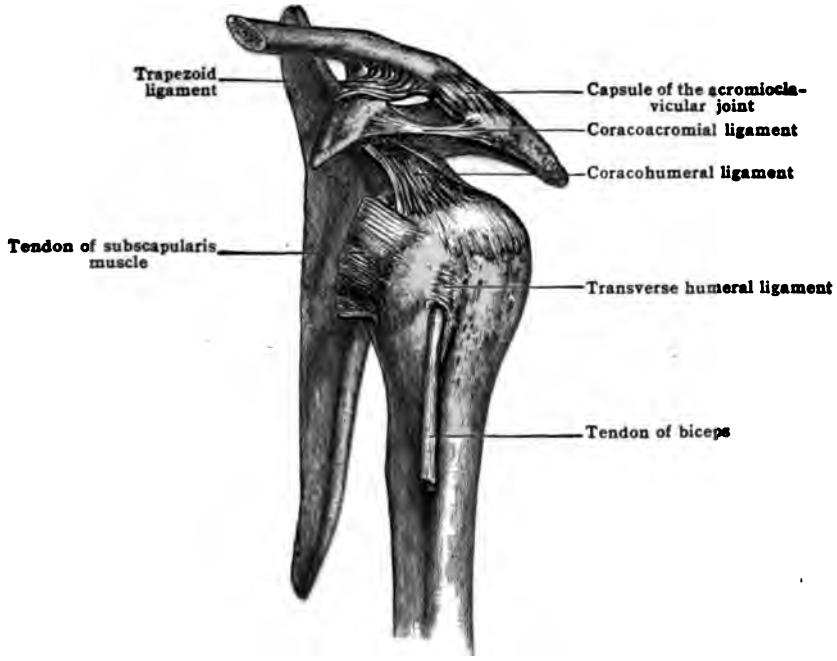
capsule below. The capsule also receives an upward slip from the pectoralis major. The supraspinatus often sends a slip into the capsule from its upper edge (fig. 321).

The **coracohumeral ligament** (fig. 323) is a strong broad band, which is attached above to the lateral edge of the root and horizontal limb of the coracoid process nearly as far as the tip. From this origin it is directed backward along the line of the biceps tendon to blend with the capsule, and is inserted into the greater tuberosity of the humerus.

Seen from the back, it looks like an uninterrupted continuation of the capsule, while from the front it looks like a fan-shaped prolongation from it overlying the rest of the ligament. At its origin there is sometimes a bursa between it and the capsule.

The **glenoid ligament** or **lip** [labrum glenoidale] (figs. 323, 325) is a narrow rim of dense fibrocartilage, which surrounds the edge of the glenoid socket and

FIG. 323.—LATERAL VIEW OF THE SHOULDER-JOINT, SHOWING THE CORACOHUMERAL AND TRANSVERSE HUMERAL LIGAMENTS.



deepens it. It is about 6 mm. wide above and below, but less at its sides. Its peripheral edge is inseparably attached, near the bone, with the articular capsule. Its structure is almost entirely fibrous, with but few cartilage cells intermixed. At the upper part of the fossa the **biceps tendon** is prolonged into the glenoid ligament, the tendon usually dividing and sending fibers right and left into the ligament, which may wind round nearly the whole circumference of the socket. It may, however, send fibers into one side only, usually into the lateral.

The **articular cartilage** covering the glenoid cavity is thicker at the circumference than in the center, thus tending to deepen the cavity. It is usually thickest at the lower part of the fossa; over the head of the humerus the cartilage is thickest at and below the center.

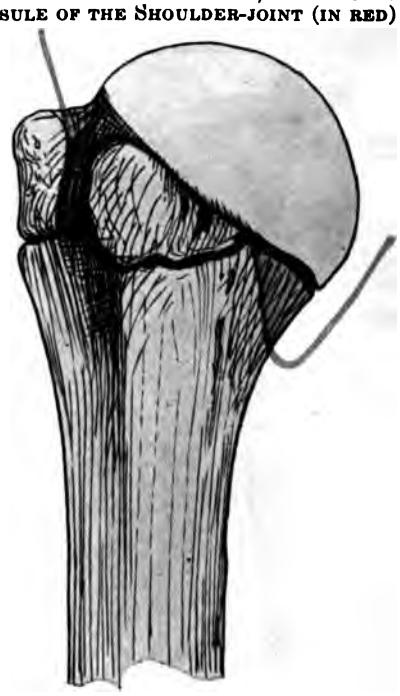
The **synovial membrane** lines the glenoid ligament, and is then reflected over the capsule as far as its attachment to the humerus, from which it ascends as far as the edge of the articular cartilage. The tendon of the biceps receives a long tubular sheath, which is continuous with the synovial membrane, both at its attached extremity and at the bicipital groove, but is free in the rest of its extent. The synovial cavity almost always communicates with the bursa under the subscapularis, and sometimes with one under the infraspinatus muscle.

It also sends a pouch-like prolongation beneath the coracoid process when the fibrous capsule is attached wide of the margin of the glenoid fossa. A few fringes are seen near the edge of the glenoid cavity, and there is often one which runs down the medial edge of the biceps tendon, extending slightly below it and making a slight groove for the tendon to lie in.

The **transverse humeral ligament** (fig. 323) is so closely connected with the capsule of the shoulder that, although it is a proper ligament of the humerus, it may well be described here. It is a strong band of fibrous tissue, which extends between the two tuberosities, roofing in the intertubercular (bicipital) groove. It is covered by a thin expansion of the capsule. It is limited to the portion of the bone above the line of the epiphysis.

Relations.—The following muscles are in contact with the capsule of the shoulder-joint. In front, the subscapularis; above, the supraspinatus; above and behind, the infraspinatus; behind, the teres minor; below, the long head of the triceps and the teres major. In the interval between the subscapularis and the supraspinatus the subacromial bursa is close to the capsule and occasionally its cavity communicates with the cavity of the joint.

FIG. 324.—THE UPPER EXTREMITY OF THE HUMERUS, ANTERIOR VIEW, TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE SHOULDER-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



The axillary (circumflex) nerve and posterior circumflex artery pass beneath the capsule in the interval between the long head of the triceps, the humerus, and the teres major. When the arm is abducted, the long head of the triceps and the teres major are drawn into closer relation with the capsule and help to prevent dislocation of the humerus.

The axillary vessels, the great nerves of the axilla, the short head of the biceps, and the coracobrachialis are separated from the joint by the subscapularis, whilst the deltoid forms a kind of cap, which extends from the front to the back over the more immediate relations.

The **arterial supply** is derived from the transverse scapular (suprascapular), anterior and posterior circumflex, subscapular, circumflex scapular (dorsalis scapulæ), and a branch from the second portion of the axillary artery.

The **nerve-supply** is derived from the suprascapular, by branches in both fossæ; and from the axillary (circumflex) and subscapular nerves.

The **movements** (cf. p. 540) of the shoulder-joint consist of flexion, extension, adduction, abduction, rotation and circumduction.

Flexion is the swinging forward, *extension* the swinging backward, of the humerus; *abduction* is the raising of the arm from, and *adduction* depression of the arm to, the side. In flexion and extension the head of the humerus moves upon the center of the glenoid fossa round an oblique line corresponding to the axis of the head and neck of the humerus, flexion being more free than extension, and in extreme flexion the scapula follows the head of the humerus, so as to keep the articular surfaces in apposition. In extension the scapula moves much less, if at all. In abduction and adduction the scapula is fixed, and the humerus rolls up and down upon the glenoid fossa; during abduction the head descends until it projects beyond the lower edge of the glenoid cavity, and the greater tuberosity impinges against the arch of the acromion; during adduction, the head of the humerus ascends in its socket, the arm at length reaches the side, and the capsule is completely relaxed.

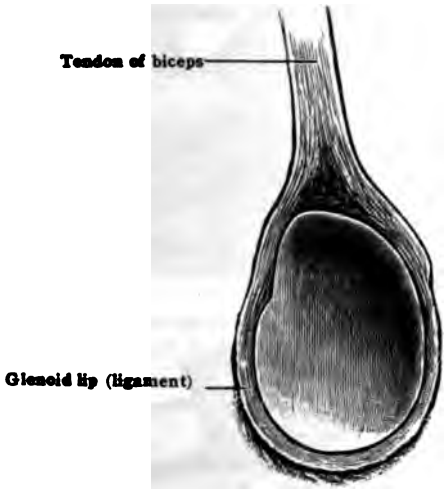
In *circumduction*, the humerus, by passing quickly through these movements, describes a cone, whose apex is at the shoulder-joint, and the base at the distal extremity of the bone. *Rotation* takes place round a vertical axis drawn through the extremities of the humerus from

the center of the head to the medial condyle; in rotation forward (that is, medialward) the head of the bone rolls back in the socket as the great tuberosity and shaft are turned forward; in rotation backward (that is, lateralward) the head of the bone glides forward, and the tuberosity and shaft of the humerus are turned backward, i. e., lateralward.

Great freedom of movement is permitted at the shoulder, and this is increased by the mobility of the scapula. Restraint is scarcely exercised at all upon the movements of the shoulder by the ligaments, but chiefly by the muscles of the joint. In abduction, the lower part of the capsule is somewhat, and in extreme abduction considerably, tightened; and in rotation medialward and lateralward, the upper part of the capsule is made tense, as is also, in the latter movement, the coracohumeral ligament.

The movements of abduction and extension have a most decided and definite resistance offered to them other than by muscles and ligaments, for the greater tuberosity of the humerus, by striking against the acromion process and coracoacromial ligament, stops short any further advance of the bone in these directions, and thus abduction ceases altogether as soon as the arm is raised to a right angle with the trunk, and extension shortly after the humerus passes the line of the trunk.

FIG. 325.—BICEPS TENDON, BIFURCATING AND JOINING THE GLENOID LIP.



Further elevation of the arm beyond the right angle, in the abducted or extended position, is effected by the rotation of the scapula round its own axis by the action of the trapezius and serratus anterior muscles upon the sternoclavicular and acromioclavicular joints respectively.

The acromion and coracoid process, together with the coracoacromial ligament, form an arch, which is separated by a bursa and the tendon of the supraspinatus from the capsule of the shoulder. Beneath this arch the movements of the joint take place, and against it the head and tuberosities are pressed when the weight of the trunk is supported by the arms; the greater tuberosity and the upper part of the shaft impinge upon it when abduction and extension are carried to their fullest extent.

No description of the shoulder-joint would be complete without a short notice of the peculiar relation which the biceps tendon bears to the joint. It passes over the head of the humerus a little to the medial side of its summit, and lies free within the capsule, surrounded only by a tubular process of synovial membrane. It is flat, with the surfaces looking upward and downward, until it reaches the intertubercular (bicipital) groove, when it assumes a rounded form. It strengthens the articulation along the same course as the coracohumeral ligament, and tends to prevent the head of the humerus from being pulled upward too forcibly against the inferior surface of the acromion. It also serves the purpose of a ligament by steadying the head of the humerus in various movements of the arm and forearm; it is let into a groove at the upper end of the bone, from which it cannot escape on account of the abutting tuberosities and the strong transverse humeral ligament which binds it down. Further, it acts like the four shoulder muscles which pass over the capsule, to keep the head of the humerus against the glenoid socket; and, moreover, it resists the tendency of the pectoralis major and latissimus dorsi muscles, in certain actions when the arm is away from the side of the body, to pull the head of the humerus below the lower edge of the cavity.

Muscles which act upon the shoulder-joint (cf. p. 397).—*Flexors or protractors.*—Deltoid (anterior fibers), pectoralis major (clavicular fibers), coracobrachialis, biceps (short head), subscapularis (upper fibers). *Extensors or retractors.*—Latissimus dorsi, deltoid (posterior fibers), teres major, teres minor, infraspinatus (lower fibers). *Abductors.*—Deltoid, supraspinatus, biceps (long head). *Adductors.*—Pectoralis major, latissimus dorsi, subscapularis, infraspinatus, teres major, teres minor, coracobrachialis, biceps (short head), triceps (lower head). *Medial rotators.*—Pectoralis major, latissimus dorsi, teres major, subscapularis, deltoid (anterior fibers). *Lateral rotators.*—Deltoid (posterior fibers), infraspinatus, teres minor. *Circumductors.*—The above groups acting consecutively.

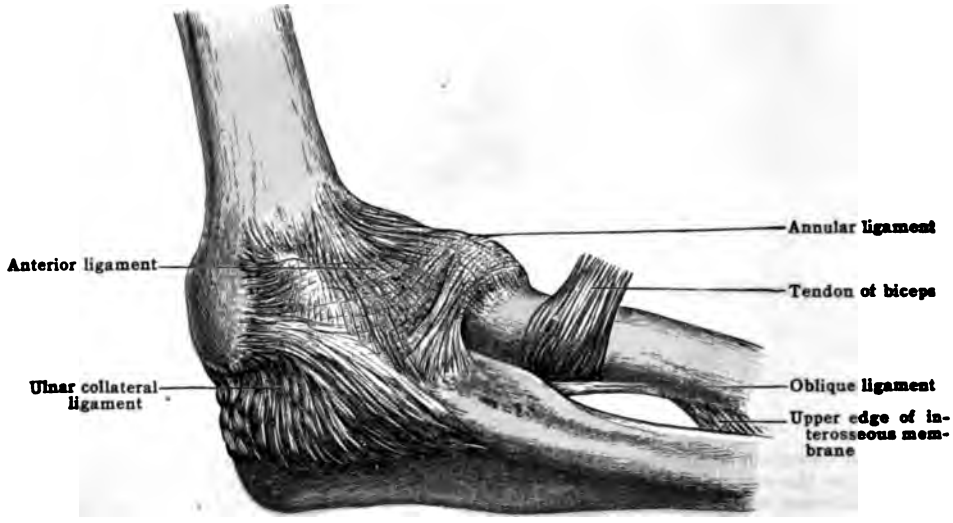
4. THE ELBOW-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The elbow-joint [articulatio cubiti] is a complete hinge, and, unlike the knee, depends for its security and strength upon the configuration of its bones rather than on the number, strength, or arrangement of its ligaments. The bones composing it are the lower end of the humerus above, and the upper ends of the radius and ulna below; the articular surface of the humerus being received partly within the semilunar notch (great sigmoid cavity) of the ulna, and partly upon the cup-shaped area (fovea) of the radial head. Thus it will be noted that the elbow includes two articulations: the **humeroulnar** and **humeroradial joints.** Besides these which enter into the mechanism of the hinge movement, there is also present within the capsule of the elbow, the **proximal radioulnar articulation,** concerned in the movements of pronation and supination.

The ligaments of the elbow form one large and capacious capsule [capsula articularis], which, by blending with the annular ligament, and then passing on to

FIG. 326.—MEDIAL VIEW OF THE ELBOW-JOINT.



be attached to the neck of the radius, embraces the elbow and the superior radioulnar joints, uniting them into one (fig. 330). Laterally, it is considerably strengthened by superadded fibers arising from the epicondyles of the humerus and inseparably connected with the capsule. For convenience of description it will be spoken of as consisting of four portions:—

Anterior.	Medial.
Posterior.	Lateral.

The **anterior portion** (fig. 326) is attached to the front of the humerus above the articular surface and coronoid fossa, in an inverted V-shaped manner, to two very faintly marked ridges which start from the front of the medial and lateral epicondyles, and meet a variable distance above the coronoid fossa. Below, it is fixed, just beyond the articular margin, to the front of the coronoid process and it is intimately blended with the front of the annular ligament, a few fibers passing on to the neck of the radius.

It varies in strength and thickness, being sometimes so thin as barely to cover the synovial membrane; at others, thick and strong, and formed of coarse decussating fibers, the majority of which descend from the medial side laterally to the radius.

The **posterior portion** (fig. 327), thin and membranous, is attached superiorly to the humerus, in much the same inverted V-shaped way as the anterior; ascending from the medial epicondyle, along the medial side of the olecranon fossa nearly to the top; then, crossing the bottom of the fossa, it descends on the lateral

side, skirting the lateral margin of the trochlear surface, and turns laterally along the posterior edge of the capitulum. Inferiorly, it is attached to a slight groove along the superior and lateral surfaces of the olecranon, and the rough surface of the ulna just beyond the radial notch, and to the annular ligament, a few fibers passing on to the neck of the radius.

FIG. 327.—LATERAL VIEW OF THE ELBOW-JOINT.

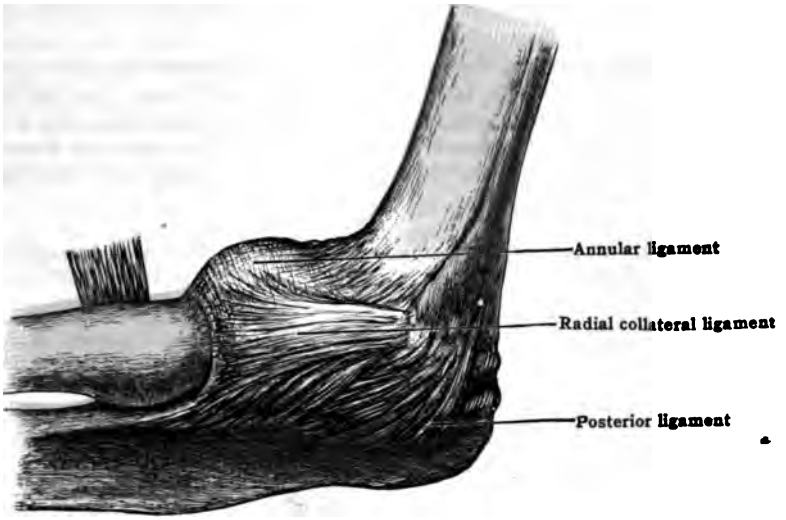
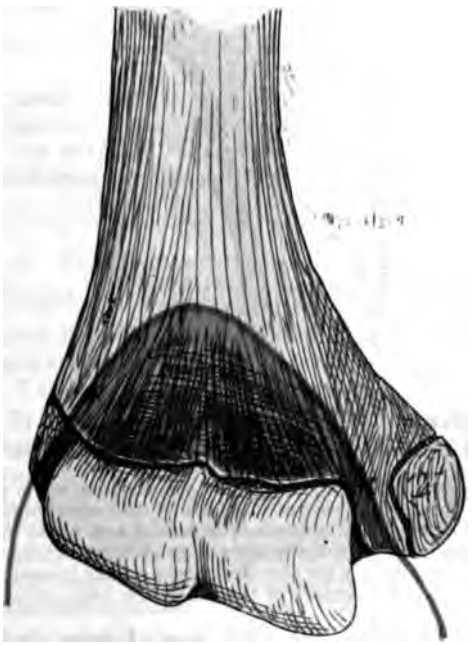


FIG. 328.—LOWER EXTREMITY OF THE HUMERUS, TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE ELBOW-JOINT (IN RED) TO THE EPIPHYSIAL LINES.



It is composed of decussating fibers, most of which pass vertically or obliquely downward, a few taking a transverse course at the summit of the olecranon fossa where the ligament is usually thinnest.

The medial portion, the ulnar collateral ligament (fig. 326), is thicker, stronger, and denser than either the anterior or posterior portions. It is triangular in form, its apex being attached to the anterior and inferior aspect of the medial epicondyle, and to the condyloid edge of the groove between the trochlea and the

condyle. The fibers radiate downward from this attachment, the anterior passing forward to be fixed to the rough overhanging medial edge of the coronoid process; the middle descend less obliquely to a ridge running between the coronoid and olecranon processes, while the posterior pass obliquely backward to the medial edge of the olecranon just beyond the articular margin.

An oblique band (the *oblique ligament* of Sir Astley Cooper) connects the margin of the olecranon process with the margin of the coronoid process. It lies superficial to the posterior fibers of the ulnar collateral ligament. Tne anterior fibers are the thickest, strongest, and most pronounced.

The **lateral portion,** the **radial collateral ligament** (fig. 327), is attached above to the lower part of the lateral epicondyle, and from this the fibers radiate to their attachment into the lateral side of the annular ligament, a few fibers being prolonged to reach the neck of the radius. The anterior fibers reach further forward than the posterior do behind. It is strong and well-marked, but less so than the medial portion.

FIG. 329.—THE UPPER EXTREMITY OF THE ULNA, TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE ELBOW-JOINT (IN RED) TO THE EPIPHYSIAL LINES.

The **synovial membrane** lines the whole of the capsule of the elbow-joint, and extends into the superior radioulnar joint, lining the annular ligament.

Outside the synovial membrane, but inside the capsule, are often seen some pads of fatty tissue; one is situated on the medial side at the base of the olecranon, another is seen on the lateral side projecting into the cavity between the radius and ulna; this latter, with a fold of synovial membrane opposite the front of the lateral lip of the trochlea, suggests the division of the joint into two parts—one medially for the ulna, and another laterally for the radius. There are also pads of fatty tissue at the bottom of the olecranon and coronoid fossæ, and at the tip of the olecranon process.

The **arterial supply** is derived from each of the vessels forming the free anastomosis around the elbow, and there is also a special branch to the front and lateral side of the joint, from the brachial artery, and the arterial branch to the brachialis also feeds the front of the joint.

The **nerve-supply** comes chiefly from the musculocutaneous; the ulnar, median, and radial (musculospiral) also gives filaments to the joint.

Relations.—In front of the joint, and in immediate relation with the capsule, are the brachialis, the superficial and deep branches of the radial (musculospiral) nerve, the radial recurrent artery, and the brachioradialis. The brachial artery, the median nerve, and the pronator teres are separated from the capsule by the brachialis. Directly behind the capsule are the triceps, the anconeus, and the posterior interosseous recurrent artery. On the medial side are the ulnar nerve, the superior ulnar collateral (inferior profunda) artery, and the upper

darts of the flexor carpi ulnaris and flexor digitorum sublimis. On the lateral side lie the extensor carpi radialis longus and the upper part of the common tendon of origin of the superficial extensors of the wrist and fingers.

The movements permitted at the elbow (cf. p. 541) are those of a true hinge-joint, viz., flexion and extension. These movements are oblique, so that the forearm is inclined medially in flexion, and laterally in extension; they are limited by the contact respectively of the coronoid and olecranon processes of the ulna with their corresponding fossæ on the humerus, and their extent is determined by the relative proportion between the length of the processes and depth of the fossæ which receive them, rather than by the tension of the ligaments, or the bulk of the soft parts over them. The anterior and posterior portions of the capsule, together with the corresponding portions of the collateral ligament, are not put on the stretch during flexion and extension; but, although they may assist in checking the velocity, and thus prevent undue force of impact, they do not control or determine the extent of these movements. The limit of extension is reached when the ulna is nearly in a straight line with the humerus; and the limit of flexion when the ulna describes an angle of from 30° to 40° with the humerus.

The obliquity of these movements is due to the lateral inclination of the upper and back part of the trochlear surface, and the greater prominence of the medial lip of the trochlea below; thus the plane of motion is directed from behind forward and medially, and carries the hand toward the middle third of the clavicle. The obliquity of the joint, the twist of the shaft of the humerus, and the backward direction of its head, all tend to bring the hand toward the midline of the body, under the immediate observation of the eye, whether for defence, employment, or nourishment. This is in striking contrast to the lower limb, where the direction of the foot diverges from the median axis of the trunk, thus preventing awkardness in locomotion. In flexion and extension, the cup-like depression of the radial head glides upon the capitulum, and the medial margin of the radial head travels in the groove between the capitulum and the trochlea. This allows the radius to rotate upon the humerus while following the ulna in all its movements. In full extension and supination, the head of the radius is barely in contact with the inferior surface of the capitulum, and projects so much backward that its posterior margin can be felt as a prominence at the back of the elbow. In full flexion the anterior edge of the radial head is received into, and checked against, the depression above the capitulum; while in midflexion the cup-like depression is fairly received upon the capitulum, and in this position, the radius being more completely steadied by the humerus than in any other, pronation and supination take place most perfectly.

Muscles which act upon the elbow-joint (cf. p. 411ff).—*Flexors.*—Brachialis, biceps, brachioradialis, pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis, flexor carpi ulnaris. *Extensors.*—Triceps, anconeus, and the muscles from the lateral epicondyle.

5. THE UNION OF THE RADIUS WITH THE ULNA

The radius is firmly united to the ulna by two joints, and an intermediate fibrous union, viz.:—

(*a*) **The superior radioulnar**—whereat the head of the radius *rotates* within the radial notch and annular ligament.

(*b*) The **union of the shafts**—the **mid-radioulnar union.**

(*c*) The **inferior radioulnar**—whereat the lower end of the radius *rolls round* the head of the ulna.

(*a*) The Superior Radioulnar Joint

Class.—*Diarthrosis.* **Subdivision.**—*Trochoides.*

The bones which enter into this joint (which is often included with the elbow-joint) are the ulna by its radial notch and the radius by the smooth vertical border or rim on its head. There is but one ligament special to the joint, viz.:—

Annular ligament of the radius.

The annular ligament (fig. 330) consists of bands of strong fibers, somewhat thicker than the capsule of the elbow-joint, which encircle the head of the radius, retaining it against the side of the ulna. The bulk of these fibers forms about three-fourths of a circle, and they are attached to the anterior and posterior margins of the radial notch; some few are continued round below the radial notch, and form a complete ligamentous circle.

The ligament is inseparably connected along its upper edge and lateral (i. e., its nonarticular) surface with the anterior, posterior, and lateral portions of the capsule of the elbow, a few of the fibers of these portions, especially of the lateral, descending to be attached to the neck of the radius. The lower part of the articulation is covered in anteriorly, posteriorly, and laterally by a thin independent membranous layer, which passes from the lower edge of the annular ligament to the neck of the radius, strengthened on the lateral side by those fibers passing down from the capsule. They are loose enough to allow the bone to rotate upon its own axis (fig. 330). Medially and below the cavity is closed in by a loose membrane, the ligamentum quadratum, which passes from the lower border of the radial notch to the neck of the radius.

The **synovial membrane** is a continuation of that of the elbow-joint, and, after lining the annular ligament, passes on to the neck of the radius, and thence up to the lower margin of the articular cartilage. It forms the *recessus sacciformis.*

The arterial and nerve-supply are the same as those to the lateral part of the elbow-joint. **Relations.**—Behind lies the anconeus and in front the lateral border of the brachialis.

(*b*) The Mid-Radioulnar Union

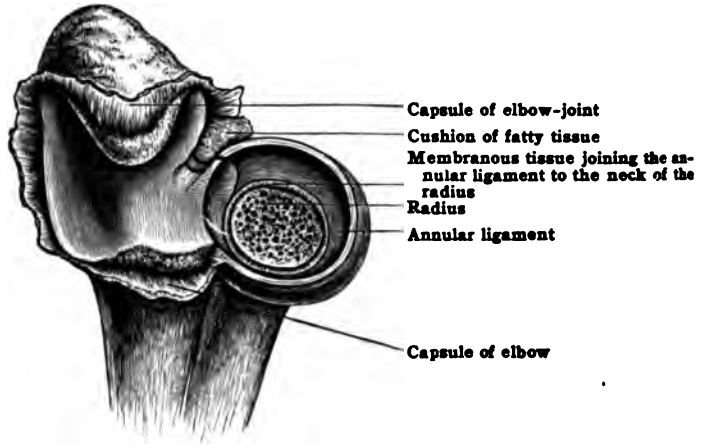
Class.—*Synarthrosis.* **Subdivision.**—*Syndesmosis.*

There are two interosseous ligaments which pass between the shafts of the bones and unite them firmly together, viz.:—

Oblique cord. Interosseous membrane.

The **oblique cord** [chorda obliqua] (figs. 326, 331) is a fairly strong, narrow band, which passes from the lower end of the rough lateral border of the coronoid process, downward and laterally to be attached to the posterior edge of the lower end of the tuberosity of the radius and the vertical ridge running from it to the medial border of the bone.

Fig. 330.—Annular Ligament and Capsule of the Elbow-joint.
(The head of the radius removed to show the membranous connection of the annular ligament with the radius.)


Capsule of elbow-joint
Cushion of fatty tissue
Membranous tissue joining the annular ligament to the neck of the radius
Radius
Annular ligament
Capsule of elbow

Some of its fibers blend with the fibers of insertion of the biceps tendon; behind, it is in close contact with the *supinator;* below, a thin membrane passes off from it to the upper edge of the interosseous membrane; the posterior interosseous vessels pass in the space between it and the interrosseous membrane; occasionally a slip is continued into the annular ligament of the superior radioulnar articulation (see fig. 331).

The **interosseous membrane** (fig. 326) is attached to the ulna at the lowest part of the ridge in front of the depression for the supinator, and along the whole length of the interosseous border as far as the inferior radioulnar articulation, approaching the front of the bone in the lower part of its attachment. To the radius it is attached along the interosseous border, from 2.5 cm. below the tuberosity to the ulnar notch for the lower end of the ulna.

It is strongest and broadest in the center, where the fibers are dense and closely packed; it is also well marked beneath the pronator quadratus, and thickens considerably at the lower end, forming a strong band of union between the two bones. Its fibers pass chiefly downward and medially, from the radius to the ulna, though some take the opposite direction; at the lower end some are transverse. On the posterior surface are one or two bands, which pass downward and laterally from the ulna to the radius, and frequently there is a strong bundle as large as the oblique cord; this, which may be called the **inferior oblique ligament** (fig. 336), stretches from the ulna, an inch and a half above its lower extremity, downward and laterally to the ridge above and behind the ulnar notch of the radius.

At its attachment to the bones, the interosseous membrane blends with the periosteum. Its upper border is connected with the oblique cord by a thin membrane, which is pierced by the posterior interosseous vessels; and the lower border, which stretches across between the two bones just above the inferior radioulnar articulation, assists in completing the capsule of that

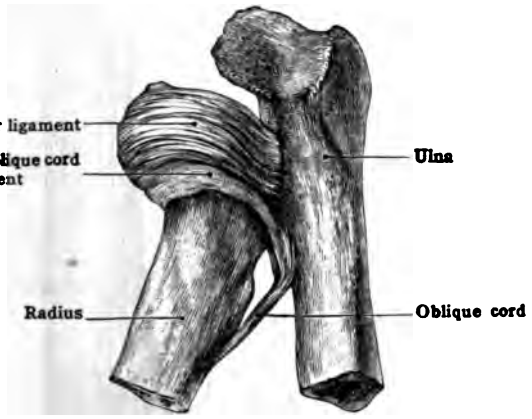
int. Its anterior surface is in relation with the flexor digitorum profundus and flexor pollicis ngus in the upper three-quarters, the lower fourth being in relation with the pronator quad- tus. The anterior interosseous vessels and nerve descend along the middle of the membrane, e artery being bound down to it. About an inch from the lower end it is pierced by the nterior interosseous artery. The posterior surface is in relation with the supinator, abductor ollicis longus, extensor pollicis longus and brevis, and the extensor indicis proprius; at its lower art, also with the posterior branch of the anterior interosseous artery, and the deep branch of the adial nerve (posterior interosseous).

(*c*) The Inferior Radioulnar Joint

Class.—*Diarthrosis.* **Subdivision.**—*Trochoides.*

This is, in one respect, the reverse of the superior; for the radius, instead of presenting a circular head to rotate within a concavity of the ulna, presents a concave surface which rolls round the head of the ulna. The articulation may be said to consist of two parts at right angles to each other; one between the radius and ulna, and the other between the ulna and the articular disk (triangular fibrocartilage).

Fig. 331.—Upper Portions of Left Ulna and Radius, to show an Occasional Slip from the Oblique Cord to the Lower Part of the Annular Ligament.
(From a dissection by Mr. W. Pearson, Royal College of Surgeons, England.)



The ligaments are:—

Anterior radioulnar. Posterior radioulnar.

Articular disk

The **articular disk** (triangular fibrocartilage) (figs. 336, and 337) assists the adius in forming an arch under which is received the first row of carpal bones. ts base is attached to the margin of the radius, separating the ulnar notch from he articular surface for the carpus, while its apex is fixed to the fossa at the base f the styloid process of the ulna. It gradually and uniformly diminishes in vidth from base to apex, becoming rounded where it is fixed to the ulna; it is oined by fibers of the ulnar collateral ligament of the wrist.

The articular disk measures about 1 cm. from side to side and from before backward. It s thicker at the circumference than in the center; smooth and concave above to adapt itself o the ulna, and smooth and slightly concave below to fit over the triquetral bone. Its anterior nd posterior borders are united to the anterior and posterior radioulnar and radiocarpal liga- nents. It is the most important structure in the inferior radiocarpal articulation, as it is a ery firm bond of union between the lower ends of the bones, and serves to limit their movements pon one another more than any other structure in either the upper or lower radioulnar joints. ts structure is fibrous at the circumference, while in the center there is a preponderance of cells. t differs from all other fibrocartilages in entering into two distinct articulations; and separates ntirely the synovial membrane of the radioulnar joint from that of the wrist.

The lower end of the **interosseous membrane** extends between the ulna and adius immediately above their points of contact. Transverse fibers between the wo bones form a sort of arch above the concave articular facet of the radius, and, oining the anterior and posterior radioulnar ligaments, complete the **articular apsule** of the inferior radioulnar joint. The ligaments represent merely hickenings of the capsule.

The **anterior radioulnar ligament** (fig. 333) is attached by one end to the anterior edge of the ulnar notch of the radius, and by the other to the rough bone above the articular surface of the ulna as far medially as the notch, as well as into the anterior margin of the triangular cartilage from base to apex.

The **posterior radioulnar ligament** (fig. 334) is similarly attached to the posterior margin of the ulnar notch at one end, and at the other to the rough bone above the articular surface of the extremity of the ulna as far medially as the groove for the extensor carpi ulnaris, with the sheath of which it is connected, as well as into the whole length of the posterior margin of the articular disk. Both the radioulnar ligaments consist of thin, almost scattered, fibers.

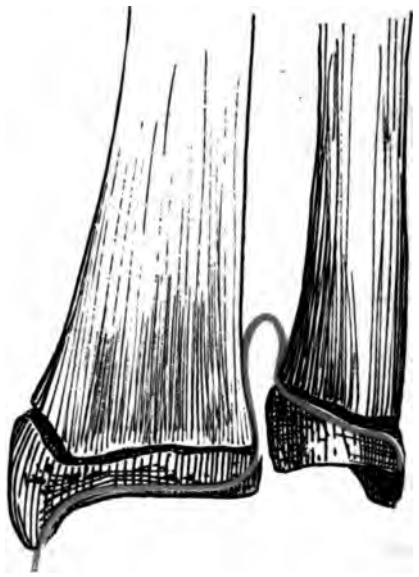
The **synovial membrane** is large and loose in proportion to the size of the joint reaching upward between the radius and ulna above the level of their articular surfaces to form the **recessus sacciformis.** The synovial cavity extends between the terminal articular surface of the ulna and the upper surface of the articular disk.

The **arterial supply** is derived from the volar interosseous artery and branches of the volar carpal rete.

The **nerve-supply** comes from the volar interosseous of the median, and the deep branch of the radial (posterior interosseous).

Relations.—Behind lies the tendon of the extensor digiti quinti proprius and in front the flexor digitorum profundus.

FIG. 332.—LOWER EXTREMITIES OF THE RADIUS AND ULNA TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE WRIST JOINT (IN RED) TO THE EPIPHYSIAL LINES. Note the upward extension of the membrana sacciformis.



The movements of the radius (cf. p. 541).—The upper end of the radius rotates upon an axis drawn through its own head and neck within the collar formed by the radial notch and the annular ligament, while the lower end, retained in position by the articular disk rolls round the head of the ulna. This rotation is called *pronation*, when the radius from a position nearly parallel to the ulna turns medialward so as to lie obliquely across it; and *supination*, when the radius turns back again, so as to uncross and lie nearly parallel with the ulna. In these movements the radius carries with it the hand, which rotates on an axis passing along the ulnar side of the hand; thus, the hand when pronated lies with its dorsum upward, as in playing the piano, while when supinated, the palm lies upward—the attitude of a beggar asking alms. Ward thus expresses the relations of the two extremities of the radius in pronation and supination: 'The head of the radius is so disposed in relation to the sigmoid cavity (ulnar notch) at the lower end that the axis of the former if prolonged falls upon the center of the circle of which the latter is a segment;' the axis thus passes through the lower end of the ulna at a point at which the articular disk is attached, and if prolonged further, passes through the ring finger. Thus the radius describes, in rotating, a blunt-pointed cone whose apex is the center of the radial head, and whose base is at the wrist; partial rotation of the bone being unaccompanied by any hinge-like or anteroposterior motion of its head, and pronation and supination occurring without disturbance to the parallelism of the bones at the superior radioulnar joint. Associated with this rotation in the ordinary way, there is some rotation of the humeroulnar shaft, which causes lateral shifting of the hand from side to side; thus, with pronation there is some abduction, and with supination some adduction combined, so that the hand can keep on the same superficies in both pronation and supination. The power of supination in man is much greater than pronation, owing to the immense power and leverage obtained by the curve of the radius, and by the attachment of the biceps tendon to the back of the tuberosity. For this reason all our screw-driving and boring tools are made to be used by supination movements.

In the undissected state, the amount of rotation it is possible to obtain is about 135°, so t neither the palm nor the fore part of the lower end of the radius can be turned completely pposite directions; yet in the living subject this amount can be greatly increased by rotation he humeroulnar shaft at the shoulder-joint.

Pronation is checked in the living subject by (a) the posterior inferior radioulnar ligament, ch is strengthened by the connection of the sheath of the extensor tendons with it; (b) the ermost fibers of the interosseous membrane; (c) the back part of the ulnar collateral and scent fibers of the posterior ligament of the wrist, and (d) the meeting of the soft parts on front of the forearm.

Supination is checked mainly (a) by the medial ulnar collateral ligaments of the wrist, but tly also by (b) the oblique cord; (c) the anterior inferior radioulnar ligament, and (d) the est fibers of the interosseous membrane.

The interosseous membrane serves, from the direction of its fibers downward and medially m the radius to the ulna, to transmit the weight of the body from the ulna to the radius in extended position of the elbow, as in pushing forward with the arms extended, or in support- one's own weight on the hands, the ulna being in intimate contact with the humerus, but t at all with the carpus; while the area of contact of the radius with the humerus is small, d that of the radius with the carpus large. Hence the weight transmitted by the ulna is mmunicated to the radius by the tightening of the interosseous membrane. Conversely, in ls upon the hand with the arm extended, the interosseous membrane acts as a sling to break e violence of the shock, and prevents the whole force of the impact from expending itself rectly upon the capitulum.

Muscles which act upon the radioulnar joints (cf. p. 416).—*Pronators.*—Pronator teres, onator quadratus, flexor carpi radialis, palmaris longus. *Supinators.*—Biceps, supinator, tensor pollicis longus. The brachioradialis is chiefly a flexor of the elbow-joint, but it takes art in the initiation of the movements of supination, when the hand is fully pronated, and of ronation when the hand is fully supinated.

6. THE RADIOCARPAL OR WRIST-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

The wrist-joint is formed by the union of the radius and articular disk above, rticulating with the navicular, lunate, and triquetral bones below; the ulna eing excluded by the intervention of the articular disk. The radius and disk ogether present a smooth surface, slightly concave both from before backward, nd from side to side, whilst the three bones of the carpus present a smooth, onvex surface, made uniformly even by the interosseous ligaments which bind hem together.

The capsule of the wrist-joint has been usually described as four separate liga- nents, and it will be convenient for the sake of a complete description to follow his method; but it must be understood that these four portions are continuous round the joint, extending from styloid process to styloid process on both its spects.

The four portions are:—

Volar radiocarpal.	Ulnar collateral.
Dorsal radiocarpal.	Radial collateral.

The **volar** (or anterior) **radiocarpal** [lig. radiocarpeum volare] (fig. 333) is a hick strong ligament, attached superiorly to the radius immediately above the nterior margin of the terminal articular facet, to the curved ridge at the root of he styloid process of the radius, and to the anterior margin of the articular disk, blending with some fibers of the capsule of the inferior radioulnar joint. It passes lownward and in a medial direction to be attached to both rows of carpal bones, specially the second, and to the volar intercarpal ligament.

The strongest and most oblique fibers arise from the root of the styloid process of the radius, nd pass obliquely over the navicular, with which only a few fibers are connected, to be inserted nto the lunate, capitate, and triquetral bones. Another set, less oblique, passes from the nargin of the facet for the lunate to be attached to the adjacent parts of the capitate, hamate, nd triquetral bones. Between the two sets of fibers, small vessels pass into the joint.

The **dorsal** (or posterior) **radiocarpal ligament** [lig. radiocarpeum dorsale] fig. 334) is attached above to the dorsal edge of the lower end of the radius, the ack of the styloid process, and the posterior margin of the fibrocartilage. It asses downward and in a medial direction to be connected with the first row of f the carpal bones, chiefly with the lunate and triquetral, and the dorsal inter- arpal ligament. This ligament is thin and membranous.

It is strengthened by (i) strong fibers passing from the back of the articular disk where hey are blended with the posterior inferior radioulnar ligament, and, from the edge of the radius

just behind the ulnar notch, to the triquetral bone; (ii) from the ridge and groove for the extensor pollicis longus to the back of the lunate and triquetral bones; and (iii) from the groove for the radial extensors to the back of the navicular and lunate. It is in relation with, and strengthened by, the extensor tendons which pass over it.

FIG. 333.—ANTERIOR VIEW OF WRIST.

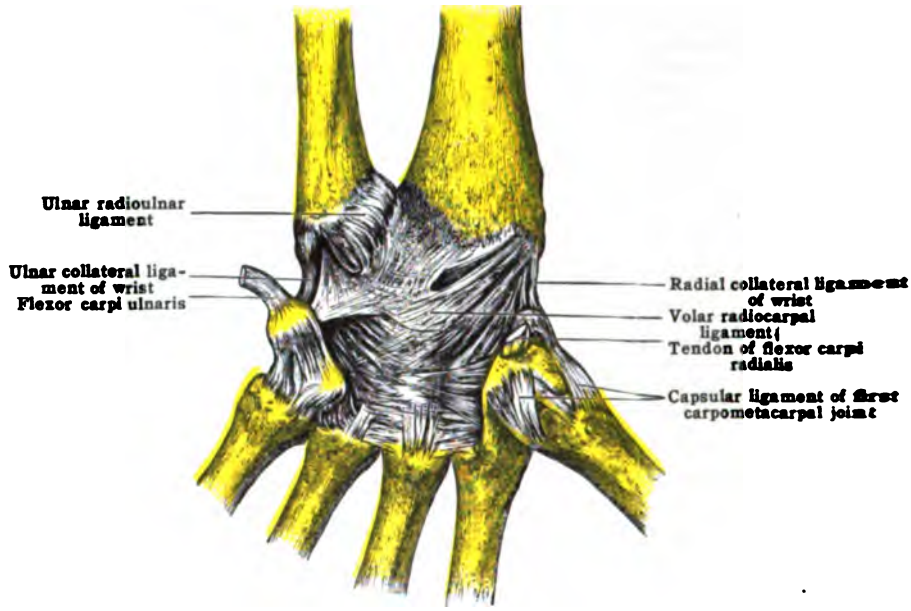
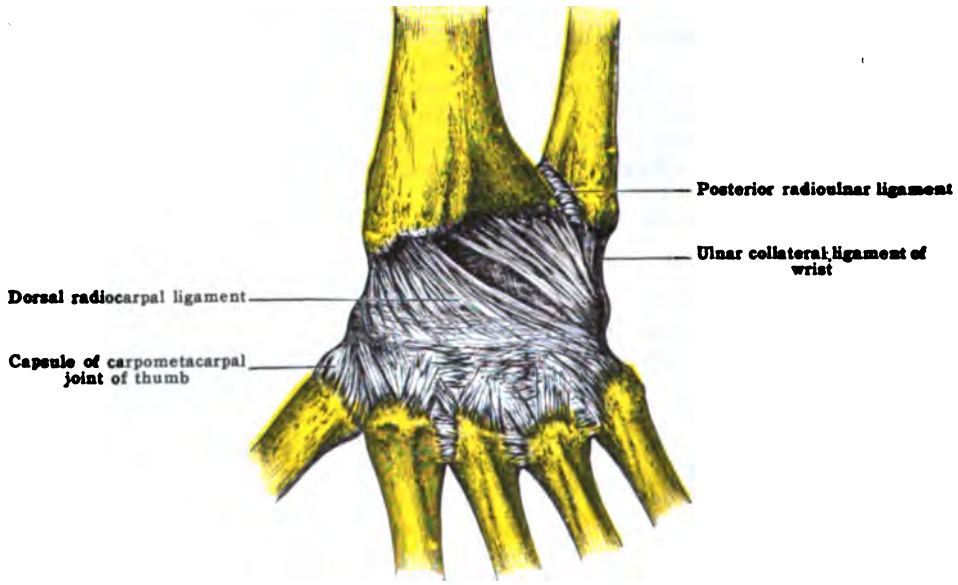

Ulnar radioulnar ligament
Ulnar collateral ligament of wrist
Flexor carpi ulnaris
Radial collateral ligament of wrist
Volar radiocarpal ligament
Tendon of flexor carpi radialis
Capsular ligament of first carpometacarpal joint

FIG. 334.—POSTERIOR VIEW OF WRIST-JOINT.

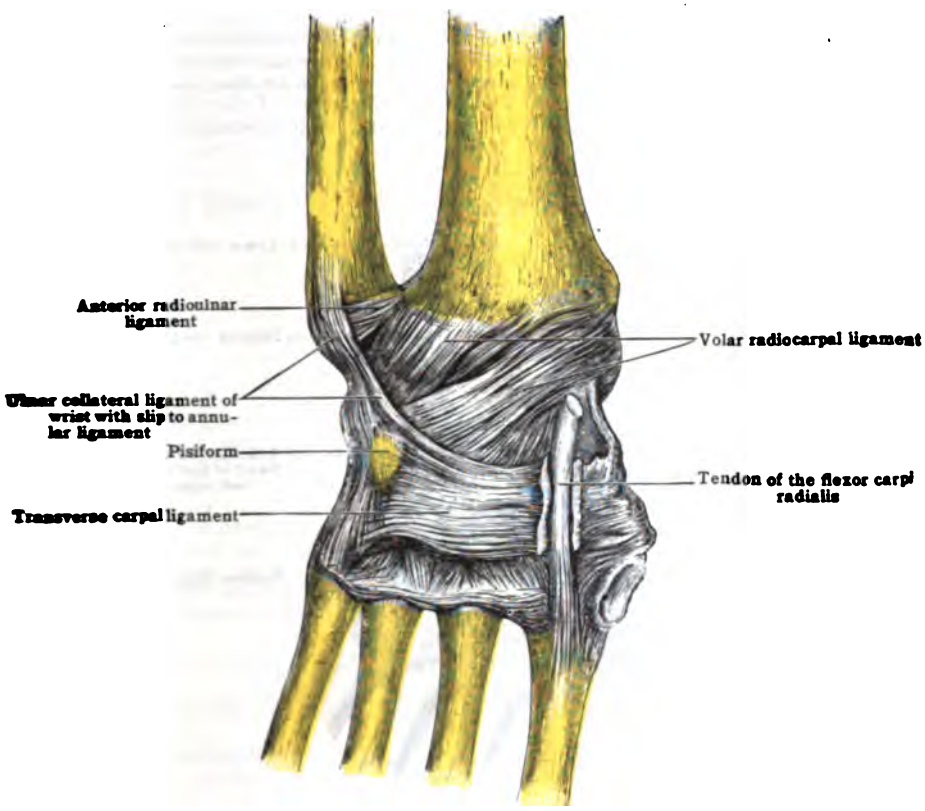

Posterior radioulnar ligament
Ulnar collateral ligament of wrist
Dorsal radiocarpal ligament
Capsule of carpometacarpal joint of thumb

The **ulnar collateral ligament** (fig. 334) is fan-shaped, with its apex above, at the styloid process of the ulna, to which it is attached on all sides, blending with the apex of the articular disk. Some of the fibers pass forward and laterally to the base of the pisiform bone and to the medial part of the upper border of the transverse carpal ligament, where it is attached to the pisiform bone; they form a thick, rounded fasciculus on the front of the wrist. Other fibers descend vertically to the medial side of the triquetral bone, and others again laterally to the dorsal surface of the triquetral. The tendon of the extensor carpi ulnaris is posterior to, and passes over, part of the fibers of the ligament.

The radial collateral ligament (fig. 333) consists of fibers which radiate from the fore part and tip of the styloid process of the radius. Some pass downward and medially, in front, to the navicular and adjacent edge of the capitate; some downward, a little forward and medially, to the tubercle of the navicular and ridge of the greater multangular; and others downward and laterally to the rough dorsal surface of the navicular.

The fibers of this ligament are not so long and strong, nor do they radiate so much as those of the ulnar collateral ligament. It is in relation with the radial artery, and the abductor pollicis longus and extensor pollicis brevis, the artery separating the tendons from the ligament.

FIG. 335.—FRONT OF WRIST WITH TRANSVERSE CARPAL LIGAMENT.


Anterior radioulnar ligament
Volar radiocarpal ligament
Ulnar collateral ligament of wrist with slip to annular ligament
Pisiform
Tendon of the flexor carpi radialis
Transverse carpal ligament

The **synovial membrane** is extensive, but does not usually communicate with the synovial membrane of the inferior radioulnar joint, being shut out by the articular disk. It is also excluded, in almost every instance, from that of the carpal joints by the interosseous ligaments between the first row of carpal bones. The styloid process of the radius is cartilage-covered medially, and forms part of the articular cavity, while that of the ulna does not.

The arterial supply is derived from the anterior and posterior carpal rami, the dorsal division of the volar interosseous, and from twigs direct from the radial and ulnar arteries.

The nerve-supply is derived from the ulnar and median in front, and the deep branch of the radial (posterior interosseous) behind.

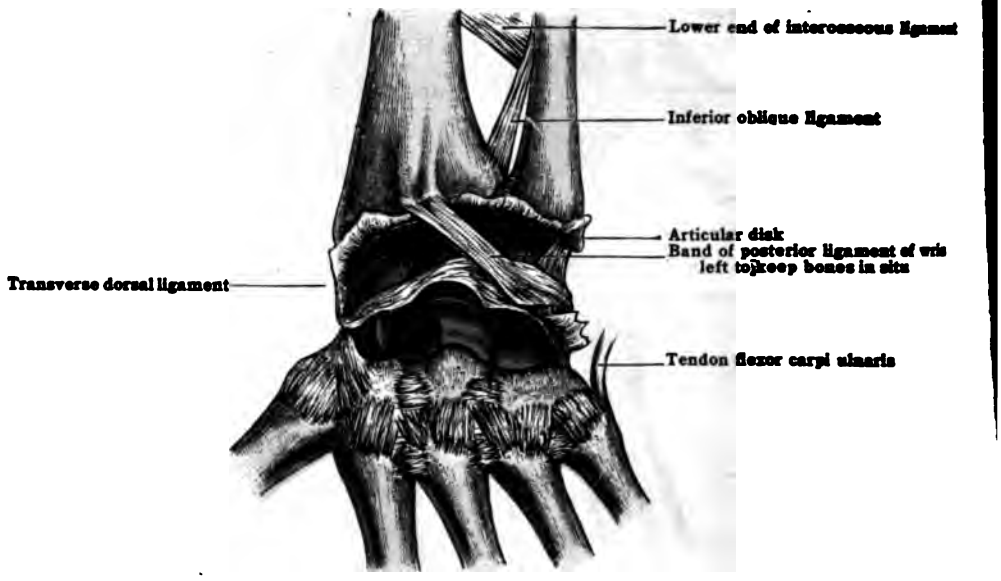
Relations.—In front of the radiocarpal joint are the tendons of the flexor muscles of the wrist and fingers, the synovial sheaths associated with them, the radial and ulnar arteries, and the median and ulnar nerves.

Behind the joint are the majority of the tendons of the extensor muscles of the wrist and fingers, with their synovial sheaths, the terminal part of the anterior and posterior interosseous arteries, and the deep branch of the radial nerve (posterior interosseous). On the radial side lie the tendons of the abductor pollicis longus and the extensor pollicis brevis. On the ulnar side the joint is subcutaneous and is crossed by the dorsal cutaneous branch of the ulnar nerve.

Movements (cf. p. 541).—The wrist is a condyloid joint, the carpus forming the condyle. It allows of movements upon a transverse axis, i. e., flexion and extension; and around an antero-posterior axis, i. e., abduction and adduction; together with a combination of these in quick succession—circumduction. Lacking only rotation on a vertical axis, it thus possesses most of the movements of a ball-and-socket joint, without the weakness and liability to dislocation

which are peculiar to these joints. This deficiency of rotation is compensated for by the movements of the radius at the radioulnar joints, viz., supination and pronation. Its strength depends chiefly upon the number of tendons which pass over it, and the close connection which exists between the fibrous tissue of their sheaths and the capsule of the wrist; also upon the proximity of the mediocarpal and carpometacarpal joints, which permits shocks and jars to be shared and distributed between them; another source of strength is the absence of any long bone on the distal side of the joint. In flexion and extension the carpus rolls backward and forward, respectively, beneath the arch formed by the radius and articular disk; flexion being limited by the dorsal ligament and dorsal portions of the collateral; extension by the volar, and volar portions of the collateral ligaments. In adduction and abduction the carpal bones glide from the ulnar to the radial side and from the radial to the ulnar side, respectively. Abduction is more limited than adduction, and is checked by the ulnar collateral ligament and by contact of the styloid process of the radius with the greater multangular; adduction is checked by the radial collateral ligament alone. One reason for adduction being more free than abduction is that the ulna does not reach so low down as the radius, and the yielding articular disk allows of greater movement upward of the ulnar end of the carpus. In circumduction the hand moves so as to describe a cone, the apex of which is at the wrist. These movements are made more easy and extensive by the slight gliding of the carpal bones upon one another, and the comparatively free motion at the mediocarpal joint. The oblique direction of the fibers of the collateral ligaments prevents any rotation at the radiocarpal joint, while it permits considerable freedom of abduction and adduction.

FIG. 336.—POSTERIOR VIEW OF THE WRIST, WITH CAPSULE CUT TO SHOW ARTICULAR SURFACES.


Lower end of interosseous ligament
Inferior oblique ligament
Articular disk
Band of posterior ligament of wrist left to keep bones in situ
Transverse dorsal ligament
Tendon flexor carpi ulnaris

Muscles which act upon the radiocarpal joint (cf. p. 416).—*Flexors.*—The flexors of the carpus and the long flexors of the fingers and the thumb, and the palmaris longus. *Extensors.*—The extensors of the carpus and fingers. *Abductors.*—Extensor carpi radialis longus, the abductor pollicis longus. *Adductor.*—Flexor carpi ulnaris, extensor carpi ulnaris.

7. THE CARPAL JOINTS

The joints of the carpus [articulatio intercarpea] may be subdivided into:—

(*a*) The **joints of the first row.**
(*b*) The **joints of the second row.**
(*c*) The **mediocarpal**, or junction of the two rows with each other.

(*a*) THE JOINTS OF THE FIRST ROW OF CARPAL BONES

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The bones of the first row, the pisiform excepted, are united by two sets of ligaments and two interosseous fibrocartilages.

Dorsal. Interosseous. Volar.

The **two dorsal intercarpal ligaments** extend transversely between the bones, and connect the navicular with the lunate, and the lunate with the triquetral. Their posterior surfaces are in contact with the posterior ligament of the wrist.

The two volar intercarpal ligaments extend nearly transversely between the bones connecting **the navicular** with the lunate, and the lunate with the triquetral. They are stronger than **the dorsal ligaments**, and are placed beneath the anterior ligament of the wrist.

The two interosseous intercarpal ligaments (fig. 337) are interposed between the navicular **and lunate**, and the lunate and triquetral bones, reaching from the dorsal to the volar surfaces, **and being** connected with the dorsal and volar ligaments. They are narrow fibrocartilages **which extend** between small portions only of the osseous surfaces. They help to form the **convex carpal** surface of the radiocarpal joint, and are somewhat wedge-shaped, their bases **being** toward the wrists, and their thin edges between the adjacent articular surfaces of the bones.

The synovial membrane is a prolongation from that of the mediocarpal joint.

The arterial and **nerve-supplies** are the same as for the mediocarpal joint.

The Joint of the Pisiform Bone with the Triquetral

This [articulatio ossis pisiformis] is an arthrodial joint which has a loose **fibrous capsule** attached to both the pisiform and triquetral bones just beyond the **margins** of their articular surfaces.

It is lined by a separate synovial membrane. Two strong rounded or flattened bands pass **downward** from the pisiform, one to the process of the hamate [lig. pisohamatum], and the **other** [lig. pisometacarpeum] to the bases of the third to fifth metacarpals; these are regarded as **prolongations** of the tendon of the flexor carpi ulnaris, and the pisiform bone may be looked **upon** in the light of a sesamoid bone developed in that tendon.

(*b*) The Joints of the Second Row of Carpal Bones

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The four bones of this row are united by three dorsal, three volar, and three interosseous ligaments.

The three dorsal ligaments (fig. 336) extend transversely and connect the greater with the lesser multangular, the lesser multangular with the capitate, and the capitate with the hamate.

The three volar ligaments are stronger than the dorsal, and are deeply placed beneath the **mass** of flexor tendons; they extend transversely between the bones in a manner similar to that of the dorsal ligaments.

Three interosseous ligaments connect the bones of the lower row of the carpus together. Two are connected with the capitate, one uniting it with the hamate (fig. 337) and the other binding it to the lesser multangular. The third ligament joins the greater and lesser multangular.

The **synovial membrane** is a prolongation of that lining the mediocarpal joint.

The **arterial** and **nerve-supplies** are the same as for the mediocarpal joint.

(*c*) The Mediocarpal Joint between the Two Rows of the Carpus

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The inferior surfaces of the bones of the first row are adapted to the superior articular surfaces of the bones of the second row. The line of this articulation is concavo-convex from side to side, and is sometimes described as having the course of a Roman S placed horizontally, ∽, a resemblance by no means strained. (i) The lateral part of the first row consists of the navicular alone; it is convex, and bears the greater and lesser multangulars. (ii) Then follows a transversely elongated socket formed by the medial part of the navicular, the lunate, and triquetral, into which are received—(*a*) the head of the capitate, which articulates with the navicular and lunate; (*b*) the upper and lateral angle of the hamate, which articulates with the navicular; and (*c*) the upper convex portion of the medial surface of the hamate, which articulates with the lateral and concave portion of the interior surface of the triquetral. (iii) The medial part of the inferior surface of the triquetral bone is convex, and turned a little backward to fit into the lower portion of the medial surface of the hamate, which is a little concave and turned forward to receive it. The central part, which forms a socket for the capitate and hamate, has somewhat the character of a condyloid joint, the capitate and hamate being the condyle, to fit into the cavity formed by the navicular, lunate, and triquetral; the other portions are typically arthrodial. The ligaments are:—(1) **radiate or anterior mediocarpal**; (2) **posterior mediocarpal**; (3) **transverse dorsal.**

The radiate, anterior or volar mediocarpal is a ligament of considerable strength, consisting **mostly of fibers which radiate from the capitate to the navicular, lunate, and triquetral; some few fibers connect the greater and lesser** multangular with the navicular, and others pass **between the hamate and triquetral.** It is covered over and thickened by fibrous tissue derived

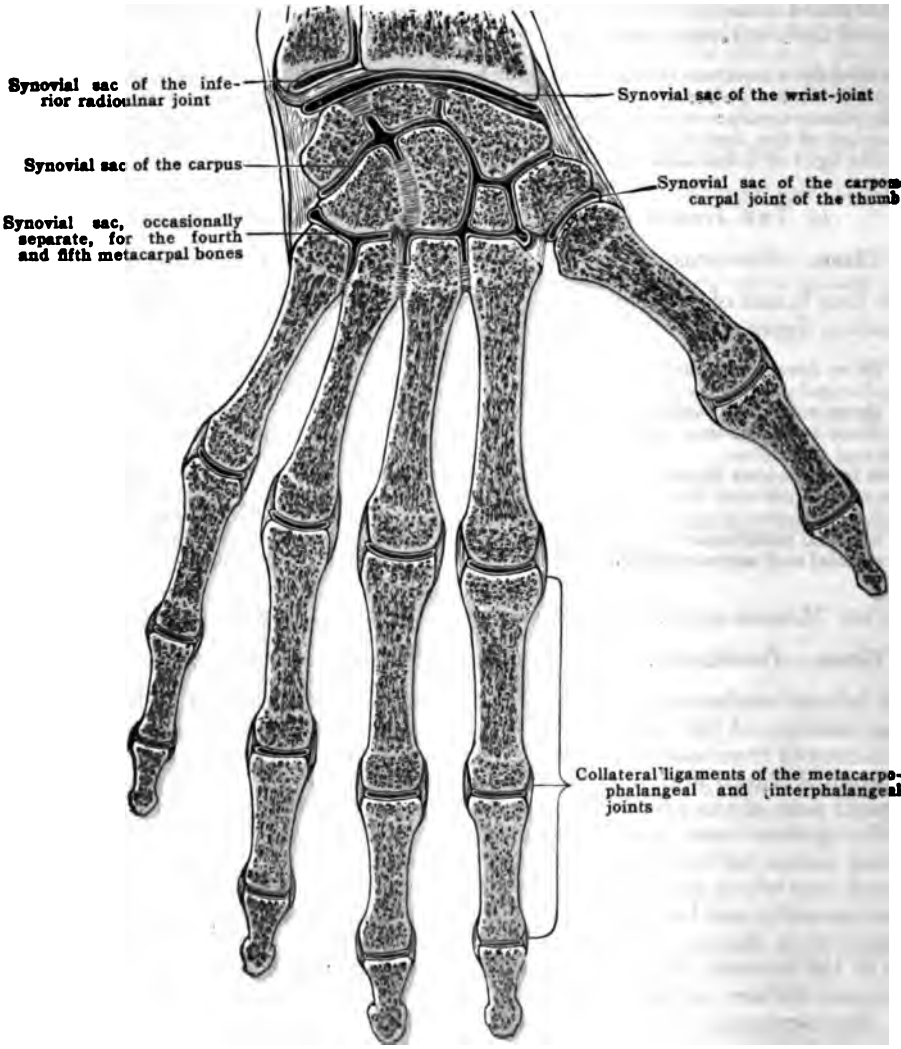
from the sheaths of the flexor tendons and the fibers of origin of the small muscles of the thumb and little finger.

The posterior or **dorsal mediocarpal ligament**, consists of fibers passing obliquely from the bones of the first row to those of the second. It is stronger on the ulnar side than on the radial, but is not so strong as the volar ligament.

The **transverse dorsal ligament** (fig. 336) is an additional band, well marked and often of considerable strength, which passes across the head of the capitate from the navicular to the triquetral bone; besides binding down the head of the capitate, it serves to fix the upper and lateral angles of the hamate in the socket formed by the first row.

The dorsal ligamets, like the volar, are strengthened by a quantity of fibrous tissue belonging to the sheaths of the extensor tendons, and by an extension of some of the fibers of the capsule of the wrist. There are no proper collateral mediocarpal ligaments; they are but prolongations of the collateral ligaments of the wrist.

FIG. 337.—ARTICULAR CAVITIES OF WRIST, HAND, AND FINGERS.


Synovial sac of the inferior radioulnar joint
Synovial sac of the carpus
Synovial sac, occasionally separate, for the fourth and fifth metacarpal bones
Synovial sac of the wrist-joint
Synovial sac of the carpometacarpal joint of the thumb
Collateral ligaments of the metacarpophalangeal and interphalangeal joints

The **synovial membrane** (fig. 337) of the carpus is common to all the joints of the carpus, and extends to the bases of the four medial metacarpal bones. Thus, besides lining the inter- or mediocarpal joint, it sends two processes upward between the three bones of the first row, and three downward between the contiguous surfaces of the lesser and greater multangular, the lesser multangular and capitate, and capitate and hamate. From these latter, prolongations extend to the four medial carpometacarpal joints and the three intermetacarpal joints.

The **arterial supply** is derived from—(*a*) the volar and dorsal carpal rami of the radial and ulnar arteries; (*b*) the carpal branch of the volar interosseous; (*c*) the recurrent branches from the deep volar arch. The terminal twigs of the volar and dorsal interosseous arteries supply the joint on its dorsal aspect.

The **nerve-supply** comes from the ulnar on the ulnar side, the median on the radial side, and the deep branch of the radial (posterior interosseous) behind.

Relations.—The relations of this joint are practically the same as those of the radiocarpal nt, except that the flexor carpi ulnaris does not cross the front, the ulnar artery is separated om it by the transverse carpal ligament, and the radial artery passes across its lateral border stead of in front.

The movements of the carpal articulations between bones of the same row are very limited d consist only of slight gliding upon one another; but, slight as they are, they give elasticity the carpus and break the jars and shocks which result from blows or falls upon the hand.

The movements of one row of bones upon the other at the mediocarpal joint are more tensive, especially in the direction of flexion and extension, so that the hand enjoys a greater nge of these movements than is permitted at the wrist-joint alone. At the wrist, extension is ore free than flexion; but this is balanced by the greater freedom of flexion than of extension the mediocarpal joint, and by flexion at the carpometacarpal joint, so that on the whole the nge of flexion of the hand is greater than that of extension.

A slight amount of side-to-side motion accompanied by a limited degree of rotation also kes place; this rotation consists in the head of the capitate and the superior and lateral angle f the hamate bone rotating in the socket formed by the three bones of the upper row, and in a liding forward and backward of the greater and lesser multangular upon the navicular.

In addition to the ligaments, the undulating outline and the variety of shapes of the apposed ccets render this joint very secure.

Bearing in mind the mobility of this mediocarpal joint and the carpometacarpal, we see t once the reason for the radial and ulnar flexors and extensors of the carpus being prolonged own to their insertion into the base of metacarpus, for they produce the combined effect f motion at each of the three transverse articulations:—(1) at the wrist; (2) at the mediocarpal; 3) at the carpometacarpal joints.

Muscles which act upon the midcarpal joint.—The muscles which act upon this joint are he same as those which act upon the radiocarpal joint.

8. THE CARPOMETACARPAL JOINTS

These may be divided into two sets, namely:—

(*a*) The **carpometacarpal joints of the four medial fingers.**
(*b*) The **carpometacarpal joints of the thumb.**

The inferior surfaces of the bones of the second row of the carpus present a omposite surface for the four medial metacarpal bones; the greater multangular resents in addition a distinct and separate saddle-shaped surface for the base of ıe metacarpal bone of the thumb.

(*a*) The Four Medial Carpometacarpal Joints

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

These joints exist between the greater and lesser multangular, capitate, and amate bones above, and the four medial metacarpal bones below. The liga- ents which unite them are, dorsal, volar and interosseous.

The dorsal ligaments (fig. 336).—Three dorsal ligaments pass to the second metacarpal ne: one from each of the carpal bones with which it articulates, viz., the greater and lesser ultangular, and capitate. Two dorsal bands pass from the capitate to the third metacarpal ne. Two dorsal bands pass to the fourth bone: viz., one from the hamate, and another from e capitate; the latter is sometimes wanting. The fifth bone has only one band passing to it om the hamate.

The volar ligaments (fig. 333).—One strong band passes from the second metacarpal bone the greater multangular medial to the ridge for the transverse carpal ligament; it is covered r the sheath of the flexor carpi radialis.

Three bands pass from the third metacarpal: one laterally to the greater multangular, a iddle one upward to the capitate, and a third medially over the fourth to reach the fifth meta- rpal and the hamate bones.

One ligament connects the fourth bone to the hamate.

One ligament connects the fifth bone to the hamate, the fibers extending medially, and con- ecting the dorsal and volar ligaments. The ligament to the fifth bone is strengthened in front r the prolonged fibers of the flexor carpi ulnaris and the strong medial slip of the ligament of e third metacarpal bone; and posteriorly, by the tendon of the extensor carpi ulnaris.

The interosseous ligament (fig. 337) is limited to one part of the articulation, and consists short fibers connecting the contiguous angles of the hamate and capitate with the third and urth metacarpal bones toward their volar aspect. There is, however, a thick strong ligament nnecting the edge of the greater multangular with the lateral border of the base of the second etacarpal bone; it helps to separate the carpometacarpal joint of the thumb from the common rpometacarpal joint, and to close in the radial side of the latter joint.

The synovial membrane is a continuation of the mediocarpal joint; occasionally there is separate membrane between the hamate and fourth and fifth metacarpal bones (fig. 337); hile that between the fourth and capitate is lined by the synovial sac of the common joint.

The arteries to the four medial carpometacarpal joints are as follows:—

(1) For the index finger: twigs are supplied by the trunk of the radial on the dorsal and volar pects, and by the dorsal and volar metacarpal branches. (2) For the middle finger: the first

dorsal metacarpal by the branch which passes upward to join the dorsal carpal arch, and a branch from the deep volar arch which joins the volar carpal arch. (3) For the ring finger: the deep volar arch and recurrent twigs from the second dorsal metacarpal in the same manner as for the middle finger. (4) For the little finger: the ulnar and its deep branch; also twigs from the second dorsal metacarpal.

The **nerves** are supplied to these joints by the deep volar branch of the ulnar, the deep branch of the radial (posterior interosseous), and the median.

Relations.—In front of the four medial carpometacarpal joints are the flexors of the fingers with their synovial sheath. The flexor carpi radialis crossing in front of the lateral part of the joint and the fibers of the oblique adductor pollicis which spring from the capitate and lesser multangular are also anterior relations. Behind the joints are the extensors of the wrist and fingers with their synovial sheaths and the dorsal metacarpal arteries. At the lateral border of the joints between the index and lesser multangular lies the radial artery.

The **movements** permitted at these joints (cf. p. 541), though slight, serve to increase those of the mediocarpal and wrist-joints. The joint between the fifth metacarpal and the hamate bones approaches somewhat in shape and mobility the first carpometacarpal joint; it has a greater range of flexion and extension, but its side-to-side movement is nearly as limited as that of the three other metacarpal bones; the process of the hamate bone limits its flexion. Motion toward the ulnar side is checked by the strong palmar band which unites the base of the fifth metacarpal to the base of the third, and the strong transverse ligament at the head of the bones. The mobility of the second, third, and fourth metacarpal bones is very limited, and consists almost entirely of a slight gliding upon the carpal bones, i. e., flexion and extension; that of the third and fourth bones is extremely slight, as there is no long flexor attached to either; but, owing to the close connection of the bases of the metacarpal bones, the radial and ulnar flexors and extensors of the carpus act on all by their pull on the particular bone into which they are inserted.

Abduction, or movement toward the radial side, is prevented by the impaction of the second bone against the greater multangular; a little adduction is permitted, and is favored by the slope given to the hamate and fifth metacarpal bones.

There is also a slight gliding between the fourth and fifth bones, when the concavity they present toward the palm is deepened to form the 'cup of Diogenes.'

Muscles which act upon the four medial carpometacarpal joints are the flexors and extensors of the wrist and fingers (cf. p. 437).

(*b*) The Carpometacarpal Joint of the Thumb

Class.—*Diarthrosis.* **Subdivision.**—*Ephippial.*

The bones entering into this joint are the base of the first metacarpal and the greater multangular. The first metacarpal bone diverges from the other four, contrasting very strongly with the position of the great toe. It is due to this divergence that the thumb is able to be opposed to each and all the fingers. The ligament which unites the bones is the

Articular capsule.

The **articular capsule** (figs. 333, 334) consists of fibers which pass from the margin of the articular facet on the greater multangular, to the margin of the articular facet at the base of the first metacarpal bone.

The fibers are stronger on the dorsal than on the volar aspect. They are not tense enough to hold the bones in close contact, so that while they restrict they do not prevent motion in any direction. The medial fibers are stronger than the lateral.

The **synovial membrane** is lax, and distinct from the other synovial membranes of the carpus.

The **arteries** of the carpometacarpal joint of the thumb are derived from the trunk of the radial, the first volar metacarpal, and the dorsalis pollicis.

The **nerves** are supplied by the branches of the median to the thumb.

Relations.—Behind are the long and short extensor tendons of the thumb, and behind and laterally the tendon of the abductor pollicis longus. The tendon of the flexor pollicis longus is in front and fibers of the flexor pollicis brevis and opponens pollicis muscles are also anterior relations. To the medial side is the radial artery as it passes forward into the palm of the hand.

The **movements** of this joint (cf. p. 541) are regulated by the shape of the articular surfaces, rather than by the ligaments, and consist of flexion, extension, abduction, adduction, and circumduction, but not rotation. In flexion and extension the metacarpal bone slides to and fro upon the multangular; in abduction and adduction it slides from side to side or, more correctly, revolves upon the anteroposterior axis of the joint. The power of opposing the thumb to any of the fingers is due to the forward and medial obliquity of its flexion movement, which is by far its most extensive motion. Abduction is very free, while adduction is limited on account of the proximity of the second metacarpal bone. The movement of the greater multangular upon the rest of the carpus somewhat increases the range of all the movements of the thumb.

Muscles which act upon the carpometacarpal joint of the thumb (cf. p. 437).—*Flexors.*—Flexor pollicis brevis, flexor pollicis longus, opponens pollicis. *Extensors.*—Extensores pollicis brevis and longus and abductor pollicis longus. *Abductors.*—Abductores pollicis longus and brevis. *Adductors.*—The transverse and oblique adductor pollicis, opponens, first dorsal interosseous. *Muscles producing opposition.*—Opponens, flexor brevis oblique adductor.

9. THE INTERMETACARPAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The metacarpal of the thumb is not connected with any other metacarpal bone. The second, third, fourth, and fifth metacarpal bones are in actual contact at their bases, and are held firmly together by the following ligaments (in addition to the articular capsule):—

Dorsal. Interosseous ligaments. Volar.

The dorsal ligaments (fig. 335) are layers of variable thickness of strong, short fibers, which pass transversely from bone to bone, filling up the irregularities on the dorsal surfaces.

The volar ligaments are transverse layers of ligamentous tissue passing from bone to bone; they cannot be well differentiated from the other ligaments and fibrous tissue covering the bones.

The interosseous ligaments (fig. 337) pass between the apposed surfaces of the bones, and are attached to the distal sides of the articular facets, so as to close in the synovial cavities on this aspect; where there are two articular facets, the fibers extend upward between them nearly as far as their carpal facets. That between the fourth and fifth is the weakest.

The synovial membrane is prolonged downward from the common carpal sac.

The arteries to the intermetacarpal joints are twigs from the volar and dorsal metacarpal arteries; the twigs pass upward between the interosseous muscles.

The nerves are derived from the ulnar and the deep branch of radial (posterior interosseous).

The Union of the Heads of the Metacarpal Bones

The distal extremities of these bones are connected together on their volar aspects by what is called the **transverse ligament** [ligg. capitulorum transversa]. This consists of three short bands of fibrous tissue, which unite the second and third, third and fourth, and the fourth and fifth bones. They are rather more than 6 mm. deep, and rather less in width, and limit the distance to which the metacarpal bones can be separated. They are continuous above with the fascia covering the interosseous muscles; below, they are connected with the subcutaneous tissue of the web of the hand. They are on a level with the front surface of the bones, and are blended on either side with the edges of the glenoid ligament in front, with the lateral ligaments of the metacarpophalangeal joint, and also with the sheaths of the tendons. In front, a lumbrical muscle passes with the digital arteries and nerves; while behind, the interossei muscles pass to their insertions.

10. THE METACARPOPHALANGEAL JOINTS

(*a*) The Metacarpophalangeal Joints of the Four Medial Fingers

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

In these joints the cup-shaped extremity of the base of the first phalanx fits on to the rounded head of the metacarpal bone, and is united by the following ligaments (in addition to the articular capsule):—

Collateral. Volar accessory.

The volar accessory (or glenoid) **ligament** (fig. 338) is a fibrocartilaginous plate which seems more intended to increase the depth of the phalangeal articular facet in front, than to unite the two bones. It is much more firmly attached to the margin of the phalanx than to the metacarpal bone, being only loosely connected with the palmar surface of the latter by some loose areolar tissue which covers in the synovial membrane, here prolonged some little distance upon the surface of the bone. At the sides, it is connected with the collateral ligaments and the transverse metacarpal ligament. A sesamoid bone sometimes exists at the medial border of the joint of the little finger.

The collateral ligaments (337 and 338) are strong and firmly connect the bones with one another; each is attached above to the corresponding tubercle, and to a depression in front of the tubercle, of the metacarpal bone. From this point the fibers spread widely as they descend on either side of the base of the phalanx; the anterior fibers are connected with the accessory volar ligament; the posterior blend with the tendinous expansion at the back of the joint.

The joint is covered in **posteriorly** by the expansion of the extensor tendon, and some loose areolar tissue passing from its under surface to the bones (fig. 338).

The synovial membrane is loose and capacious, and invests the inner surface of the ligaments which connect the bones.

The arteries come from the digital or volar metacarpal vessels of the deep arch.

The nerves are derived from the digital branches, or from twigs of the branches of the ulnar to the interosseous muscles.

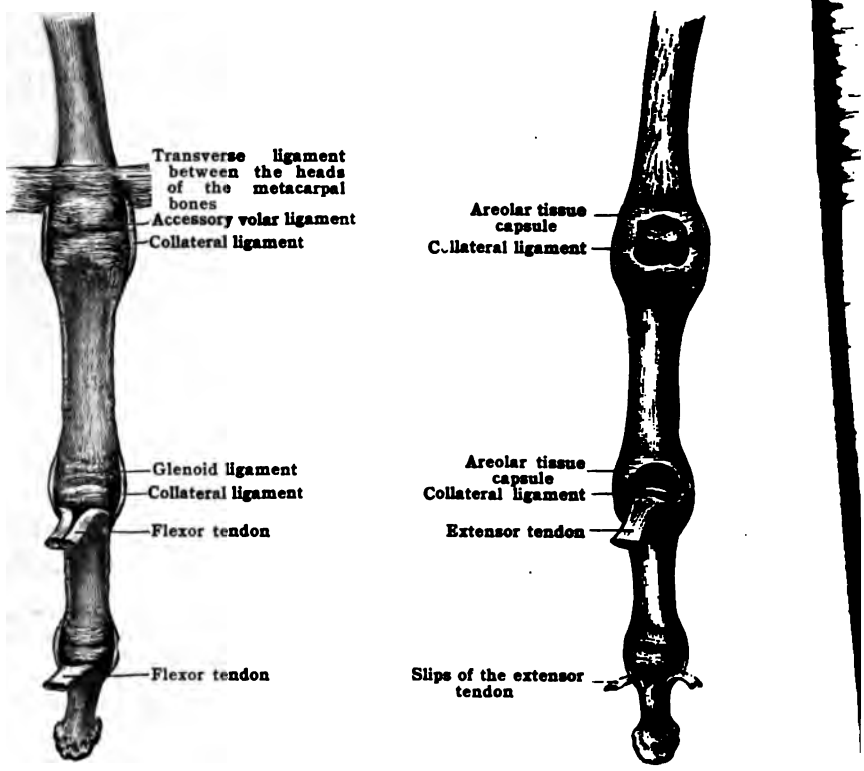
Relations.—1. The metacarpophalangeal joints of the middle three digits. In front the tendons of the flexor profundus and flexor sublimis digitorum. On the radial side, a lumbrical, an interosseous muscle, and digital nerves and vessels; on the ulnar side, an interosseous muscle and digital vessels and nerves. Behind, the common extensor tendon and in the case of the index digit the tendon of the extensor indicis.

2. The metacarpophalangeal joint of the little finger. In front, the flexor digiti quinti brevis and the tendons of the flexor profundus and sublimis digitorum muscle which go to

this digit. Behind, the extensor digiti quinti to a slip of the extensor digitorum communis sometimes. On the radial side, a lumbrical, the third palmar interosseous muscle, digital vessels and nerves. On the ulnar side, digital vessels and nerves.

The movements permitted at these joints (cf. p. 542) are flexion, extension, abduction, adduction, and circumduction. Flexion is the most free of all and may be continued until the phalanx is at a right angle with the metacarpal bone. This is in accord with the fact that the articular surface of the head of the bone is prolonged so much further on the volar aspect, and that the synovial membrane is here so loose and ample. Extension is the most limited of the movements, and can only be carried to a little beyond the straight line. Abduction and adduction are fairly free, but not so free as flexion. Flexion is associated with adduction, and extension with abduction. This may be proved by opening the hand, when the fingers involuntarily separate as they extend, while in closing the fist they come together again. The free abduction, adduction, and circumduction which are permitted at these joints are due to the fact that the long axes of the articular facets are at right angles to one another.

FIG. 338.—ANTERIOR AND POSTERIOR VIEWS OF LIGAMENTS OF THE FINGERS.



Muscles acting on the middle three digits.—*Flexors.*—Flexor digitorum profundus, flexor digitorum sublimis, lumbricales. *Extensors.*—Extensor digitorum communis and on the index digit the extensor indicis. *Abductors.*—Dorsal interossei. *Adductors.*—Volar interossei.

Muscles acting on the metacarpophalangeal joint of the little finger.—*Flexors.*—Flexor digiti quinti brevis, flexor digitorum sublimis, flexor digitorum profundus, lumbricalis. *Extensors.*—Extensor digitorum communis, extensor digiti quinti. *Abductor.*—Abductor digiti quinti. *Adductor.*—Third volar interosseous.

(*b*) THE METACARPOPHALANGEAL JOINT OF THE THUMB

Class.—*Diarthrosis* **Subdivision.**—*Ginglymus.*

The head of the metacarpal bone of the thumb differs considerably from the corresponding ends of the metacarpal bones of the fingers. It is less convex, wider from side to side, the volar edge of the articular surface is raised and irregular, and here on either side of the median line are the two facets for the sesamoid bones. The base of the first phalanx of the thumb, too, is more like the base of the second phalanx of one of the other fingers. The ligaments are:—

Collateral. Articular capsule. Dorsal.

The collateral ligaments are short, strong bands of fibers, which radiate from depressions on either side of the head of the metacarpal bone to the base of the first phalanx and sesamoid

As they descend they pass a little forward, so that the greater number are inserted in
f the center of motion.
dorsal ligament consists of scattered fibers which pass across the joint from one col-
ligament to the other, completing the **articular capsule** and protecting the synovial sac.
sesamoid bones are two in number, situated on either side of the middle line, and con-
together by strong transverse fibers which form the floor of the groove for the long
endon; they are connected with the base of the phalanx and head of the metacarpal bone
ng fibers. Anteriorly they give attachment to the short muscles of the thumb, and pos-
are smooth for the purpose of gliding over the facets. The collateral ligaments are
inserted into their sides.
arteries and **nerves** come from the digital branches of the thumb.
ations—Of the metacarpophalangeal joint of the thumb: In front and externally
or pollicis brevis and superficial head of flexor pollicis brevis. In front and medially
and transverse adductors and deep head of flexor pollicis brevis. Directly in front,
pollicis longus and terminal branches of first volar metacarpal artery. Behind, extensor
brevis and longus tendons. On either side, the dorsal digital vessels and the digital

movements (cf. p. 542) are chiefly flexion and extension, very little side-to-side move-
being permitted, and that only when the joint is slightly bent. Thus this joint more
approaches the simple hinge character than the corresponding articulations of the fingers.
umb gets its freedom of motion at the carpometacarpal joint; the fingers get theirs at
tacarpophalangeal, but they are not endowed with so much freedom as the thumb

scles which act upon the metacarpophalangeal joint of the thumb—*Flexors*.—Flexor
brevis, flexor pollicis longus. *Extensors*—Extensor pollicis brevis, extensor pollicis

11. THE INTERPHALANGEAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

ie ligaments which unite the phalanges of the thumb and of the fingers are
dition to the articular capsule):—

Accessory volar. Collateral.

accessory volar (or glenoid) **ligament** (fig. 338), sometimes called the sesamoid body,
firmly connected with the base of the distal bone, and loosely, by means of fibroareolar
with the head of the proximal one. It blends with the collateral ligaments at the sides,
er it pass the flexor tendons. Occasionally a sesamoid bone is developed in the cartilage
nterphalangeal joint of the thumb.
collateral ligaments (figs. 337, 338) are strong bands which are attached to the rough
ions on the sides of the upper phalanx, and to the projecting margins of the lower phalanx
joint. They are tense in every position, and entirely prevent any side to side motion;
e connected posteriorly with the expansion of the extensor tendon.
sually (fig. 338) the joint is covered in by the deep surface of the extensor tendon, and a
broareolar tissue extends from the tendon, and thickens the posterior portion of the
al sac, completing the **articular capsule**.
synovial membrane is loose and ample, and extends upward a little way along the shaft
proximal bone.
arteries and **nerves** come from their respective digital branches.
relations of the interphalangeal joints are the flexor and extensor tendons and the
vessels and nerves.
movements are limited to flexion and extension (see fig. 462). Flexion is more free,
be continued till one bone is at a right angle to the other, and is most free at the junction
first and second bones; the second phalanx can be flexed on the first through 110° to
hen the latter is not flexed. The greater freedom of flexion is due to the greater extent of
icular surface in front of the heads of the proximal bones, and to the direction of the
f the collateral ligaments, which pass a little forward to their insertion into the distal

muscles which act upon the interphalangeal joints are the extensors and flexors of
its and the lumbricales.

THE ARTICULATIONS OF THE LOWER LIMB

e articulations of the lower limb are the following:—

1. The **hip-joint.**
2. The **knee-joint.**
3. The **tibiofibular union.**
4. The **ankle-joint.**
5. The **tarsal joints.**
6. The **tarsometatarsal joints.**
7. The **intermetatarsal joints.**
8. The **metatarsophalangeal joints.**
9. The **interphalangeal joints.**

1. THE HIP-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Enarthrodia.*

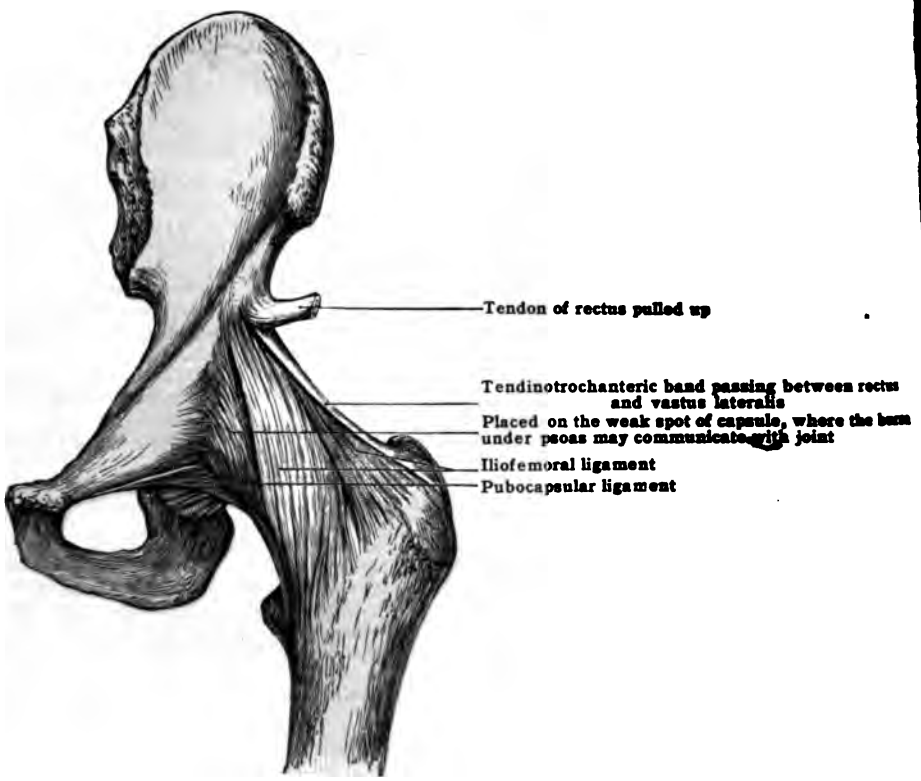
The hip-joint [articulatio coxæ] is the most typical example of a ball-and-socket joint in the body, the round head of the femur being received into the cup-shaped cavity of the acetabulum (figs. 342, 1139). Both articular surfaces are coated with cartilage, that covering the head of the femur being thicker above where it has to bear the weight of the body, and thinning out to a mere edge below; the pit for the ligamentum teres is the only part uncoated, but the cartilage is somewhat heaped up around its margin. Covering the acetabulum, the cartilage is horseshoe-shaped, and thicker above than below, being deficient over the depression at the bottom of the acetabulum, where a mass of fatty tissue—the so-called synovial or Haversian gland—is lodged.

The ligaments of the joint are:—

Articular capsule.	Ligamentum teres.
Transverse.	Glenoid lip.

The **articular capsule** is one of the strongest ligaments in the body. It is large and somewhat loose, so that in every position of the body some portion of

FIG. 339.—ANTERIOR VIEW OF THE ARTICULAR CAPSULE OF THE HIP-JOINT.


Tendon of rectus pulled up
Tendinotrochanteric band passing between rectus and vastus lateralis
Placed on the weak spot of capsule, where the bursa under psoas may communicate with joint
Iliofemoral ligament
Pubocapsular ligament

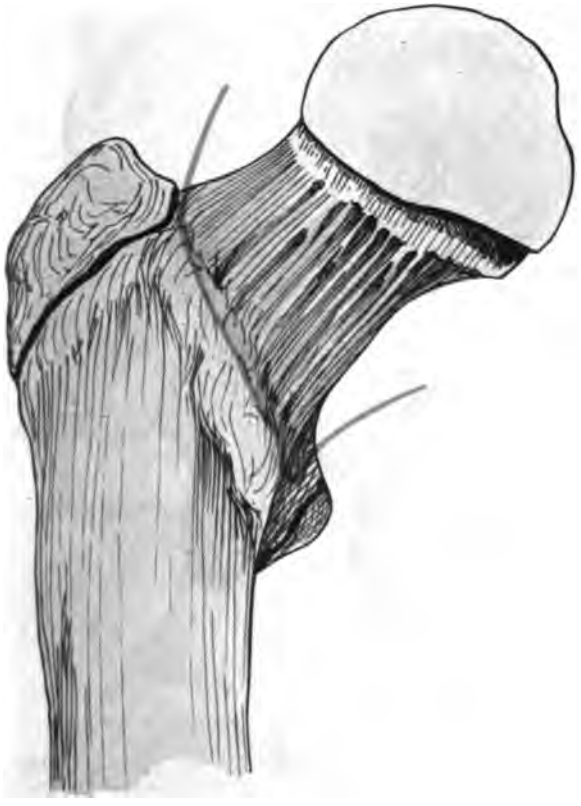
it is relaxed. At the pelvis it is attached, superiorly, to the base of the anterior inferior iliac spine; curving backward, it becomes blended with the deep surface of the reflected tendon of the rectus femoris; posteriorly, it is attached a few millimeters from the acetabular rim; and below, to the upper edge of the groove between the acetabulum and tuberosity of the ischium. Thus it reaches the transverse ligament, being firmly blended with its outer surface, and frequently sends fibers beyond the notch to blend with the obturator membrane. Anteriorly it is attached to the pubis near the obturator notch, to the iliopectineal eminence and thence backward to the base of the inferior iliac spine.

A thin strong stratum is given off from its superficial aspect behind; this extends beneath the gluteus minimus and small rotators, to be attached above to the dorsum of the ilium higher

than the reflected tendon of the rectus, and posteriorly to the ilium and ischium nearly as far as the sciatic notch. As this expansion passes over the long tendon of the rectus, the tendon may be described as being in part contained within the substance of the capsule.

At the femur, the capsule is fixed to the anterior portion of the upper border of the great trochanter and to the cervical tubercle. Thence it runs down the intertrochanteric line as far as the medial border of the femur, where it is on a level with the lower part of the lesser trochanter. It then runs upward and backward along an oblique line about 1.6 cm. in front of the lesser trochanter, and continues its ascent along the back of the neck nearly parallel to the intertrochanteric crest, and from 12 to 16 mm. above it; finally, it passes along the medial side of the trochanteric fossa to reach the anterior superior angle of the great trochanter.

FIG. 340.—UPPER EXTREMITY OF THE FEMUR (ANTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE HIP-JOINT (IN RED) TO THE EPIPHYSEAL LINES.



On laying open the capsule, some of the deeper fibers are seen reflected upward long the neck of the femur, to be attached much nearer the head: these are the retinacula. One corresponds to the upper, and another to the lower, part of the intertrochanteric line; a third is seen at the upper and back part of the neck. They form flat bands, which lie on the femoral neck.

Superadded to the capsule, and considerably strengthening it, are three auxiliary bands, whose fibers are intimately blended with, and in fact form part of, the capsule, viz., the iliofemoral, ischiocapsular, and pubocapsular ligaments.

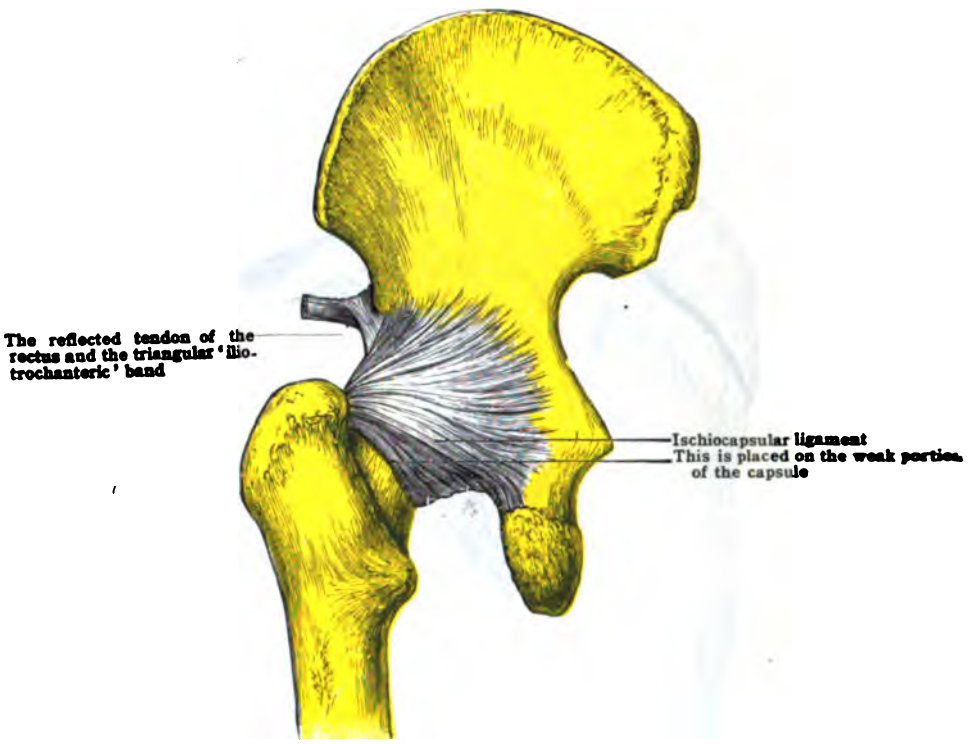
The iliofemoral ligament (fig. 339) is the longest, widest, and strongest of the bands. It is of triangular shape, with the apex attached above to a curved line on the ilium immediately below and behind the anterior inferior spine, and its base below to the anterior edge of the greater trochanter and to the spiral line as far as the medial border of the shaft. The highest or most lateral fibers are coarse, almost straight, and shorter than the rest; the most medial fibers are also thick and strong, but oblique. This varying obliquity of the fibers, and their accumulation at the borders, explain why this band has been described as the Y-shaped ligament; but it should be noted that the Y is inverted. About the center of its base, near the femoral attachment, is an aperture transmitting an articular twig from the ascending branch of the external circumflex artery.

The ischiocapsular ligament (fig. 341) is formed of very strong fibers attached all along the upper border of the groove for the external obturator, and to the ischial margin of the ace-

tabulum above the groove. The highest of these incline a little upward as they pass laterally to be fixed to the greater trochanter in front of the insertion of the piriformis tendon, while the other fibers curve more and more upward as they pass laterally to their insertion at the inner side of the trochanteric fossa, blending with the insertion of the external rotator tendons. When the joint is in flexion, these fibers pass in nearly straight lines to their femoral attachment, and spread out uniformly over the head of the femur; but in extension they wind over the back of the femur in a zonular manner [*zona orbicularis*], embracing the posterior aspect of the neck of the femur.

The **pubocapsular** (**pectineofemoral**) ligament (fig. 339) is a distinct but narrow set of fibers which are individually less marked than the fibers of the other two bands; they are fixed above to the obturator crest and to the anterior border of the iliopectineal eminence, reaching as far down as the pubic end of the acetabular notch. Below, they reach the neck of the femur, and are fixed above and behind the lowermost fibers of the iliofemoral band, with which they blend.

FIG. 341.—POSTERIOR VIEW OF THE ARTICULAR CAPSULE OF THE HIP-JOINT.


The reflected tendon of the rectus and the triangular 'ilio-trochanteric' band
Ischiocapsular ligament
This is placed on the weak portion of the capsule

In **thickness** and strength the capsule varies greatly; thus, if two lines be drawn, one from the anterior inferior spine to the medial border of the femur near the lesser trochanter, and the other from the anterior part of the groove for the external obturator to the trochanteric fossa, all the ligament between these lines on the lateral and upper aspects of the joint is very thick and strong, while that below and to the medial side, except at the narrow pubocapsular ligament, is thin and weak, so that the head of the bone can be seen through it. The capsule is thickest in the course of the iliofemoral ligament, toward the lateral part of which it measures over 6 mm. Between the iliofemoral and ischiocapsular ligaments the capsule is very strong, and with it here, near the acetabulum, is incorporated the reflected tendon of the rectus, and here also a triangular band of fibers runs downward and forward to be attached by a narrow insertion to the ridge on the front border of the great trochanter near the gluteus minimus (the **iliotrochanteric band**) (fig. 341).

The capsule is strengthened also at this point by a strong band from the under surface of the gluteus minimus, and by the **tendinotrochanteric band** which passes down from the reflected tendon of the rectus to the vastus lateralis (externus) (fig. 339). This is closely blended with the capsule near the lateral edge of the iliofemoral ligament.

The thinnest part of the capsule is between the pubocapsular and iliofemoral ligaments; this is sometimes perforated, allowing the bursa under the psoas to

communicate with the joint. The capsule is also very thin at its attachment to the back of the femoral neck, and again opposite the acetabular notch.

The ligamentum teres (figs. 342, 343) is an interarticular flat band which extends from the acetabular fossa to the head of the femur, and is usually about

FIG. 342.—SECTION THROUGH THE HIP-JOINT, SHOWING THE GLENOID LIP, LIGAMENTUM TERES, AND RETINACULA.

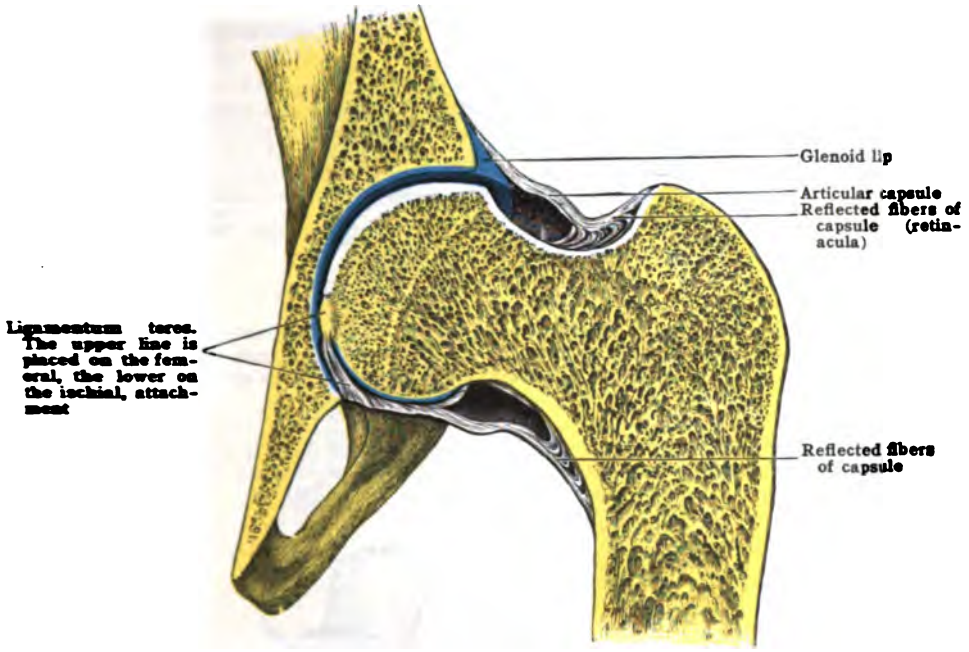
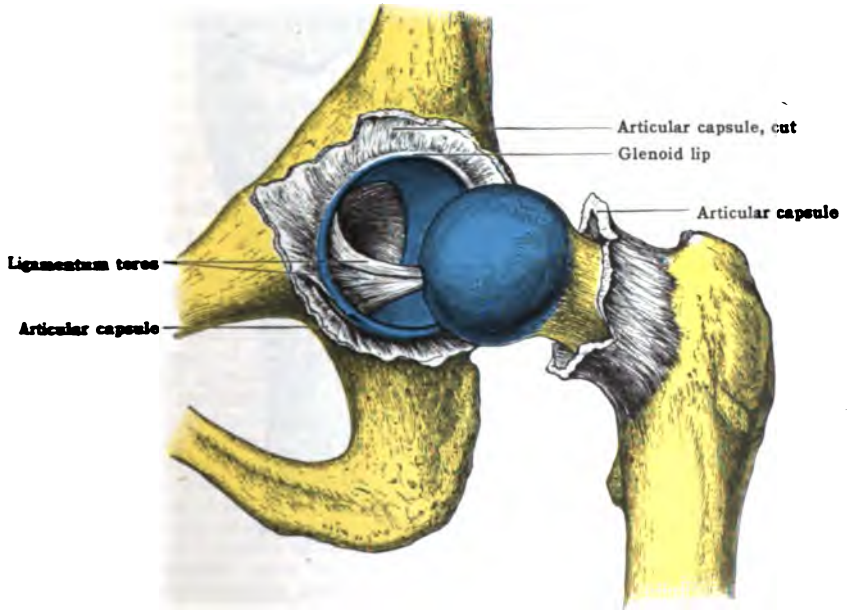

Glenoid lip
Articular capsule
Reflected fibers of capsule (retinacula)
Ligamentum teres. The upper line is placed on the femoral, the lower on the ischial, attachment
Reflected fibers of capsule

FIG. 343.—HIP-JOINT AFTER DIVIDING THE ARTICULAR CAPSULE AND DISARTICULATING THE FEMUR.



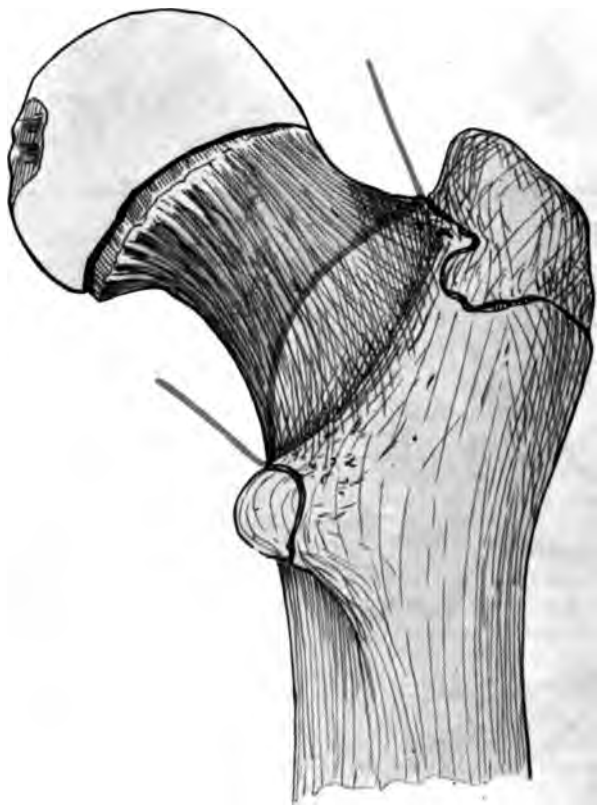
3.7 cm. long. It has two bony attachments, one on either side of the acetabular notch immediately below the articular cartilage, while intermediate fibers spring from the lower surface of the transverse ligament. The ischial portion is the stronger, and has several of its fibers arising outside the cavity, below and in

connection with the origin of the transverse ligament, where it is also continuous with the capsule and periosteum of the ischium. At the femur it is fixed to the front part of the depression on the head, and to the cartilage round the margin of the depression.

FIG. 344.—PORTIONS OF ISCHIUM AND PUBIS, SHOWING THE ACETABULAR NOTCH AND THE LIGAMENTUM TERES ATTACHED OUTSIDE THE ACETABULUM.

It is covered by a prolongation of synovial membrane, which also covers the cushion of fat in the recess of the acetabulum; the portion of the membrane reflected over the fatty tissue does not cling closely to the round ligament, but forms a triangular fold, the apex of which is at the femur.

FIG. 345.—THE UPPER EXTREMITY OF THE FEMUR (POSTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE HIP-JOINT (IN RED) TO THE EPIPHYSIAL LINES.



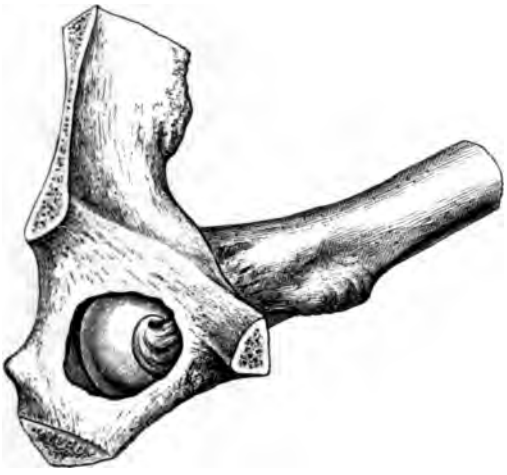
The **transverse ligament** [lig. transversum acetabuli] (fig. 344) passes across the acetabular notch and converts it into a foramen; it supports part of the glenoid lip, and is connected with the ligamentum teres and the capsule. It is composed of decussating fibers, which arise from the margin of the acetabulum on either side of the notch, those coming from the pubis being more superficial, and

o form the deep part of the ligament at the ischium, while those superfi-
ıe ischium are deep at the pubis. It thus completes the rim of the ace-

glenoid lip (cotyloid fibrocartilage) (figs. 342, 343) is a yellowish-white
ɜ, which deepens the acetabulum by surmounting its margin. It varies
;th and thickness, but is stronger at its iliac and ischial portions than
ɜ. Its base is broad and fixed to the bony rim as well as to the articular
of the acetabulum on the inner, and the periosteum on the outer, side of
ends inseparably with the transverse ligament which supports it over the
ar notch.

ɜe margin of the glenoid lip is thin; on section it is somewhat lunated, having its outer
ıvex and its articular face concave and very smooth in adaptation to the head of the
ich it tightly embraces a little beyond its greatest circumference. It somewhat
the aperture of the acetabulum, and retains the head of the femur within its grasp
ion of the muscles and capsular ligament. It is covered on both aspects by synovial
ɜ.

FIG. 346.—LIGAMENTUM TERES, LAX IN FLEXION.



synovial membrane lines the capsule and both surfaces of the glenoid
passes over the border of the acetabulum to reach and cover the fatty
it contains. The part covering the fatty cushion is unusually thick, and
ıed round the edges of the rough bony surface on which the cushion rests.
nbrane is loosely reflected off this on to the ligamentum teres, along
is prolonged to the head of the femur; thus the fibers of the round liga-
ɜ shut out from the joint cavity. From the capsule the synovial mem-
also reflected below on to the neck of the femur, whence it passes over
acula to the margin of the articular cartilage.

rterial supply comes from—(*a*) the transverse branches of the medial and lateral
: arteries; (*b*) the lateral branch of the obturator sends a branch through the acetabular
ıeath the transverse ligament, which ramifies in the fat at the bottom of the ace-
ınd travels down the round ligament to the head of the femur; (*c*) the inferior branch
p division of the superior gluteal; and (*d*) the inferior gluteal (sciatic) arteries. The
ɔm the obturator to the ligamentum teres is sometimes very large when the branch
ıedial circumflex does not also supply the ligament.
perior and inferior gluteal send several branches through the coxal attachment of the
:apsule: these anastomose freely beneath the capsule around the outer aspect of
ɔulum, and supply some branches to enter the bone, and others which enter the
of the glenoid lip. There is quite an arterial crescent upon the posterior and postero-
ortions of the acetabulum; but no vessels are to be seen on the inner aspect of the
ɔ. A fold of synovial membrane on the lower aspect of the neck often conveys to the
e femur a branch of an artery—generally a branch of the medial circumflex.
ıerve-supply comes from—(*a*) femoral (anterior crural), (*b*) anterior division of the
(*c*) the accessory obturator (where present), and (*d*) the sacral plexus, by a twig from
to the quadratus femoris, or from the upper part of the great sciatic, or from the lower
e sacral plexus.
ıas.—In *front* and in contact with the capsule are the psoas bursa, the tendinous
e psoas magnus, and the iliacus. Still more anteriorly and not in contact are the
tery, the femoral (anterior crural) nerve, the rectus femoris, the sartorius, and the
:iæ latæ muscles.

Above and in close relation with the capsule are the piriformis, the obturator internus the gemelli, and the reflected head of the rectus femoris, whilst more superficially lie the gluteus minimus and medius.

Behind and in close relation with the capsule are the obturator externus, the gemelli and obturator internus, and the piriformis. More superficially lie the quadratus femoris, the sciatic and posterior femoral cutaneous nerves, and the gluteus maximus.

Below the obturator externus, the pectineus, and the medial circumflex artery are in close relation with the capsule.

The movements (cf. p. 543).—The hip-joint, like the shoulder, is a ball-and-socket joint, but with a much more complete socket and a corresponding limitation of movement. Each variety of movement is permitted, viz., flexion, extension, abduction, adduction, circumduction, and rotation; and any two or more of these movements not being antagonistic can be combined, i. e., flexion or extension associated with abduction or adduction can be combined with rotation in or out.

FIG. 347.—LIGAMENTUM TERES, VERY LAX IN COMPLETE EXTENSION.

It results from the obliquity of the neck of the femur that the movements of the head in the acetabulum are always more or less of a rotatory character. This is more especially the case during flexion and extension, and two results follow from it. First, the bearing surfaces of the femur and acetabulum preserve their apposition to each other, so that the amount of articular surface of the head in the acetabulum does not sensibly diminish *pari passu* with the transit of the joint from the extended to the flexed position, as would necessarily be the case if the movement of the femoral head, like that of the thigh itself, was simply angular, instead of rotatory and angular. Secondly, as rotation of the head can continue until the ligaments are tight without being checked by contact of the neck of the thigh bone with the rim of the acetabulum, flexion of the thigh so far as the joint is concerned is practically unlimited. Flexion is the most important and most extensive movement, and in the dissected limb, before the ligaments are disturbed, can be carried to 160°, and is then checked by the lower fibers of the ischiocapsular ligament. In the living subject simple flexion can continue until checked by the contact of the soft parts at the groin, if the knee be bent; if the knee be straight, flexion of the hip is checked in most persons by the hamstring muscles at nearly a right angle. This is very evident on trying to touch the ground with the fingers without bending the knees, the chief strain being felt at the popliteal space. This is due to the shortness of the hamstrings. Extension is limited by the iliofemoral ligament.

Abduction and lateral rotation can be performed freely in every position of flexion and extension—abduction being limited by the pubocapsular ligament; lateral rotation by the iliofemoral ligament, especially its medial portion, during extension; but by the lateral portion, as well as by the ligamentum teres, during flexion.

Adduction is very limited in the extended thigh on account of the contact with the opposite limb. In the slightly flexed position adduction is more free than in extension, and is then limited by the lateral fibers of the iliofemoral band and the superior portion of the capsule. In flexion the range is still greater, and limited by the ischiocapsular ligament, the ligamentum teres being also rendered nearly tight. Medial rotation in the extended position is limited by the lower fibers of the iliofemoral ligament; and in flexion by the ischiocapsular ligament and the portion of the capsule between it and the iliofemoral band.

The iliofemoral band also prevents the tendency of the trunk to roll backward on the thigh bones in the erect posture, and so does away with the necessity for muscular power for this purpose; it is put on stretch in the stand-at-ease position.

The ligamentum teres is of little use in resisting violence or in imparting strength to the joint. It assists in checking lateral rotation, and adduction during flexion. A ligament can only be of use when it is tight, and it was found by trephining the bottom of the acetabulum, removing the fat, and threading a piece of whip cord round the ligament, that the ligament was slack in simple flexion, and very loose in complete extension, but that its most slack condition was in abduction. It is tightest in flexion combined with adduction and lateral rotation and almost as tight in flexion with lateral rotation alone, and in flexion with adduction alone (figs. 346–348).

Muscles which act upon the hip-joint (cf. p. 487ff.).—*Flexors.*—The psoas and iliacus, the rectus femoris, the pectineus, the adductors, the sartorius, the tensor fasciæ latæ, and the gluteus

FIG. 348.—LIGAMENTUM TERES, DRAWN TIGHT IN FLEXION COMBINED WITH LATERAL ROTATION AND ADDUCTION.

medius. *Extensors.*—The gluteus maximus, the posterior fibers of the glutei medius and minimus, the biceps, the semitendinosus, the semimembranosus, and the ischial fibers of the adductor magnus; also (slightly) the piriformis, obturator internus and gemelli. *Abductors.*—Gluteus maximus (upper fibers), tensor fasciæ latæ, gluteus medius, gluteus minimus, and, when the joint is flexed, the piriformis, obturator internus, the gemelli, and the sartorius also become abductors. *Adductors.*—Adductores magnus, longus, brevis, and minimus, semitendinosus, biceps, the gracilis, the pectineus, the quadratus femoris, and the lower fibers of the gluteus maximus. *Medial rotators.*—Psoas (slightly), adductor magnus, semimembranosus, the anterior fibers of the gluteus medius and minimus, and the tensor fasciæ latæ. *Lateral rotators.*—Gluteus maximus, posterior fibers of gluteus medius and minimus, the adductors, obturator externus, quadratus femoris, obturator internus, the gemelli, and the piriformis when the joint is extended.

2. THE KNEE-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

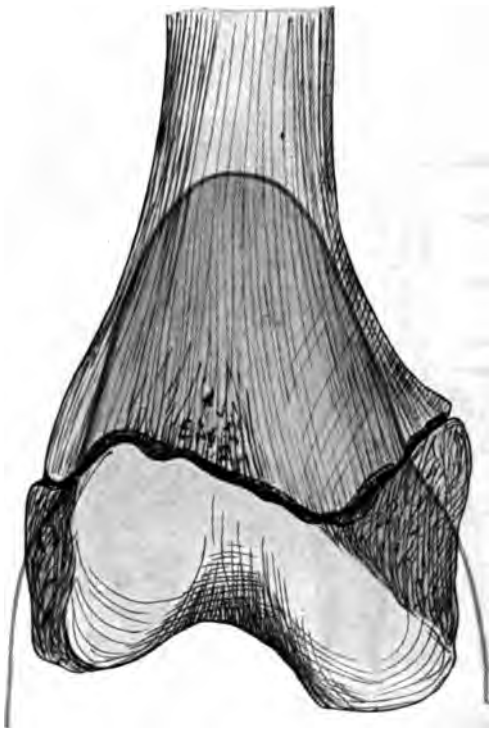
The knee is the largest joint in the body. It is rightly described as a ginglymoid joint, but there is also an arthrodial element; for, in addition to flexion and extension, there is a sliding backward and forward of the tibia upon the femoral condyles, as well as slight rotation round a vertical axis. It is one of the most superficial, and, as far as adaptation of the bony surfaces goes, one of the weakest joints, for in no position are the bones in more than partial contact. Its strength lies in the number, size, and arrangement of the ligaments, and the powerful muscles and fascial expansions which pass over the articulation and enable it to withstand the leverage of the two longest bones in the body. It may be said to consist of two articulations with a common synovial membrane—the patellofemoral and the tibiofemoral, the latter being double. It is composed of the condyles and trochlear surface of the femur, the condyles of the tibia, and the

pass between it and the bone. Superficially, a bursa separates it from the tendons of the gracilis and semitendinosus muscles and from the aponeurosis of the sartorius muscle.

The **fibular** (external) **collateral ligament** (fig. 350) consists of two portions: anterior and posterior. The **anterior,** which is the longer and better marked, is a strong, rounded cord, about 5 cm. long, attached above to the tubercle on the lateral side of the lateral epicondyle of the femur, just below and in front of the origin of the lateral head of the gastrocnemius, whilst the tendon of the popliteus arises from the groove below and in front of it. Below, it is fixed to the middle of the lateral surface of the head of the fibula, 1.2 cm. or more anterior to the apex.

Superficially is the tendon of the biceps, which splits to embrace its lower extremity; while beneath it pass the popliteus tendon in its sheath, and the inferior lateral articular vessels and nerve. Some fibers of the peroneus longus occasionally arise from the lower end of the ligament. The **posterior** portion is 8 mm. behind the anterior. It is broader and less defined; fixed below to the apex of the fibula, it inclines upward and somewhat backward, and ties down the popliteus against the lateral condyle of the tibia, blending beneath the lateral head of the gastrocnemius with the oblique popliteal ligament of the knee, of which it is really a portion.

FIG. 351.—THE LOWER EXTREMITY OF THE FEMUR (ANTERIOR VIEW) TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE KNEE-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



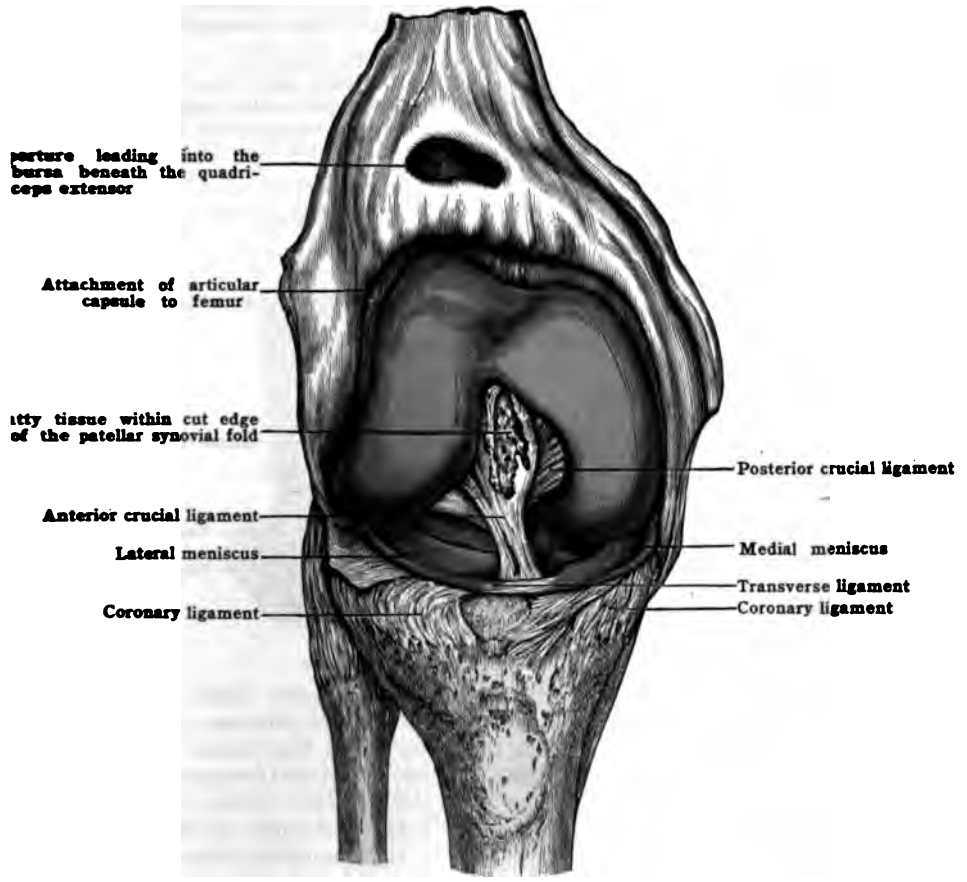
The **oblique popliteal ligament** (ligament of Winslow) (fig. 350) is a broad dense structure of interlacing fibers, with large orifices for vessels and nerves. It is attached above to the femur close to the articular margins of the condyles, stretching across the upper margin of the intercondyloid fossa, to which it is connected by fibro-fatty tissue; it thus reaches across from the tibial to the fibular collateral ligaments. Below, it is fixed to the border of the lateral condyle of the tibia, to the bone just below the posterior intercondyloid notch and to the shaft of the tibia below the medial condyle, blending with the descending slip of the semimembranosus and tibial collateral ligament.

Superficially, an oblique fasciculus from the semimembranosus runs across the center, passing upward and laterally from near the back part of the medial condyle of the tibia to the lateral epicondyle of the femur, where it joins the lateral head of the gastrocnemius, a sesamoid plate being sometimes developed at the point of junction. This slip greatly strengthens the oblique popliteal ligament, of which, if not the chief constituent, it is at least a very important part.

Its deep surface is closely connected with the semilunar menisci (especially the medial) and coronary ligaments, and in the interval between the cartilages with the posterior crucial ligament is fibro-fatty tissue within the joint. Superficially it forms part of the floor of the popliteal ace. A special band, the *arcuate ligament*, is sometimes found extending from the lateral condyle passing under the oblique ligament and attaching to the head of the fibula by two ands [retinaculum ligamenti arcuati].

The articular capsule (fig. 352) is thin but strong, covering the synovial membrane, and forming a loose sac. It is attached to the femur near the articular margin on the medial side, but further away on the lateral; it passes beneath the fibular collateral ligament to join the sheath of the popliteus. Medially it joins the tibial collateral ligament. Below, it is fixed to the upper as well

FIG. 352.—ANTERIOR VIEW OF THE INTERNAL LIGAMENTS OF THE KNEE-JOINT.


perture leading into the bursa beneath the quadriceps extensor
Attachment of articular capsule to femur
atty tissue within cut edge of the patellar synovial fold
Anterior crucial ligament
Lateral meniscus
Coronary ligament
Posterior crucial ligament
Medial meniscus
Transverse ligament
Coronary ligament

s the medial and lateral borders of the patella and the anterior border of the ead of the tibia. It is strengthened superficially between the femur and patella y an expansion from the articularis genu (subcrureus) and is separated from he fibrous expansion of the extensor tendon by a layer of fatty tissue. The synoial membrane lines its deep surface, and holds it against the borders of the semiinar menisci; it is also attached to the coronary ligaments.

Internal Ligaments

The **anterior crucial ligament** (figs. 352, 353) is strong and cord-like. It is ttached to the medial half of the fossa in front of the intercondyloid eminence f the tibia, and to the lateral border of the medial articular facet as far back as he medial intercondyloid tubercle. It passes upward, backward, and laterally o the back part of the medial surface of the lateral condyle of the femur. To he tibia, it is fixed behind the anterior extremity of the medial semilunar menisus. Behind and to the lateral side it has the anterior extremity of the lateral ieniscus, a few fibers of which blend with the lateral edge of the ligament.

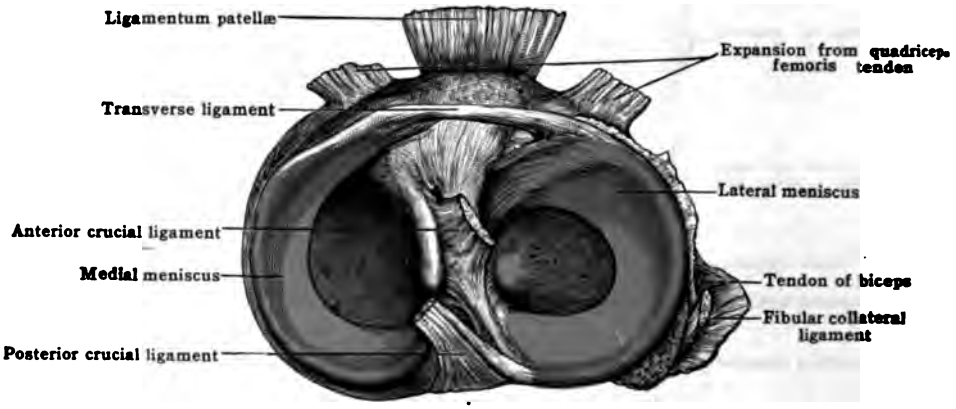
Its anterior fibers at the tibial end are strongest and longest, being fixed highest on the femur; while the posterior, springing from the intercondyloid eminence, are shorter and more oblique. Near the spine, a slip is sometimes given off to the posterior crucial ligament.

The **posterior crucial ligament** (figs. 352, 353, 355) is stronger and less oblique than the anterior. It is fixed below to the greater portion of the fossa behind the intercondyloid eminence of the tibia, especially the lateral and posterior portion, and then medially along the posterior intercondyloid fossa; being joined by fibers, which arise between the intercondyloid tubercles, it ascends to the anterior part of the lateral surface of the medial condyle of the femur, having a wide crescentic attachment 1.5 cm. in extent just above the articular surface.

Behind, it is connected at the tibia directly with the oblique ligament, and a little higher up by means of a quantity of interposed areolar tissue. In front it rests upon the posterior horn of the medial semilunar meniscus, and receives a large slip from the lateral meniscus, which ascends along it, either in front or behind, to the femur; higher up in front it is connected with the anterior crucial ligament.

Until they rise above the intercondyloid eminence of the tibia the two crucial ligaments are closely bound together, so that no interspace exists between their tibial attachments and the point of decussation; the only space between them is therefore a V-shaped one corresponding to the upper half of their X-shaped arrangement, and this is a mere chink in the undissected state, and can be seen from the front only, owing to the fatty tissue beneath the synovial membrane which surrounds their femoral attachment.

FIG. 353.—STRUCTURES LYING ON THE HEAD OF THE TIBIA. (Right knee.)



The interarticular **menisci** (semilunar fibrocartilages) (figs. 352, 353) are two crescentic disks resting upon the circumferential portions of the articular facets of the tibia, and moving with the tibia upon the femur. They somewhat deepen the tibial articular surfaces, and are dense and compact in structure, becoming looser and more fibrous near their extremities, where they are firmly fixed in front of and behind the intercondyloid eminence of the tibia. The circumferential border of each is convex, thick, and somewhat loosely attached to the borders of the condyles of the tibia by the coronary ligaments and the reflexion of the synovial membrane. The inner border is concave, thin, and free. About 1.3 cm. broad at the widest part, they taper somewhat toward their extremities, and cover rather less than two-thirds of the articular facets of the tibia. Their upper surfaces are slightly concave, and fit on to the femoral condyles, while the lower are flat and rest on the head of the tibia; both surfaces are smooth and covered by synovial membrane.

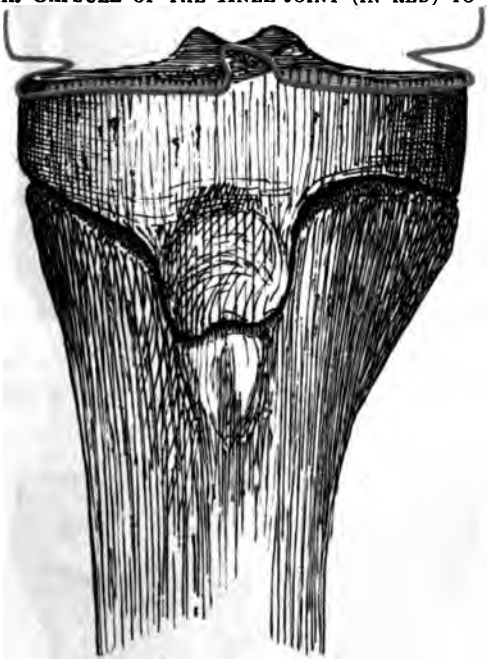
The **lateral meniscus** (fig. 353) is nearly circular in form and less firmly fixed than the medial, and consequently slides more freely upon the tibia. Its anterior cornu is attached to a narrow depression along the lateral articular facet, just in front of the lateral intercondyloid tubercle of the tibia, close to, and on the lateral side of, the anterior crucial ligament; a small slip from the cornu is often fixed to the tibia in front of the crucial ligament. The posterior cornu is firmly attached to the tibia behind the lateral intercondyloid tubercle, blending with the posterior crucial ligament, and giving off a well-marked fasciculus, which runs up along the anterior border of the ligament to be attached to the femur (ligament of Wrisberg, fig. 359). It also sends a narrow slip into the back part of the anterior crucial ligament. Its outer border is grooved toward its posterior part by the popliteus tendon, which is held to it by fibrous tissue and synovial membrane, and separates it from the fibular collateral ligament. From its anterior border is given off the transverse ligament.

The **medial meniscus** (fig. 353) is a segment of a larger circle than the lateral, and has an outline more oval than circular. Its anterior cornu is wide, and has a broad and oblique attachment to the anterior margin of the head of the tibia. It reaches from the margin of the condyle toward the middle of the fossa in front of the intercondyloid eminence, being altogether in front of the anterior crucial ligament. The posterior cornu is firmly fixed by a broad insertion in an anteroposterior line along the medial side of the posterior intercondyloid fossa, from the medial tubercle to the posterior margin of the head of the tibia. Its convex border is connected with the tibial collateral ligament and the semimembranosus tendon.

The **transverse ligament** (figs. 352, 353) is a rounded, slender, short cord, which extends from the convex border of the lateral meniscus to the concave border or anterior cornu of the medial, near which it is sometimes attached to the bone. It is an accessory band of the lateral meniscus, and is situated beneath the synovial membrane.

The **coronary ligaments** (fig. 352) connect the margins of the semilunar disks with the head of the tibia. The lateral is much more lax than the medial, permitting the lateral disk to change its position more freely than the medial. They are not in reality separate structures, but consist of fibers of the several surrounding ligaments of the knee-joint which become attached to the margins of the disk as they pass over them.

FIG. 354.—THE UPPER EXTREMITY OF THE TIBIA (ANTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE KNEE-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



The **synovial membrane** (figs. 349, 351, 354–357, 1149) of the knee forms the largest synovial sac in the body. Bulging upward from the patella, it follows the capsule of the joint into a large *cul-de-sac* beneath the tendon of the extensor muscles on the front of the femur. It reaches some distance beyond the articular surface of the bone, and communicates very frequently with a large bursa interposed between the tendon and the femur above the line of attachment of the articular capsule. After investing the circumference of the lower end of the femur, it is reflected upon the fibrous envelope of the joint formed by the capsular, posterior, and collateral ligaments. The cavity may communicate with that of the superior tibiofibular joint.

The synovial membrane covers a great portion of the crucial ligaments, but leaves uncovered the back of the posterior crucial where the latter is connected with the posterior ligament, and the lower part of both crucial ligaments where they are united. Thus the ligaments are completely shut out of the synovial cavity. Along the fibrous envelope the synovial membrane is conducted down to the semilunar menisci, over both surfaces of which it passes, and is reflected off the under surface on to the coronary ligaments, and thence down to the head of the tibia, around the circumference of which it extends a short way. It dips down between the external

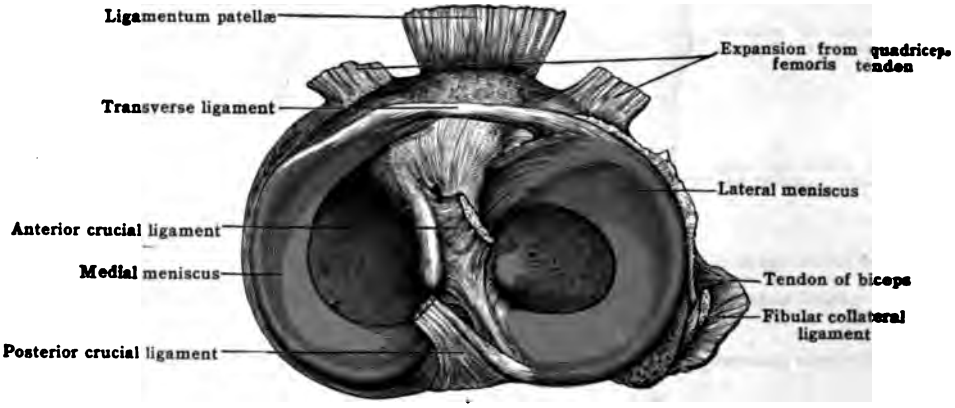
Its anterior fibers at the tibial end are strongest and longest, being fixed highest on the femur; while the posterior, springing from the intercondyloid eminence, are shorter and more oblique. Near the spine, a slip is sometimes given off to the posterior crucial ligament.

The **posterior crucial ligament** (figs. 352, 353, 355) is stronger and less oblique than the anterior. It is fixed below to the greater portion of the fossa behind the intercondyloid eminence of the tibia, especially the lateral and posterior portion, and then medially along the posterior intercondyloid fossa; being joined by fibers, which arise between the intercondyloid tubercles, it ascends to the anterior part of the lateral surface of the medial condyle of the femur, having a wide crescentic attachment 1.5 cm. in extent just above the articular surface.

Behind, it is connected at the tibia directly with the oblique ligament, and a little higher up by means of a quantity of interposed areolar tissue. In front it rests upon the posterior horn of the medial semilunar meniscus, and receives a large slip from the lateral meniscus, which ascends along it, either in front or behind, to the femur; higher up in front it is connected with the anterior crucial ligament.

Until they rise above the intercondyloid eminence of the tibia the two crucial ligaments are closely bound together, so that no interspace exists between their tibial attachments and the point of decussation; the only space between them is therefore a V-shaped one corresponding to the upper half of their X-shaped arrangement, and this is a mere chink in the undissected state, and can be seen from the front only, owing to the fatty tissue beneath the synovial membrane which surrounds their femoral attachment.

FIG. 353.—STRUCTURES LYING ON THE HEAD OF THE TIBIA. (Right knee.)



The interarticular **menisci** (semilunar fibrocartilages) (figs. 352, 353) are two crescentic disks resting upon the circumferential portions of the articular facets of the tibia, and moving with the tibia upon the femur. They somewhat deepen the tibial articular surfaces, and are dense and compact in structure, becoming looser and more fibrous near their extremities, where they are firmly fixed in front of and behind the intercondyloid eminence of the tibia. The circumferential border of each is convex, thick, and somewhat loosely attached to the borders of the condyles of the tibia by the coronary ligaments and the reflexion of the synovial membrane. The inner border is concave, thin, and free. About 1.3 cm. broad at the widest part, they taper somewhat toward their extremities, and cover rather less than two-thirds of the articular facets of the tibia. Their upper surfaces are slightly concave, and fit on to the femoral condyles, while the lower are flat and rest on the head of the tibia; both surfaces are smooth and covered by synovial membrane.

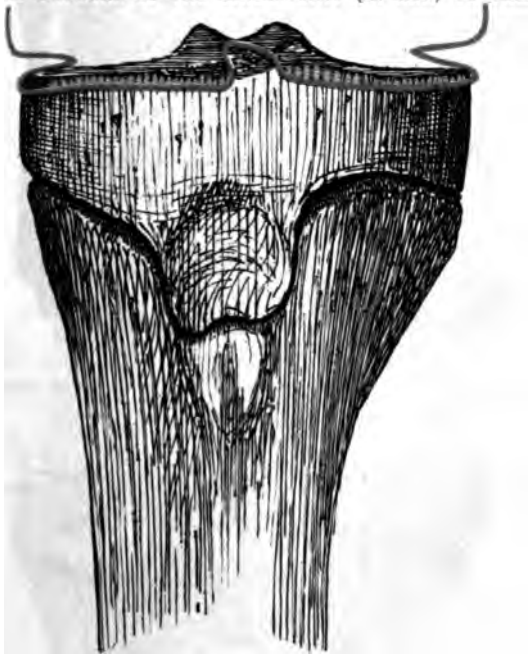
The **lateral meniscus** (fig. 353) is nearly circular in form and less firmly fixed than the medial, and consequently slides more freely upon the tibia. Its anterior cornu is attached to a narrow depression along the lateral articular facet, just in front of the lateral intercondyloid tubercle of the tibia, close to, and on the lateral side of, the anterior crucial ligament; a small slip from the cornu is often fixed to the tibia in front of the crucial ligament. The posterior cornu is firmly attached to the tibia behind the lateral intercondyloid tubercle, blending with the posterior crucial ligament, and giving off a well-marked fasciculus, which runs up along the anterior border of the ligament to be attached to the femur (ligament of Wrisberg, fig. 359). It also sends a narrow slip into the back part of the anterior crucial ligament. Its outer border is grooved toward its posterior part by the popliteus tendon, which is held to it by fibrous tissue and synovial membrane, and separates it from the fibular collateral ligament. From its anterior border is given off the transverse ligament.

The **medial meniscus** (fig. 353) is a segment of a larger circle than the lateral, and has an outline more oval than circular. Its anterior cornu is wide, and has a broad and oblique attachment to the anterior margin of the head of the tibia. It reaches from the margin of the condyle toward the middle of the fossa in front of the intercondyloid eminence, being altogether in front of the anterior crucial ligament. The posterior cornu is firmly fixed by a broad insertion in an anteroposterior line along the medial side of the posterior intercondyloid fossa, from the medial tubercle to the posterior margin of the head of the tibia. Its convex border is connected with the tibial collateral ligament and the semimembranosus tendon.

The **transverse ligament** (figs. 352, 353) is a rounded, slender, short cord, which extends from the convex border of the lateral meniscus to the concave border or anterior cornu of the medial, near which it is sometimes attached to the bone. It is an accessory band of the lateral meniscus, and is situated beneath the synovial membrane.

The **coronary ligaments** (fig. 352) connect the margins of the semilunar disks with the head of the tibia. The lateral is much more lax than the medial, permitting the lateral disk to change its position more freely than the medial. They are not in reality separate structures, but consist of fibers of the several surrounding ligaments of the knee-joint which become attached to the margins of the disk as they pass over them.

FIG. 354.—THE UPPER EXTREMITY OF THE TIBIA (ANTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE KNEE-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



The **synovial membrane** (figs. 349, 351, 354–357, 1149) of the knee forms the largest synovial sac in the body. Bulging upward from the patella, it follows the capsule of the joint into a large *cul-de-sac* beneath the tendon of the extensor muscles on the front of the femur. It reaches some distance beyond the articular surface of the bone, and communicates very frequently with a large bursa interposed between the tendon and the femur above the line of attachment of the articular capsule. After investing the circumference of the lower end of the femur, it is reflected upon the fibrous envelope of the joint formed by the capsular, posterior, and collateral ligaments. The cavity may communicate with that of the superior tibiofibular joint.

The synovial membrane covers a great portion of the crucial ligaments, but leaves uncovered the back of the posterior crucial where the latter is connected with the posterior ligament, and the lower part of both crucial ligaments where they are united. Thus the ligaments are completely shut out of the synovial cavity. Along the fibrous envelope the synovial membrane is conducted down to the semilunar menisci, over both surfaces of which it passes, and is reflected off the under surface on to the coronary ligaments, and thence down to the head of the tibia, around the circumference of which it extends a short way. It dips down between the external

meniscus and the head of the tibia as low as the superior tibiofibular ligament, reaching in nearly as far as the intercondyloid notch, and forming a bursa for the play of the popl tendon.

FIG. 355.—ANTERIOR VIEW OF THE KNEE-JOINT, SHOWING THE SYNOVIAL LIGAMENT (Anterior portion of capsule with the extensor tendon thrown downward.)

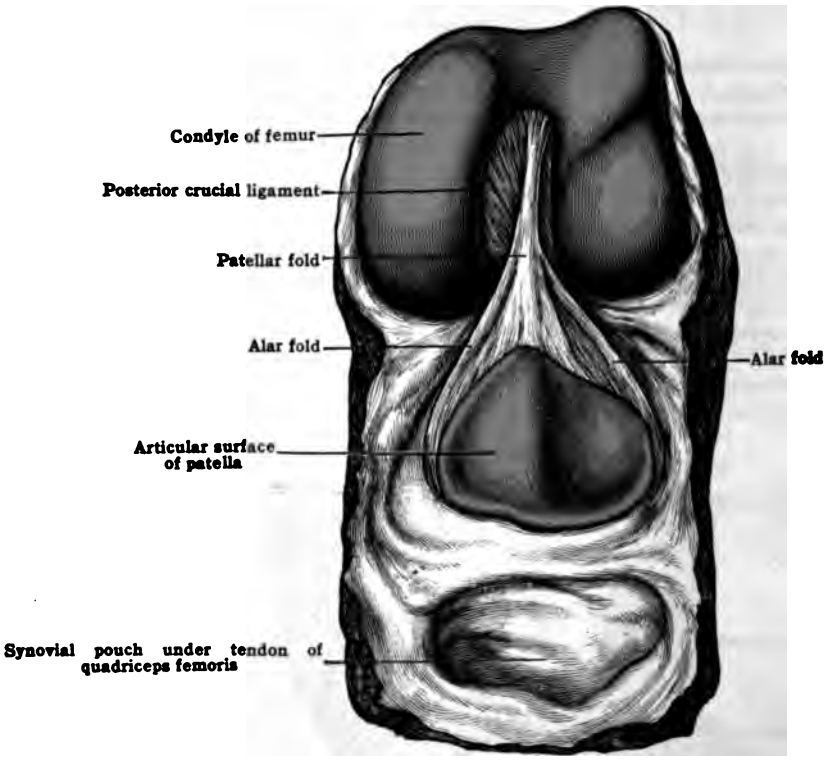
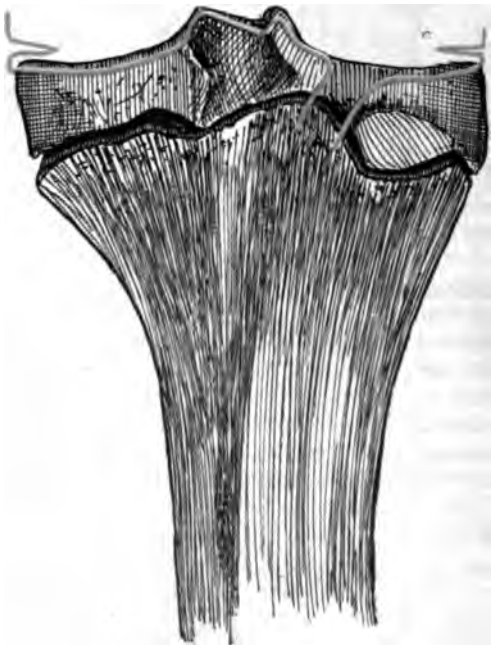


FIG. 356.—THE UPPER EXTREMITY OF THE TIBIA (POSTERIOR VIEW), TO SHOW THE RELA OF THE ARTICULAR CAPSULE OF THE KNEE-JOINT (IN RED) TO THE EPIPHYSIAL LIN

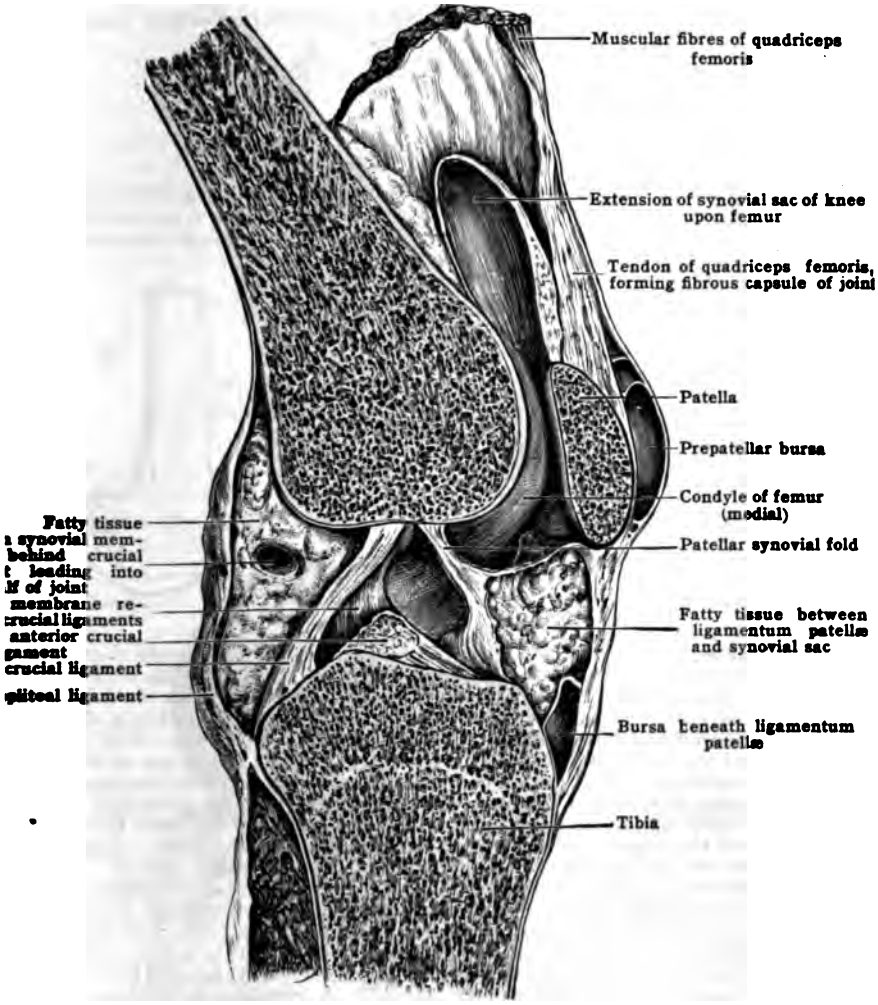


At the back of the joint two pouches are prolonged beneath the muscles, one on each between the condyle of the femur and the origin of the gastrocnemius. Large processes of s vial membrane also project into the joint, and being occupied by fat serve as padding to fi

The chief of these processes, the **patellar synovial fold** (ligamentum mucosum) (figs. 357), springs from the infrapatellar fatty mass. This so-called ligament is the central of the large process of synovial membrane, of which the alar folds form the free margins. ds from the fatty mass, below the patella, backward and upward to the intercondyloid the femur, where it is attached in front of the anterior crucial, and lateral to the poste- ial ligament. Near the femur it is thin and transparent, consisting of a double fold of membrane, but near the patella it contains some fatty tissue. Its anterior or upper ee, and fully 2.5 cm. long; the posterior or lower edge is half the length, and is attached ucial ligaments above, but is free below.

ng backward from the capsule on each side of the patella is a prominent crescentic ned by reduplications of the synovial membrane—these are the **alar folds** (fig. 355). e margins are concave and thin, and are lost below in the patellar fold. There is a sa above and another below each ligament.

FIG. 357.—SAGITTAL SECTION OF THE KNEE-JOINT.
(The bones are somewhat drawn apart.)



rterial supply of the knee-joint is derived from the art. genu suprema (anastomotica); rior and inferior medial and lateral articular; the medial articular; the descending f the lateral circumflex; the anterior recurrent branch from the anterior tibial; and the tibial recurrent.

nerve-supply comes from the great sciatic, femoral, and obturator sources. The atic gives off the tibial and common peroneal; the tibial sends two, sometimes three —one with the medial articular artery; one with the inferior medial, and sometimes the superior medial articular artery; the common peroneal gives a branch which accom- s superior, and another which accompanies the inferior articular artery, and a recurrent hich follows the course of the anterior recurrent branch of the anterior tibial artery. ral sends an articular branch from the nerve to the vastus lateralis; a second from the the vastus medialis; and sometimes a third from that to the vastus intermedius. Thus three articular twigs to the knee derived from the muscular branches of the femoral.

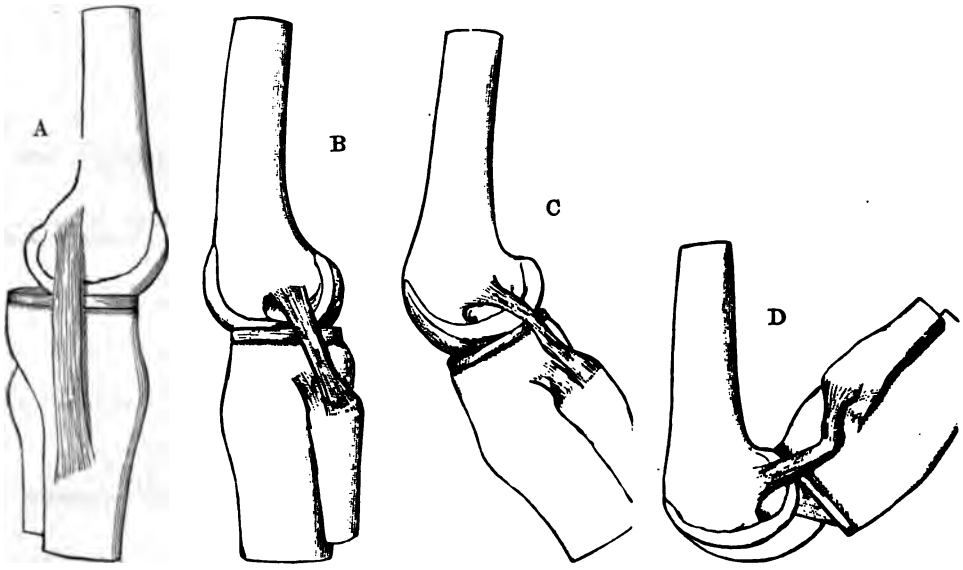
The obturator by its deep division sends a branch through the adductor magnus on to the popliteal artery, which enters the joint posteriorly.

Relations.—Anteriorly and at the sides the knee-joint is merely covered and protected by skin, fascia, and the tendinous expansions of the quadriceps extensor muscle. Laterally and posteriorly it is crossed by the biceps tendon. Medially and posteriorly lie the sartorius and the tendons of the gracilis and semitendinosus muscles. Posteriorly it is in relation with the popliteal vessels and nerves, the semimembranosus, the two heads of the gastrocnemius, and the plantaris. The tendon of the popliteus pierces the capsule behind and medial to the biceps tendon.

The movements which occur at the knee-joint are flexion and extension, with some slight amount of rotation in the bent position (cf. also p. 544). These movements are not so simple as the corresponding ones at the elbow, for the knee is not a simple hinge-joint. The movements of rotation instead of occurring between tibia and fibula, as between radius and ulna, are movements of the tibia with the fibula upon the condyles of the femur.

The knee differs from a true hinge-joint, like the elbow or ankle, in the following particulars:—

FIG. 358.—THE COLLATERAL LIGAMENTS OF THE KNEE IN FLEXION AND EXTENSION.



1. The points of contact of the femur with the tibia are constantly changing. Thus, in the flexed position, the posterior part of the articular surface of the tibia is in contact with the rounded back part of the femoral condyles; in the semiflexed position the middle parts of the tibial facets articulate with the anterior rounded part of the condyles; while in the fully extended position the anterior and middle parts of the tibial facets are in contact with the anterior flattened portion of the condyles. So with the patella: in extreme flexion the medial articular facet rests on the lateral part of the medial condyle of the femur; in flexion the upper pair of facets rests on the lower part of the trochlear surface of the femur; in midflexion the middle pair rests on the middle of the trochlear surface; while in extension the lower pair of facets on the patella rests on the upper portion of the trochlear surface of the femur. This difference may be described as the shifting of the points of contact of the articular surface.

2. It differs from a true hinge in that, in passing from a state of extension to one of flexion, the tibia does not revolve round a single transverse axis drawn through the lower end of the femur, as the ulna does round the lower end of the humerus. The articular surface of the tibia slides forward in extension and backward in flexion; thus the axis round which the tibia revolves upon the femur is a shifting one, as is seen by reference to fig. 358, B, C, D.

3. Another point of difference is that extension is accompanied by lateral rotation, and flexion by medial rotation. This rotation occurs round a vertical axis drawn through the middle of the lateral condyle of the femur and the lateral condyle of the tibia, and is most marked at the termination of extension and at the commencement of flexion. This rotation of the leg at the knee is a true rotation about a vertical axis, and thus differs from the obliquity of the flexion and extension movements at the elbow which is due to the oblique direction of the articular surfaces of the bones.

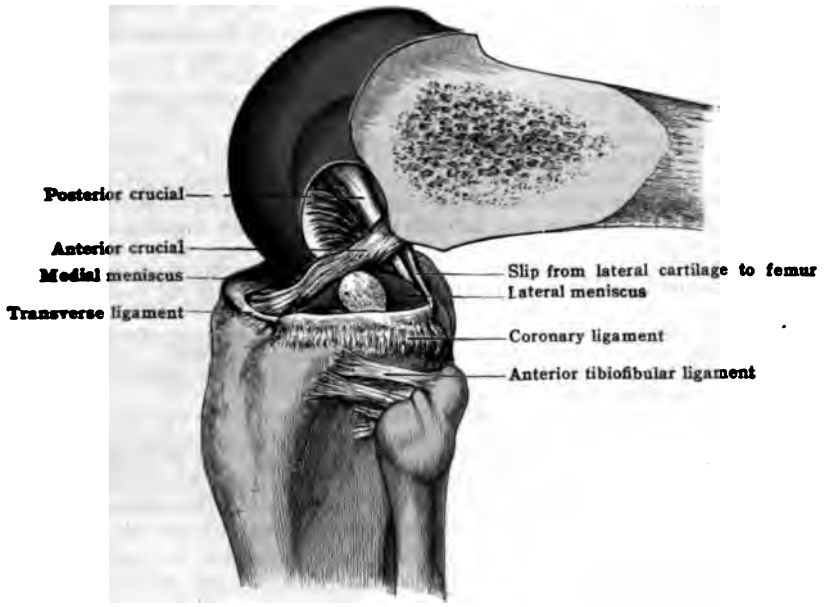
4. The anteroposterior spiral curve of the femoral condyles is such that the anterior part is an arc of a greater circle than the posterior; hence certain ligaments which are tightened during extension are relaxed during flexion, and thereby a considerable amount of rotatory movement is permitted in the flexed position. The axis of this rotation is longitudinal, and passes through the medial intercondyloid tubercle of the tibia, so that the lateral condyle moves in the arc of a larger circle than does the medial, and is therefore required to move more freely and easily; hence the shape of the lateral articular facet and the loose connection of the lateral meniscus which is adapted to it.

In extension of the knee-joint all the ligaments are on the stretch with the exception of the **ligamentum patellæ** and front of the capsule. Extension is checked by both the crucial ligaments and the collateral ligaments (figs. 358, A, B, and 359).

In flexion the ligamentum patellæ and anterior portion of the capsule are on the stretch; so also is the posterior crucial in extreme flexion, though it is not quite tight in the semiflexed state of the joint. All the other ligaments are relaxed (fig. 358, C, D), although the relaxation

FIG. 359.—SECTION OF KNEE, SHOWING CRUCIAL LIGAMENTS IN EXTENSION.

FIG. 360.—CRUCIAL LIGAMENTS IN FLEXION.



of the anterior crucial ligament is slight in extreme flexion (fig. 360). Flexion is only checked during life by the contact of the soft parts, i. e., the calf with the back of the thigh.

Rotation medially is checked by the anterior crucial ligament; the collateral ligaments being loose. Rotation laterally is checked by the collateral ligaments; the crucial ligaments have no controlling effect on it, as they are untwisted by it.

Sliding movements are checked by the crucial and collateral ligaments—sliding forward especially by the anterior, and sliding backward by the posterior crucial.

Muscles which act upon the knee-joint (cf. p. 497ff.).—*Flexors.*—Biceps, semimembranosus, semitendinosus, sartorius, gastrocnemius, plantaris, and popliteus. *Extensor.*—Quadriceps extensor. **Medial** *Rotators.*—Sartorius, gracilis, semitendinosus, semimembranosus, popliteus. **Lateral** *Rotator.*—Biceps.

3. THE TIBIOFIBULAR UNION

The fibula is connected with the tibia throughout its length by an interosseous membrane, and at the upper and lower extremities by means of two joints. Very little movement is permitted between the two bones. The union therefore includes: (*a*) The **superior tibiofibular joint**; (*b*) The **middle tibiofibular union**; (*c*) The **inferior tibiofibular joint.**

(*a*) The Superior Tibiofibular Joint

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The superior tibiofibular joint is about 6 mm. below, and quite distinct from, the knee at its upper and anterior part; but at its posterior and superior aspect, where the border of the lateral condyle of the tibia is bevelled by the popliteus muscle, the joint is in the closest proximity to the bursa from the knee-joint beneath the tendon of that muscle. There is often a communication between the synovial cavities of the two joints, which are separated by a thin septum. The ligaments uniting the bones are:—

Articular capsule. Anterior tibiofibular (capitular).
Posterior tibiofibular (capitular).

The **articular capsule** is a well-marked fibroareolar structure; it is attached close round the articular margins of the tibia and fibula. In front it is shut off completely from the knee-joint by the capsule of the knee and the coronary ligament; but behind, it is often very thin, and may communicate with the knee-joint through the bursa under the popliteus tendon.

The **anterior tibiofibular (capitular) ligament** [lig. capituli fibulæ] (fig. 359) consists of a few fibers which pass upward and medially from the fibula to the tibia. It lies beneath the anterior portion of the tendon of the biceps.

The **posterior tibiofibular (capitular) ligament** [lig. capituli fibulæ] (fig. 350) consists of a few fibers which pass upward and medially between the adjacent bones, from the head of the fibula to the lateral condyle of the tibia.

The **superior interosseous ligament** consists of a mass of dense yellow fibroareolar tissue, binding the opposed surfaces of the bones together for 2 cm. (¾ in.) below the articular facets. It is continuous with the interosseous membrane along the tibia.

The **biceps tendon** is divided by the fibular collateral ligament of the knee; of the two divisions the anterior is by far the stronger, and is inserted into the lateral condyle of the tibia as well as to the front of the head of the fibula, and thus the muscle, acting on both bones, tends to brace them more tightly together; indeed, it holds the bones strongly together after all other connections have been severed.

The **arterial supply** is from the inferior lateral articular and recurrent tibial arteries.

The **nerve-supply** is from the inferior lateral articular, and also from the recurrent branch of the common peroneal.

Relations.—In front, the upper ends of the tibialis anterior, the extensor digitorum longus, and the peroneus longus. Behind, the tendon of the popliteus overlapped by the lateral head of the gastrocnemius. Laterally, the biceps tendon and the common peroneal nerve. Below and medially, the anterior tibial vessels.

The **movements** are but slight, and consist merely of a gliding of the two bones upon each other. The joint is so constructed that the fibula gives some support to the tibia in transmitting the weight to the foot. The articular facet of the tibia overhangs, and is received upon the articular facet of the head of the fibula in an oblique plane. This joint allows of slight yielding of the lateral malleolus during flexion and extension of the ankle-joint, the whole fibula gliding slightly upward in flexion, and downward in extension, of the ankle.

(*b*) The Middle Tibiofibular Union

Class.—*Synarthrosis.* **Subdivision.**—*Syndesmosis.*

The **interosseous membrane** [membrana interossea cruris] is attached along the lateral border of the tibia and the interosseous border of the fibula. It is deficient above for about 2.5 cm. or more. Its upper border is concave, and over it pass the anterior tibial vessels.

The membrane consists of a thin aponeurotic and translucent lamina, formed of oblique fine fibers, some of which run from the tibia to the fibula, and some from the fibula to the tibia, but all are inclined downward. They are best marked at their attachment to the bones, and gradually grow denser and thicker as they approach the inferior interosseous ligament. The chief use of the membrane is to afford a surface for the origin of muscles. It is continuous below with the inferior interosseous ligament.

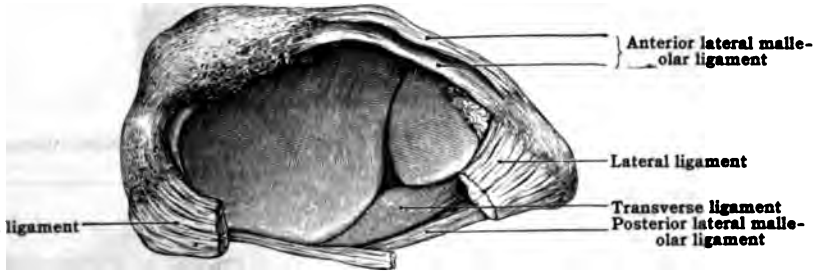
In front of the interosseous membrane lie the tibialis anterior, the extensor digitorum longus, the extensor hallucis longus, and the anterior tibial vessels and nerves. Behind it is in relation with the tibialis posterior, the flexor hallucis longus, and the peroneal artery.

(*c*) The Inferior Tibiofibular Articulation

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

This junction is formed by the lower ends of the tibia and fibula. The rough triangular surface on each of these bones formed by the bifurcation of their interosseous lines is closely and firmly united by the inferior interosseous ligament. The fibula is in actual contact with the tibia by an articular facet, which is small in size, crescentic in shape, and continuous with the articular facet of the malleolus.

Fig. 361.—Lower Ends of Left Tibia and Fibula, showing the Ligaments. The synovial fold between these bones has been removed to show the transverse ligament forming part of the capsule of the joint, and the deeper fibers of the anterior lateral malleolar ligament which come into contact with the talus.
(From a dissection by Mr. W. Pearson, of the Royal College of Surgeons Museum.)



The ligaments which unite the bones are:—

Anterior lateral malleolar ligament.	Transverse ligament.
Posterior lateral malleolar ligament.	Inferior interosseous ligament.

The anterior lateral malleolar ligament (anterior inferior tibiofibular ligament) (figs. 361 and 366) is a strong triangular band about 2 cm. wide, and is attached to the lower extremity of the tibia at its anterior and lateral angle, close to the margin of the facet for the talus and passes downward and laterally to the anterior border and contiguous surface of the lower end of the fibula, some fibers passing along the edge nearly as far as the origin of the anterior talofibular ligament.

The fibers increase in length from above downward. In front it is in relation with the peroneus tertius and deep fascia of the leg, and gives origin to fibers of the anterior ligament of the ankle-joint. Behind, it lies in contact with the interosseous ligament, and comes into contact with the articular surface of the talus (see figs. 361 and 362).

The posterior lateral malleolar ligament (figs. 361 and 366) is very similar to the anterior, extending from the posterior and lateral angle of the lower end of the tibia downward and laterally to the lowest 1.5 cm. (½ in.) of the border separating the medial from the posterior surface of the shaft of the fibula, and to the upper part of the posterior border of the lateral malleolus. It is in relation in front with the interosseous ligament; below, it touches the transverse ligament.

The inferior interosseous ligament is a dense mass of short, felt-like fibers, passing transversely between and firmly uniting the opposed rough triangular surfaces at the lower ends of the tibia and fibula, except for 1 cm. at the extremity, where there is a synovial cavity. It extends from the anterior to the posterior lateral malleolar ligaments, reaching upward 4 cm. in front, but only half this height behind.

The **transverse ligament** (fig. 361, 364) is a strong rounded band, attached to nearly the whole length of the inferior border of the posterior surface of the tibia, just above the articular facet for the talus. It then inclines a little forward and downward, to be attached to the medial surface of the lateral malleolus, just above the fossa, and into the upper part of the fossa itself.

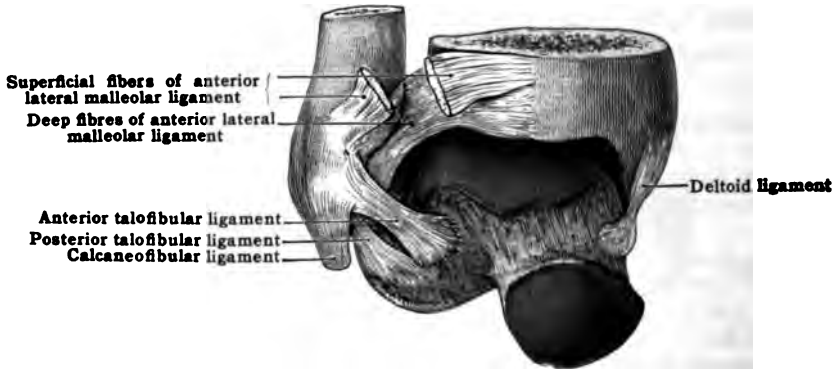
The **synovial membrane** is continuous with that of the ankle-joint; it projects upward between the bones beyond their articular facets as high as the inferior interosseous ligament.

The **nerve-supply** is the same as that of the ankle-joint; the **arterial supply** is from the peroneal and the anterior peroneal, and sometimes from the anterior tibial, or its lateral malleolar branch.

Relations.—In front of the inferior tibiofibular joint are the anterior peroneal artery and the tendon of the peroneus tertius, and behind it are the posterior peroneal artery and the pad of fat which lies in front of the tendo Achillis.

The **movement** permitted at this joint is a slight gliding, chiefly in an upward and downward direction, of the fibula on the tibia. The bones are firmly braced together and yet form a slightly yielding arch, thus allowing a slight side to side expansion during extreme flexion, when the broad part of the talus is brought under the arch, by the upward gliding of the fibula on the tibia. To this end the direction of the fibers of the lateral malleolar ligaments is downward from tibia to fibula. This mechanical arrangement secures perfect contact of the articular surfaces of the ankle-joint in all positions of the foot.

FIG. 362.—RIGHT ANKLE-JOINT, SHOWING THE LIGAMENTS.
(From a dissection by Mr. W. Pearson, of the Royal College of Surgeons' Museum.)


Superficial fibers of anterior lateral malleolar ligament
Deep fibres of anterior lateral malleolar ligament
Anterior talofibular ligament
Posterior talofibular ligament
Calcaneofibular ligament
Deltoid ligament

4. THE ANKLE-JOINT

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The ankle [articulatio talocruralis] is a perfect ginglymus or hinge-joint. The bones which enter into its formation are: the lower extremity and medial malleolus of the tibia, and the lateral malleolus of the fibula, above; and the upper and lateral articular surfaces of the talus (astragalus) below. The ligaments (supplementing the articular capsule) uniting the bones are:—

Anterior.	Deltoid.
Posterior.	Lateral ligament.

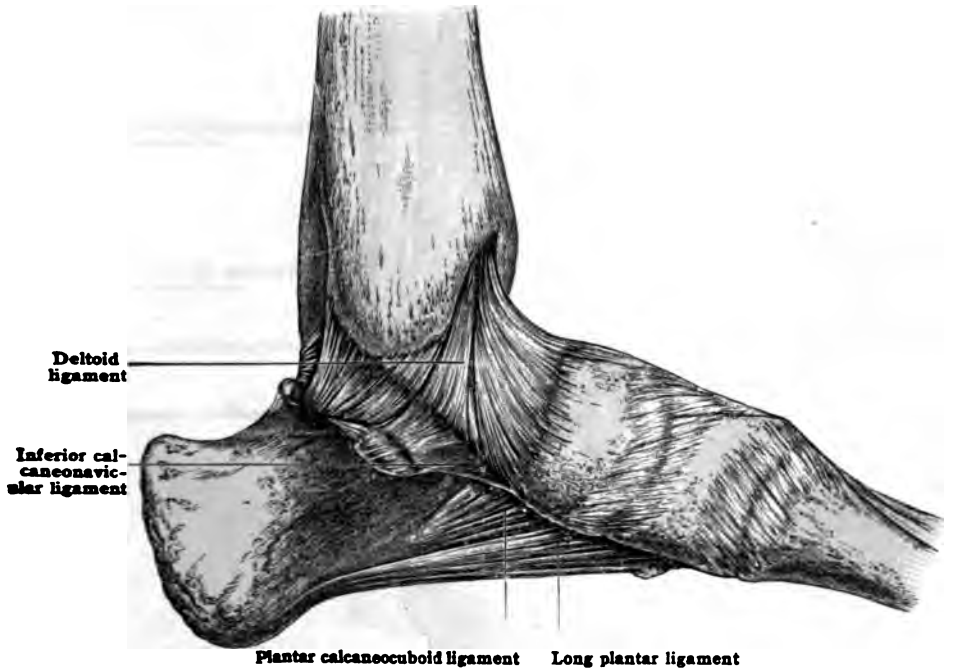
The **anterior ligament** (fig. 366) is a thin, membranous structure, which completes the capsule in front of the joint. It is attached above to the anterior border of the medial malleolus, to a crest of bone just above the transverse groove at the lower end of the tibia, to the anterior lateral malleolar ligament, and to the anterior border of the lateral malleolus. Below, it is attached to the rough upper surface of the neck of the talus (astragalus). Medially it is thicker, and is fixed to the talus close to the facet for the medial malleolus, being continuous with the deltoid ligament, and passing forward to blend with the talonavicular ligament. Laterally it is attached to the talus, just below and in front of the angle between the superior and lateral facets, close to their edges, and joins the anterior talofibular ligament.

It is in relation, in front with the tibialis anterior muscle, the anterior tibial vessels and nerve, the extensor tendons of the toes, and the peroneus tertius; and behind with a mass of fat and synovial membrane.

The posterior ligament (fig. 364) is a very thin and disconnected membranous structure, attached above to the lateral malleolus, medial to the peroneal groove; to the posterior margin of the lower end of the tibia lateral to the groove for the tibialis posterior; and to the posterior lateral malleolar ligament. Below, it is attached to the posterior surface of the talus from the deltoid to the lateral ligaments. The passage of the flexor hallucis longus tendon over the back of the joint materially strengthens the posterior ligament.

The deltoid ligament (fig. 363) is attached superiorly to the medial malleolus along its lower border, and to its anterior surface superficial to the anterior ligament; some very strong fibers are fixed to the notch in the lower border of the malleolus, and, getting attachment below to the rough depression on the medial side of the talus, form a deep portion to the ligament. The ligament radiates. The posterior fibers [lig. talotibiale posterius] are short, and incline a little back-

FIG. 363.—MEDIAL VIEW OF THE ANKLE AND THE TARSUS, SHOWING THE GROOVE FOR THE TENDON OF THE TIBIALIS POSTERIOR.



ward to be fixed to the rough medial surface of the talus, close to the superior articular facet, and into the tubercle to the medial side of the flexor hallucis longus groove. The fibers next in front are numerous and form a thick and strong mass, filling up the rough depression on the medial surface of the talus, whilst some [lig. calcaneotibiale] pass over the talocalcaneal joint to the upper and medial border of the sustentaculum tali. The fibers which are connected above with the anterior surface of the malleolus [lig. tibionaviculare] pass downward and somewhat forward to be attached to the navicular and to the margin of the calcaneonavicular ligament.

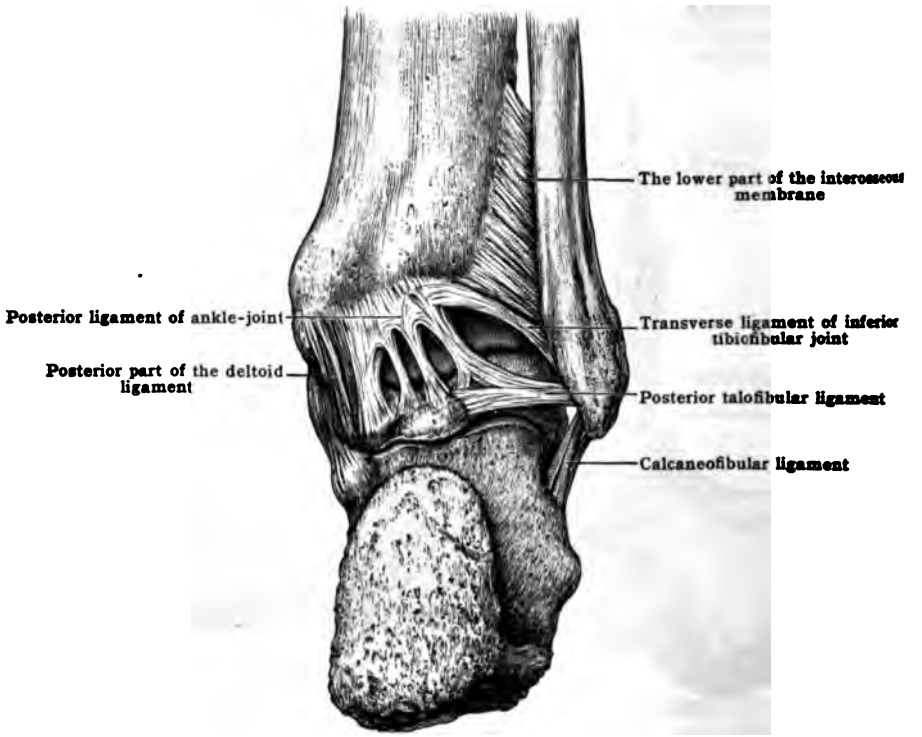
The lateral ligament (figs. 362, 364, 366) consists of three distinct slips. The **anterior talofibular ligament** (anterior fasciculus), is ribbon-like and passes from the anterior border of the lateral malleolus near the tip to the rough surface of the talus in front of the lateral facet, and overhanging the sinus tarsi. The **calcaneofibular ligament** (middle fasciculus), is a strong roundish bundle, which extends downward and somewhat backward from the anterior border of the lateral malleolus close to the attachment of the anterior fasciculus, and from the lateral surface of the malleolus, just in front of the apex, to a tubercle on the middle of the lateral surface of the calcaneum. The **posterior talofibular ligament** (posterior fasciculus), is almost horizontal; it is a strong, thick band attached at one end to the posterior border of the malleolus, and slightly to the fossa on the

medial surface; and at the other end to the talus, behind the articular facet for the fibula, as well as to a tubercle on the lateral side of the groove for the *flexor hallucis longus*.

The middle fasciculus is covered by the tendons of the *peronei longus* and *brevis;* and in extension, the posterior fasciculus is received into the pit on the medial surface of the lateral malleolus.

The **synovial membrane** is very extensive. Besides lining the ligaments of the ankle, it extends upward between the tibia and fibula, forming a short *cul-de-sac* as far as the interosseous ligament. Upon the anterior and posterior ligaments it is very loose, and extends beyond the limits of the articulation. It is said to contain more synovia than any other joint.

FIG. 364.—LIGAMENTS SEEN FROM THE BACK OF THE ANKLE-JOINT.


The lower part of the interosseous membrane
Posterior ligament of ankle-joint
Transverse ligament of inferior tibiofibular joint
Posterior part of the deltoid ligament
Posterior talofibular ligament
Calcaneofibular ligament

The **nerve-supply** is from the saphenous, posterior tibial, and the lateral division of the anterior tibial.

The **arterial supply** comes from the anterior tibial, the anterior peroneal, the lateral malleolar, the posterior tibial, and posterior peroneal.

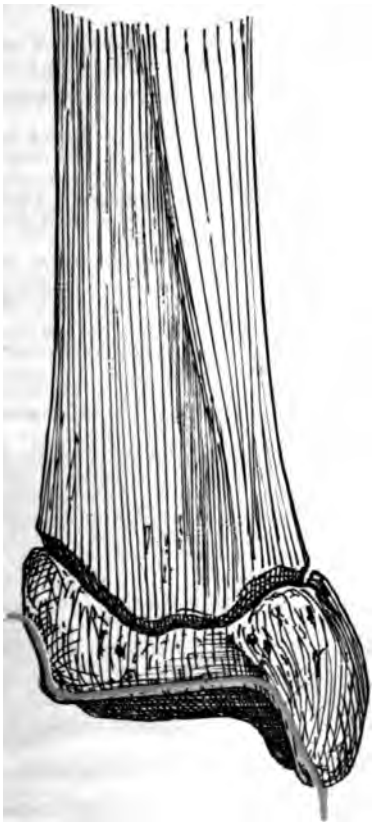
Relations.—In front and in contact with the anterior ligament, from medial to lateral aspects, are the tendon of the tibialis anterior, the tendon of the extensor hallucis longus, the anterior tibial vessels, the anterior tibial nerve, the tendons of the extensor digitorum longus, and the tendon of the peroneus tertius. To the medial side of the tibialis anterior and to the lateral side of the peroneus tertius the joint is subcutaneous anteriorly. Behind and laterally are the tendons of the peroneus longus and brevis. Behind and medially, from medial to lateral side, are the tendon of the tibialis posterior, the tendon of the flexor digitorum longus, the posterior tibial vessels, the posterior tibial nerve, and the tendon of the flexor hallucis longus. Directly behind is a pad of fat which intervenes between the tendo Achillis and the joint. Below and on the lateral side, crossing the middle fasciculus of the lateral ligament, are the tendons of the peroneus longus and brevis. Below and on the medial side, crossing the deltoid ligament, are the tendons of the tibialis posterior and the flexor digitorum longus.

Movements (cf. p. 545).—This being a true hinge-joint, flexion and extension are the only movements of which it is capable, there being no side to side motion, except in extreme extension, when the narrowest part of the talus is thrust forward into the widest part of the tibiofibular arch. In flexion the talus is tightly embraced by the malleoli, and side-to-side movement is impossible. Flexion of the ankle-joint is limited by:—(i) nearly the whole of the fibers of the deltoid ligament none but the most anterior being relaxed; (ii) the posterior and middle portions of the lateral ligament, especially the posterior; (iii) the posterior ligament of the ankle. It is also limited by the neck of the talus abutting on the edge of the tibia.

In most European ankle-joints the anterior edge of the lower end of the tibia is kept from actual contact with the neck of the talus in positions of extreme flexion by the intervention of a pad of fat situated beneath the anterior extension of the anterior ligament. In races which adopt a squatting posture, however, an actual articulation may be developed between these two bony surfaces, a facet being present both upon the anterior margin of the tibia and upon the neck of the talus. These facets are known as 'squatting facets' and are of common occurrence in ancient bones and in the bones of modern oriental people.

Extension of the ankle-joint is limited by:—(1) the anterior fibers of the deltoid ligament; (2) the anterior and middle portions of the lateral ligament; (3) the medial and stronger fibers of the anterior ligament. It is also limited by the posterior portion of the talus meeting with the tibia. Thus the middle portion of the lateral ligament is always on the stretch, owing to its

FIG. 365.—THE LOWER EXTREMITY OF THE TIBIA (ANTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE ANKLE-JOINT (IN RED) TO THE EPIPHYSIAL LINE.



obliquely backward direction, whereby it limits flexion; and its attachment to the fibula in front of the malleolar apex, whereby it prevents over-extension as soon as the foot begins to twist medialward. This medial twisting, or adduction of the foot, is partly due to the greater posterior length of the medial border of the superior articular surface of the talus, and to the less proportionate height posteriorly of the lateral border of that surface, but chiefly to the side to side movement in the talocalcaneal joints. Flexion and extension take place round a transverse axis drawn through the body of the talus. The movement is not in a direct anteroposterior plane, but on a plane inclined forward and laterally from the middle of the astragalus to the intermetatarsal joint of the second and third toes.

Muscles which act on the ankle-joint (cf. p. 508).—*Flexors.*—Tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus tertius. *Extensors.*—Tibialis posterior, flexor digitorum longus, flexor hallucis longus, peroneus longus, peroneus brevis, soleus, gastrocnemius, plantaris.

5. THE TARSAL JOINTS

These may be divided into the following sub-groups:—(*a*) The **talocalcaneal union**; (*b*) The **articulations of the anterior portion of the tarsus**; (*c*) The **mediotarsal joint.** For skeletal relations see figs. 262 and 263. For an account of the longitudinal and transverse arches of the foot, which should be studied in connection with the joints, see pp. 251, 1464.

(*a*) The Talocalcaneal Union

There are two joints which enter into this union—viz., an anterior and a posterior; the former communicates with the mediotarsal; the posterior is separate and complete in itself. This joint is formed by the posterior articular facet of the calcaneus and the corresponding facet on the lower surface of the talus. The two bones are united by an articular capsule with the following ligaments:—

(1) *The Posterior Talocalcaneal Joint*

Class.—*Diarthrosis.*	**Subdivision.**—*Arthrodia.*
Interosseous.	Lateral talocalcaneal.
Posterior talocalcaneal.	Medial talocalcaneal.

The **interosseous ligament** (figs. 366 and 367) is a strong band connecting the apposed surfaces of the calcaneus and talus along their oblique grooves. It is composed of several vertical laminæ of fibers, with some fatty tissue in between.

It is better marked, deeper, and broader laterally. Strong laminæ extend from the rough inferior and lateral surfaces of the neck of the talus to the rough superior surface of the calcaneus anteriorly, forming the posterior boundary of the anterior talocalcaneal joint; these have been described as the **anterior (interosseous) ligament.** The posterior laminæ extend from the roof of the sinus tarsi to the calcaneus immediately in front of the lateral facet, thus forming the anterior part of the capsule of the posterior joint.

The **lateral talocalcaneal ligament** (fig. 366) extends from the groove just below and in front of the lateral articular facet of the talus, to the calcaneus some little distance from the articular margin. Its fibers are nearly parallel with those of the calcaneofibular ligament of the ankle, which passes over it and adds to its strength. It fills up the interval between the calcaneofibular and anterior talofibular ligaments, a considerable bundle of its fibers blending with the anterior border of the calcaneofibular.

The **posterior talocalcaneal ligament** passes from the lateral tubercle of the talus and lower edge of the groove for the flexor hallucis longus to the calcaneus, a variable distance from the articular margin.

The **medial talocalcaneal ligament** includes two portions. The first is a narrow band of well-marked fibers passing obliquely downward and forward from the medial tubercle of the talus, just behind the medial end of the sinus tarsi, to the calcaneus behind the sustentaculum tali, thus completing the floor of the groove for the flexor hallucis longus tendon. The second portion, which is often considered a separate ligament, is described below with the anterior talocalcaneal joint.

The **synovial sac** is distinct from any other.

The **nerve-supply** is from the posterior tibial or one of its plantar branches.

The **arteries** are, a branch from the posterior tibial, which enters at the medial end of the sinus tarsi; and twigs from the tarsal, lateral malleolar, and the peroneal, which enter at the lateral end of the sinus.

(2) *The Anterior Talocalcaneal Joint*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

This joint is formed by the anterior facet on the upper surface of the calcaneus and the facets on the lower surface of the neck and head of the talus; it is bounded on the sides and behind by ligaments, and communicates anteriorly with the talonavicular joint. The ligaments are:—

Interosseous.	Medial talocalcaneal.
	Lateral calcaneonavicular.

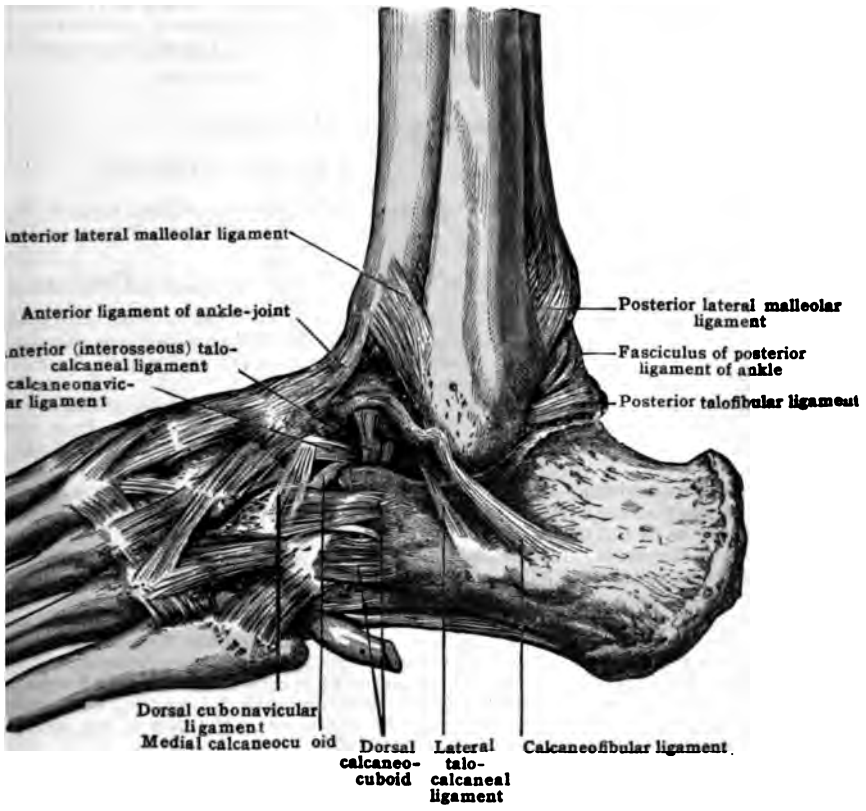
The **interosseous ligament** by its anterior laminæ limits this joint posteriorly. It has been already described with the posterior talocalcaneal joints.

The **medial talocalcaneal** ligament (second portion; see above) consists of short fibers attached above to the medial surface of the neck of the talus, and below to the upper edge of the free border of the sustentaculum tali, blending posteriorly with the medial extremity of the interosseous ligament, and anteriorly with the upper border of the plantar calcaneonavicular ligament. It is strengthened by the deltoid ligament, the anterior fibers of which are also attached to the plantar calcaneonavicular ligament.

The **lateral calcaneonavicular** (figs. 366 and 367) limits this, as well as the talonavicular joint, on the lateral side. It is a strong, well-marked band, extending from the rough upper surface of the calcaneus, lateral to the anterior facet, to a slight groove on the lateral surface of the navicular near the posterior margin. It blends below with the plantar calcaneonavicular, and above with the talonavicular ligament. Its fibers run obliquely forward and medially. The deltoid ligament and middle fasciculus of the lateral ligament of the ankle-joint also add to the security of these two joints, and assist in limiting movements between the bones by passing over the talus to the calcaneus.

synovial membrane is continuous with that of the talonavicular joint. The **arteries** **es are** derived from the same sources as those of the mediotarsal joints.
movements of which these two joints are capable (cf. p. 545) are adduction and abduc- **h some amount** of rotation. Adduction, or inclination of the sole medialward (inver- **combined** with some medial rotation of the toes, and some lateral rotation of the heel; **duction**, or inclination of the foot lateralward (eversion), is associated with turning of **laterally** and the heel medially. Thus the variety and the range of movements of the **the leg**, which at the ankle are almost limited to flexion and extension, are increased. **oid** moves with the calcaneus, while the navicular revolves on the head of the talus. **alking**, the heel is first placed on the ground; the foot is slightly adducted; but as the **ings forward**, first the lateral then the medial toes touch the ground, the talus presses **the navicular** and sinks upon the plantar calcaneonavicular ligament; the foot then **slightly abducted**. When the foot is firmly placed on the ground, the weight is trans- **o it obliquely** downward and medially, so that if the ligaments between the calcaneus **s did not check abduction**, medial displacement of the talus from the tibiofibular arch

FIG. 366.—LATERAL VIEW OF THE LIGAMENTS OF THE FOOT AND ANKLE.



nly be prevented by the tendons passing round the medial ankle (especially the tibialis **:)**. If the ligaments be too weak to limit abduction, the weight of the body increases it, **es the medial** malleolus and talus downward and medially, giving rise to flat foot.
advantages of the obliquity and peculiar arrangement of the posterior talocalcaneal **ion are seen** in walking:—(1) for the posterior facet of the calcaneus receives the whole **f the body** when the heel is first placed on the ground; (2) by the upward pressure of **t against the talus** it transfers the weight to the ball of the toes as the heel is raised, the **: edge of the sustentaculum tali** and the anterior and lateral part of the upper surface **lcaneus preventing** the talus from being displaced too far forward by the superincum- **ght; and** (3) the calcaneus serves to suspend the talus when, with the heel raised by **r action**, the other foot is being swung forward.

b) THE ARTICULATIONS OF THE ANTERIOR PART OF THE TARSUS

se include (1) the cubonavicular; (2) cuneonavicular; (3) intercuneiform; **) cuneocuboid** joints. The general relations and articular cavities are **in fig. 369.**

(1) *The Cubonavicular Union*

Class.—*Syndesmosis* (or *Diarthrosis*). **Subdivision.**—*Arthrodia* (occasional).

The joint cavity is only occasionally present, forming an arthrodial diarthrosis. This joint is often included in the transverse tarsal. The ligaments which unite the cuboid and navicular are:—

Dorsal. Plantar. Interosseous.

The **dorsal cubonavicular ligament** (fig. 366) runs forward and laterally from the lateral end of the dorsal surface of the navicular to the middle third of the medial border of the cuboid on its dorsal aspect, passing over the posterior lateral angle of the third cuneiform bone. It is wider laterally.

The **plantar cubonavicular ligament** is a well-marked strong band, which runs forward and laterally, from the plantar surface of the navicular to the depression on the medial surface of the cuboid, and slightly into the plantar surface just below it.

The **interosseous cubonavicular ligament** is a strong band which passes between the apposed surfaces of these bones from the dorsal to the plantar ligaments. Some of its posterior fibers reach the plantar surface of the foot behind the cubonavicular ligament, and radiate laterally and backward over the medial border of the cuboid to blend with the anterior extremity of the plantar calcaneocuboid ligament.

(2) *The Cuneonavicular Articulation*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The navicular articulates anteriorly with the three cuneiform bones (fig. 369). The ligaments uniting the bones are:—

Dorsal. Medial. Plantar.

The **dorsal cuneonavicular ligament** is very strong, and stretches as a continuous structure, on the dorsal surface of the navicular, between the tubercle of the navicular on the medial side, and the dorsal cubonavicular ligament laterally, passing forward and a little laterally to the dorsal surfaces of the three cuneiform bones.

The **medial cuneonavicular ligament** is a very strong thick band which connects the tubercle of the navicular with the medial surface of the first cuneiform bone. It is continuous with the dorsal and plantar ligaments. Its lower border touches the tendon of the tibialis posterior.

The **plantar cuneonavicular ligament** forms, like the dorsal, a continuous structure extending between the plantar surfaces of the bones. Its fibers pass forward and laterally. It is in relation below with the tendon of the tibialis posterior.

The *synovial membrane* is continuous with that of the cuneocuboid joint and also with those of the intercuneiform joints (fig. 369).

It must be noticed that the expanded tendon of insertion of the tibialis posterior, and the ligaments uniting the navicular with the cuboid and cuneiform bones, pass forward and laterally, while the peroneus longus tendon and the ligaments uniting the first and second rows of bones, except the medial half of the dorsal talonavicular ligaments, pass forward and medially. This arrangement is admirably adapted to preserve the arches of the foot, and especially the transverse arch. Had these tendons and ligaments run directly forward, all the strain on the transverse arch would have fallen on the interosseous ligaments, but as it is, the arch is braced up by the above-mentioned structures.

(3) *The Intercuneiform and* (4) *The Cuneocuboid Articulations*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The articular surfaces and cavities are indicated in fig. 369. The ligaments uniting these bones are divided into three sets:—

Dorsal. Interosseous. Plantar.

The **dorsal ligaments** are three in number, two, the **dorsal intercuneiform**, connecting the three cuneiform bones, and a third, the dorsal **cuneocuboid**, uniting the third cuneiform with the cuboid. They pass between the contiguous margins of the bones, and are blended behind with the dorsal ligaments of the cubonavicular and cuneonavicular joints.

The **plantar ligaments** are two in number: a very strong one, the **plantar intercuneiform**, passes laterally and forward from the lateral side of the base of the first cuneiform to the apex of the second cuneiform, winding somewhat to its lateral side. The second, the **plantar cuneocuboid**, connects the apex of the third cuneiform with the anterior half of the medial surface of the cuboid along its plantar border, joining with the plantar cubonavicular ligament behind.

The **interosseous ligaments** are three in number. They are strong and deep masses of ligamentous tissue which connect the second cuneiform with the first and third cuneiform bones, and the third cuneiform with the cuboid; occupying all the non-articular portions of the apposed surfaces of the bones. The ligaments extend the whole vertical depth between the second cunei-

m and the third, and the third cuneiform and the cuboid, and blend with the dorsal and ntar ligaments; they are situated in front of the articular facets, and completely shut off synovial cavity behind from that in front. The ligament between the first and second cuneirm bones occupies the inferior and anterior two-thirds of the apposed surfaces, and does not nerally extend high enough to separate the synovial cavity of the anterior tarsal joint from at of the second and third metatarsal and cuneiform bones. If it does extend to the dorsal rface, it divides the facets completely from one another, making a seventh synovial sac in the ot.

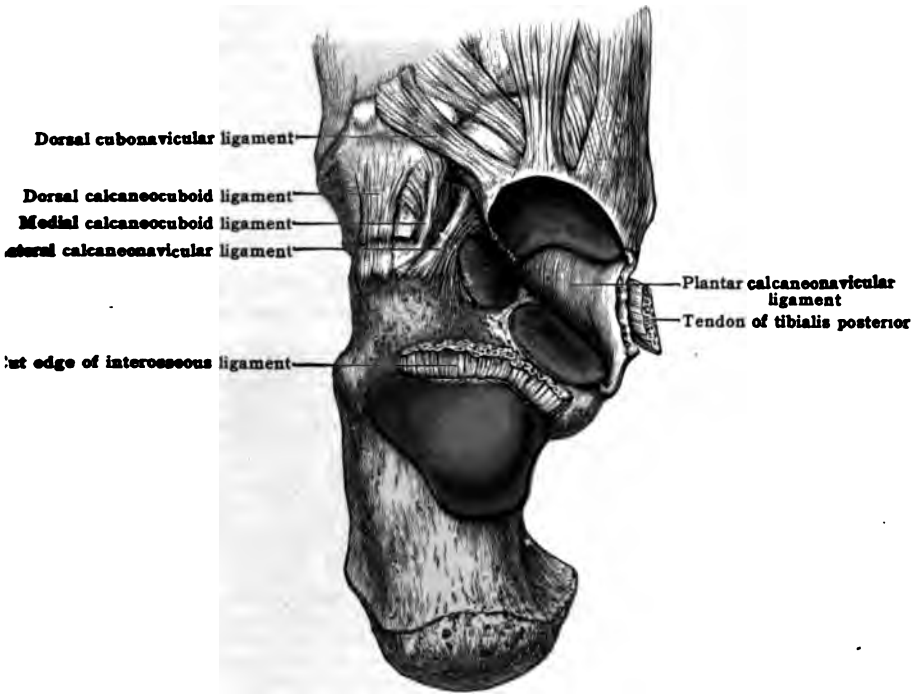
The **synovial cavity** is shown in fig. 369. It is continuous posteriorly with that of the cuneonavicular, and anteriorly (between the second and third cuneiforms) it communicates with the cond and third tarsometatarsal joints.

The **arterial supply** is from the metatarsal and plantar arteries.

The **nerves** are derived from the deep peroneal and medial and lateral plantar.

The **movement** permitted in these joints is very limited, but is of importance in adding to he general pliancy and elasticity of the tarsus without allowing any sensible alteration in the osition of the different parts of the foot, as do the mediotarsal and talocalcaneal joints. It s simply a gliding motion, and either deepens or widens the transverse arch. The third cuneiorm being wedged in between the others is less movable, and so forms a pivot upon which the est can move. The movement is produced more by the weight of the body than by direct nuscular action; and of the muscles attached to this part of the tarsus, all deepen the arch save he tibialis anterior, which pulls the first cuneiform up, and so tends to widen it.

IG. 367.—VIEW OF THE FOOT FROM ABOVE, WITH THE TALUS REMOVED TO SHOW THE PLANTAR AND LATERAL CALCANEONAVICULAR LIGAMENTS.



(*c*) THE TRANSVERSE TARSAL (CHOPART'S) JOINTS

The articulations of the anterior and posterior portions of the tarsus, although the same transverse line, consist of two separate joints, viz., (1) a medial, the onavicular, which communicates with the anterior talocalcaneal articulation; d (2) a lateral, the calcaneocuboid, which is complete in itself. The move-nts of the anterior upon the posterior portions of the foot take place at these nts simultaneously. It will be most convenient to deal with the joints sepa-ely as regards the ligaments; while the arteries, nerves, and movements will considered together.

(1) *The Talonavicular Articulation*

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia* (?).

Although it resembles a ball-and-socket joint, it is usually classified as arthro-l, on account of the limited extent of movement. It communicates with

the anterior talocalcaneal articulation, and two of the ligaments which close it in do not touch the talus, but pass from the calcaneus to the navicular. The uniting ligaments include, in addition to the articular capsule, the following:—

Lateral calcaneonavicular. Plantar calcaneonavicular.
Talonavicular.

The **lateral calcaneonavicular** has been already described (p. 342).

The **plantar calcaneonavicular ligament** (figs. 367 and 368) is an exceedingly dense, thick plate of fibroelastic tissue. It extends from the sustentaculum tali and the lower surface of the calcaneus in front of a ridge curving laterally to the anterior tubercle of that bone, to the whole width of the inferior surface of the navicular, and also to the medial surface of the navicular behind the tubercle. Medially it is blended with the anterior portion of the deltoid ligament of the ankle, and laterally with the lower border of the lateral calcaneonavicular ligament. It is thickest along the medial border. Its upper surface loses the well-marked fibrous appearance which the ligament has in the sole, and becomes smooth and faceted. In contact with the lower surface of the ligament the tendon of the tibialis posterior passes, giving considerable support to the head of the talus by augmenting the power and protecting the spring of the ligament. The fibers of the ligament run forward and medially. On account of its elasticity it is sometimes termed the **spring ligament.**

The **talonavicular ligament** is a broad, thin, but well-marked layer of fibers which passes from the dorsal and lateral surfaces of the neck of the talus to the whole length of the dorsal surface of the navicular. Many of the fibers converge to their insertion on the navicular. The fibers low down on the lateral side blend a little way from their origin with the upper edge of the lateral calcaneonavicular ligament, and then pass forward and medially to the navicular; those next above pass obliquely and with a distinct twist over the upper and lateral side of the head of the talus to the center of the dorsum of the navicular, overlapping fibers from the medial side of the talus as well as some from the anterior ligament of the ankle-joint.

Synovial membrane.—The talonavicular is lined by a continuation of the same synovial membrane as that lining the anterior talocalcaneal joint (fig. 369).

(2) *The Calcaneocuboid Articulation*

Class.—*Diarthrosis.* **Subdivision.**—*Saddle-shaped Arthrodia.*

The ligaments which are supplementary to the articular capsule and unite the bones forming the lateral part of the mediotarsal joint are:—

Medial calcaneocuboid. Dorsal cancaneocuboid.
Long plantar. Plantar calcaneocuboid.

The **medial calcaneocuboid ligament** (fig. 367) is a strong band of fibers attached to the calcaneus along the medial part of the non-articular ridge above the articular facet for the cuboid, and also to the upper part of the medial surface close to the articular margin, and passes forward to be attached to the depression on the medial surface of the cuboid, and also to the rough angle between the medial and inferior surfaces. At the calcaneus this ligament is closely connected with the lateral calcaneonavicular ligament. Toward the sole it is connected with the plantar calcaneocuboid ligament, and superiorly with the dorsal calcaneocuboid.

The **dorsal calcaneocuboid** (fig. 367) is attached to the dorsal surfaces of the two bones, extending low down laterally to blend with the lateral part of the plantar calcaneocuboid ligament. Over the medial half, or more, the ligament stretches some distance beyond the margins of the articular surfaces, reaching well forward upon the cuboid to be attached about midway between its anterior and posterior borders; but toward the lateral side, the ligament is much shorter, and is attached to the cuboid behind its tubercle.

The **long plantar ligament** (fig. 368) is a strong, dense band of fibers which is attached posteriorly to the whole of the inferior surface of the calcaneus between the posterior tubercles and the rounded eminence (the anterior tubercle) at the anterior end of the bone. Most of its fibers pass directly forward, and are fixed to the lateral two-thirds or more of the oblique ridge behind the peroneal groove on the cuboid, while some pass further forward and medially, expanding into a broad layer, and are inserted into the base of the second, third, fourth, and medial half of the fifth metatarsal bones. This anterior expanded portion completes the canal for the peroneus longus tendon, and from its lower surface arise the oblique adductor hallucis and the flexor digiti quinti brevis muscles.

The **plantar calcaneocuboid** (short plantar) (fig. 368) is attached to the rounded eminence (anterior tubercle) at the anterior end of the lower surface of the calcaneus, and to the bone in front of it, and then takes an oblique course forward and medially, and is attached to the whole of the depressed inferior surface of the cuboid behind the oblique ridge, except its lateral angle. It is strongest near its lateral edge, and is formed by dense strong fibers.

The **synovial membrane** is distinct from that of any other tarsal joint.

The **arterial supply** of the mediotarsal joints is from the anterior tibial, from the tarsal and metatarsal branches of the dorsalis pedis, and from the plantar arteries.

The **nerve-supply** of the mediotarsal joints is from the lateral division of the deep peroneal, and occasionally from the superficial peroneal or lateral plantar.

Relations.—On the *dorsal aspect* of the midtarsal joint lie the tendons of the tibialis anterior, extensor hallucis longus extensor digitorum longus, and peroneus tertius, the muscular part

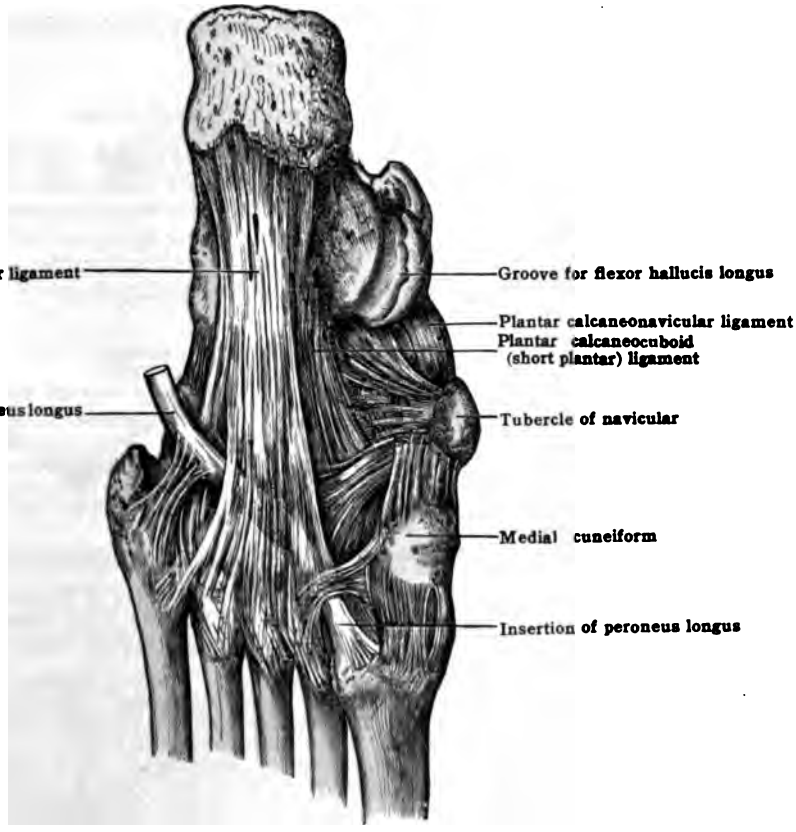
of the extensor digitorum brevis, the dorsalis pedis artery, and the deep peroneal (anterior tibial) nerve. On its *plantar aspect* are the tendons of the flexor digitorum longus and hallucis longus, quadratus plantæ (accessorius), and the medial and lateral plantar vessels and nerves. It is crossed laterally by the tendons of the peroneus longus and brevis and medially by the tendon of the tibialis posterior.

The **movements** (cf. p. 545) which take place at the mediotarsal joints are mainly flexion and extension, with superadded side-to-side and rotatory movements. Flexion at these joints is simultaneous with extension of the ankle, and *vice versa*. Flexion and extension do not take place upon a transverse, but round an oblique, axis which passes from the medial to the lateral side, and somewhat backward and downward through the talus and calcaneus.

Combined with flexion and extension is also some rotatory motion round an anteroposterior axis which turns the medial or lateral border of the foot upward. There is also a fair amount of side-to-side motion whereby the foot can be inclined medially (i. e., adducted) or laterally (i. e., abducted).

These movements of the mediotarsal joint occur in conjunction with those of the ankle and talocalaneal joints. Rotation at the talocalaneal joint is, however, round a vertical

FIG. 368.—LIGAMENTS OF THE SOLE OF THE LEFT FOOT.



axis in a horizontal plane, and so turns the toes medially or laterally; whereas at the mediotarsal union the axis is anteroposterior and the medial or lateral edge of the foot is turned upward. Gliding at the talocalcaneal joint elevates or depresses the edge of the foot, while at the mediotarsal it adducts or abducts the toes without altering the relative position of the calcaneus to the talus.

Thus flexion at the mediotarsal joint is associated with adduction and medial rotation of the foot, occurring simultaneously with extension of the ankle; and extension at the mediotarsal joint is associated with abduction and lateral rotation, occurring simultaneously with flexion of the ankle.

Flexion and medial rotation are far more free than extension and lateral rotation, which latter movements are arrested by the ligaments of the sole as soon as the foot is brought into the position in which it rests on the ground.

Although the talonavicular resembles a ball-and-socket joint, yet, owing to the union of the navicular with the cuboid, its movements are limited by the shape of the calcaneocuboid joint; this latter being concavoconvex from above downward, prevents rotation round a vertical axis, and also any side-to-side motion except in a direction obliquely downward and medially, and upward and laterally. This is also the direction of freest movement at the talonavicular joint. Movement is also limited by the ligamentous union of the calcaneus with the navicular. The twisting movement of the foot such as turning it upon its medial or lateral edge, and the increase

or diminution of the arch, take place at the tarsal joints, especially the mediotarsal and talocalcaneal articulations. Here too those changes occur which, owing to paralysis of some muscles or contraction of others, result in talipes equinovarus, or valgus.

Muscles which act on the midtarsal joint (cf. p. 545).—*Medial rotators* (inverters).—Tibialis anterior and posterior acting simultaneously; they are aided by the flexor digitorum longus and flexor hallucis longus. *Lateral rotators* (everters).—The peronei longus, brevis, and tertius, acting simultaneously. They are aided by the extensor digitorum longus.

6. THE TARSOMETATARSAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

There may be said to be three articulations between the tarsus and metatarsus, as shown in figs. 262 and 369, viz.:—

(*a*) The medial, between the first cuneiform and first metatarsal bones.
(*b*) The intermediate, between the three cuneiform and second and third metatarsal bones.
(*c*) The lateral, or cubometatarsal, between the cuboid and fourth and fifth metatarsal bones.

(*a*) The Medial Tarsometatarsal Joint

A complete **articular capsule** unites the first metatarsal with the first cuneiform, the fibers of which are very thick on the inferior and medial aspects; those on the lateral side pass from behind forward in the interval between the interosseous ligaments which connect the two bones forming this joint with the second metatarsal. The ligament on the plantar aspect is by far the strongest, and blends at the cuneiform bone with the cuneonavicular ligament.

(*b*) The Intermediate Tarsometatarsal Joint

Into this union there enter the three cuneiform and second and third metatarsal bones, which are bound together by the following ligaments (supplementary to the articular capsule): dorsal, plantar, interosseous.

The dorsal ligaments [ligg. tarsometarsea dorsalia].—1. Some short fibers cross obliquely from the lateral edge of the first cuneiform bone to the medial border of the base of the second metatarsal bone; they take the place of a dorsal metatarsal ligament, which is wanting between the first and second metatarsal bones.

2. Between the second cuneiform and the base of the second metatarsal bone some fibers run directly forward.

3. The third cuneiform is connected with (1) the lateral corner of the second metatarsal bone by a narrow band passing obliquely medially; (2) with the third metatarsal by fibers passing directly forward; and (3) with the fourth metatarsal by a short band passing obliquely laterally to the medial edge of its base.

The plantar ligaments [ligg. tarsometarsea plantaria].—A strong ligament unites the first cuneiform and the bases of the second and third metatarsal bones. The tibialis posterior is inserted into these bones close beside it.. Other slender ligaments connect the second cuneiform with the second, and the third cuneiform with the third metatarsal bones.

The interosseous ligaments [ligg. cuneometatarsea interossea].—(1) A strong broad interosseous ligament extends between the lateral surface of the first cuneiform and the medial surface of the base of the second metatarsal bone. It is attached to both bones below and in front of the articular facets, and separates the intermediate from the medial tarsometatarsal joint. (2) A second band is attached behind to a fossa on the anterior and lateral edge of the third cuneiform and to the interosseous ligament between it and the cuboid, and passes horizontally forward to be attached to the whole depth of the fourth metatarsal bone behind its medial facet, and to the opposed surfaces of the third and fourth below the articular facets upon their sides. It separates the middle tarsometatarsal, and intermetatarsal between the third and fourth bones, from the cubometatarsal joint. It is more firmly connected with the third bone than with the fourth. (3) A slender ligament composed only of a few fibers often passes from a small tubercle on the medial and anterior edge of the third cuneiform to a groove on the lateral edge of the second metatarsal bone between the two facets upon their sides.

The **synovial membrane** (fig. 369) is prolonged forward from that of the cuneonavicular and intercuneiform articulations.

The **arteries for the tarsometatarsal joints** are derived:—(1) for the medial, from the dorsalis pedis and medial plantar; (2) for the rest, twigs from the arcuate and deep plantar arch.

The **nerve-supply** comes from the deep peroneal and plantar nerves.

The **movements** permitted at these joints are flexion and extension of the metatarsus on the tarsus; and at the medial and lateral divisions, slight adduction and abduction. In the lateral, the side-to-side motion is freer than in the medial joint, and freest between the fifth metatarsal bone and the cuboid. In the medial joint, flexion is combined with slight abduction and extension with adduction.

There is also a little gliding, which allows the transverse arch to be increased or diminished in depth; the medial and lateral two bones sliding downward, and the two middle a little upward, when the arch is increased; and *vice versa* when the arch is flattened.

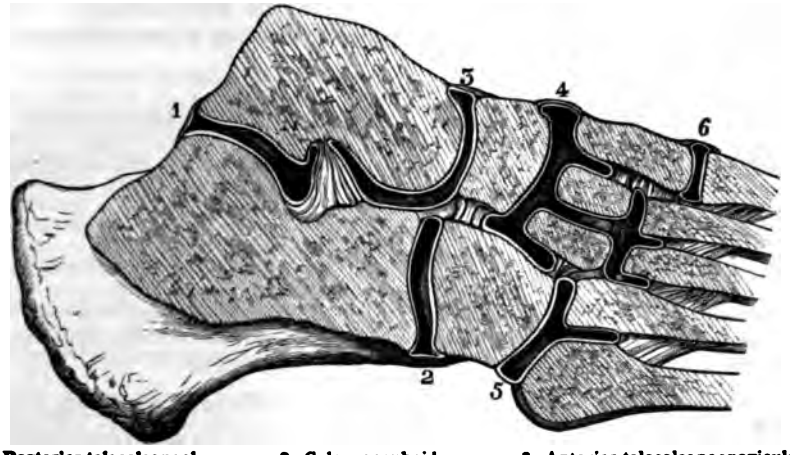
(*c*) The Lateral or Cubometatarsal Joint

The bones comprising this joint are the fourth and fifth metatarsal and the anterior surface of the cuboid, firmly connected on all sides by the articular capsule, and strengthened by the following ligaments:—

Dorsal. Plantar. Interosseous.

The **plantar cubometatarsal ligament** is a broad, well-marked ligament, which extends from the cuboid behind to the bases of the fourth and fifth metatarsal bones in front. It is continuous along the groove at the base of the fifth metatarsal bone with the dorsal ligament, and as it passes round the lateral border of the foot it is somewhat thickened, and may be described as the **lateral cubometatarsal ligament.** On its medial side it joins the interosseous

Fig. 369.—Section to show the Articular Cavities of the Foot.



1. Posterior talocalcaneal. 2. Calcaneocuboid. 3. Anterior talocalcaneonavicular.
4. Tarsal. 5. Cubometatarsal. 6. First metatarsocuneiform.

ligaments, thus completing the capsule below. It is not a thick structure, and to see it the long plantar ligament, the peroneus longus, and lateral slip of the tibialis posterior must be removed; the attachment of these structures to the fourth and fifth metatarsal bones considerably assists to unite them with the tarsus.

The **dorsal cubometatarsal ligament** is composed of fibers which pass obliquely outward and forward from the cuboid to the bases of the fourth and fifth metatarsal bones. They complete the capsule above, and are continuous laterally with the lateral cubometatarsal ligament.

The **interosseous ligament** shuts off the cubometatarsal from the middle tarsometatarsal joint. It is attached to the third cuneiform behind, and to the whole depth of the fourth metatarsal behind its medial facet, and to the apposed surfaces of the third and fourth bones below their articular facets. It is continuous below with the plantar ligament.

The **synovial membrane** is separate from the other synovial sacs of the tarsus, and is continued between the fourth and fifth metatarsal bones. (fig. 369).

Relations.—The line of the tarsometatarsal joints is crossed dorsally by the tendons of the long and short extensor muscles of the toes and the tendon of the peroneus tertius. On the plantar aspect it is in relation with the oblique adductor of the great toe, the short flexor of the great toe, the lateral plantar artery, and the tendon of the peroneus longus. Its medial end is subcutaneous except that it is crossed, near the plantar surface, by a slip of the tendon of the tibialis anterior, and its lateral end is crossed by the tendon of the peroneus brevis.

7. THE INTERMETATARSAL ARTICULATIONS

Class.—*Diarthrosis.* **Subdivision.**—*Arthrodia.*

The bases of the metatarsal bones articulate with each other as shown in figs. 262 and 369. They are firmly held in position by dorsal, plantar, and interosseous ligaments, supplementing the articular capsules. The first only occasionally articulates by means of a distinct facet with the second metatarsal (figs. 279 and 280).

The **dorsal ligaments are broad,** membranous bands passing between the four lateral toes on their dorsal aspect; but in place of one between the first and second metatarsal bones, a ligament extends from the first cuneiform to the base of the second metatarsal bone.

The **plantar ligaments** are strong, thick, well-marked ligaments which connect the bones on their plantar aspect.

The three **interosseous ligaments** between the four lateral metatarsals are very strong, and are situated at the points of union of the shaft with the bases of the bones, and fill up the spaces on their sides. They limit the synovial cavities in front of the synovial facets.

The common **synovial membrane** (fig. 369) of the tarsus extends between the second and third, and third and fourth bones; that of the cubometatarsal joint extending between the fourth and fifth.

The **arterial** and **nerve-supply** is the same as for the tarsometatarsal joints.

The **movements** consist merely of gliding, so as to allow the raising or widening of the transverse arch. Considerable flexibility and elasticity are thus given to the anterior part of the foot, enabling it to become moulded to the irregularities of the ground.

The Union of the Heads of the Metatarsal Bones

The **heads of the metatarsal bones** are connected on their plantar aspect by the **transverse ligament** [ligg. capitulorum transversa], consisting of four bands of fibers passing transversely from bone to bone, blending with the fibrocartilaginous or sesamoid plates of the metatarsophalangeal joints, and the sheaths of the flexor tendons where they are connected with the fibrocartilages. It differs from the corresponding ligament in the hand by having a band from the first to the second metatarsal bone.

8. THE METATARSOPHALANGEAL ARTICULATIONS

The skeletal relations at these joints are shown in figures 262 and 263.

(*a*) The Metatarsophalangeal Joints of the Four Lateral Toes

Class.—*Diarthrosis.* **Subdivision.**—*Condylarthrosis.*

These joints are formed by the concave proximal ends of the first phalanges articulating with the rounded heads of the metatarsal bones, and united by articular capsules strengthened by the following ligaments:—

Collateral. Dorsal. Plantar accessory.

The two **collateral ligaments** are strong bands passing from a ridge on each side of the head of the metatarsal bone to the sides of the proximal end of the first phalanx, and also to the sides of the sesamoid plate which unites the two bones on their plantar surfaces. On the dorsal aspect they are united by the dorsal ligament.

The **dorsal ligament** consists of loose fine fibers, extending between the collateral ligaments, thus completing a capsule. It is connected by fine fibers to the lower surface of the extensor tendons, which pass over and considerably strengthen this portion of the capsule.

The **plantar accessory ligament** (or sesamoid plate) helps to deepen the shallow facet of the phalanx for the head of the metatarsal bone, and corresponds to the accessory volar ligament of the fingers. It is firmly connected to the collateral ligaments and the transverse ligament, and is grooved inferiorly where the flexor tendons pass over it. It serves to prevent dorsal dislocation of the phalanx.

The second metatarsophalangeal joint is about 6 mm. in front of both the first and third metatarsophalangeal joints. The third metatarsophalangeal joint is about 6 mm. in front of the fourth, and the fourth about 9 mm. in front of the fifth. The head of the fifth metatarsal is in line with the neck of the fourth. Thus the lateral side of the longitudinal arch of the foot is shorter than the medial; it is also distinctly shallower.

(*b*) The Metatarsophalangeal Joint of the Great Toe

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

The metatarsophalangeal joint of the great toe differs from the rest in the following particulars:—

(1) The bones are on a larger scale, and the articular surfaces are more extensive.

(2) There are two grooves on the plantar surface of the metatarsal bone, one on each side of the median line, for the sesamoid bones.

(3) The sesamoid bones replace the accessory plantar ligament (sesamoid plate). They are two small hemispherical bones developed in the tendons of the flexor hallucis brevis, convex below, but flat above where they play in grooves on the head of the metatarsal bone; they are united by a strong transverse ligamentous band, which is smooth below and forms part of the channel along which the long flexor tendon plays. They are firmly united to the base of the phalanx by strong short fibers, but to the metatarsal bone they are joined by somewhat looser fibers. At the sides they are connected with the collateral ligaments and the sheath of the flexor tendon. They provide shifting leverage for the flexor hallucis brevis as well as for the flexor hallucis longus.

arteries come from the digital and metatarsal branches; and the **nerves** from the cutaneous, or from small twigs of the nerves to the interossei muscles.

movements of the metatarsophalangeal joints (cf. p. 546) are: flexion, extension, and abduction or adduction.

ion is more free than extension, and is limited by the extensor tendons and dorsal liga- extension is limited by the flexor tendons, the plantar fibers of the collateral ligaments, sesamoid plates. The side-to-side motion is possible from the shape of the bony sur- ut is very limited, being most marked in the great toe (although the joint is ginglymoid). The movement is limited by the collateral ligaments and sesamoid plates.

9. THE INTERPHALANGEAL JOINTS

Class.—*Diarthrosis.* **Subdivision.**—*Ginglymus.*

articulations between the first and second and second and third phalanges toes are similar to those of the fingers, with this important difference, that nes are smaller and the joints, especially between the second and third ges, are often ankylosed. The ligaments which unite them include, in n to the articular capsule:—

Collateral. Dorsal. Accessory plantar.

two collateral ligaments are well marked, and pass on each side of the joints from a ugh depression on the head of the proximal, to a rough border on the side of the base of al phalanx of the joint.

dorsal ligament is thin and membranous, and extends across the joint from one col- ligament to the other beneath the extensor tendon, with the deep surface of which it is ed and by which it is strengthened.

accessory plantar ligament covers in the joint on the plantar surface. It is a fibro- inous plate, connected at the sides with the collateral ligaments, and with the bones by gamentous fibers; the plantar surface is smooth, and grooved for the flexor tendons.

arteries and **nerves** are derived from the corresponding digital branches.

only movements permitted at these joints are flexion and extension.

he interphalangeal joint of the great toe there is very frequently a small sesamoid bone lays on the plantar surface of the first phalanx, in the same way as the sesamoid bones netatarsophalangeal joint play upon the plantar surface of the head of the metatarsal

tions of the muscles acting on the metatarsophalangeal and interphalangeal joints foot.—For these the student may refer to the accounts given of the relations of the onding joints in the hand and of the actions of the muscles upon those joints. See . 546, 547.

erences.—Extensive bibliographies for the joints are given in the larger works on human y by Quain, Poirier-Charpy and in the special treatise, 'Handbuch der Anatomie und nk der Gelenke,' by Professor Rudolf Fick (in von Bardeleben's Handbuch der Ana-

References to the most recent literature may be found in Schwalbe's Jahresbericht, lex Medicus and the various anatomical journals.

SECTION V

THE MUSCULATURE

REVISED FOR THE SIXTH EDITION

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ICLES, the movements of which are under the control of the will, almost
mpletely envelope the skeletal framework of the body; close in the oral,
bdominal, and pelvic cavities; separate the thoracic from the abdominal
rround the pharynx and the upper portion of the esophagus; and are
nected with the eye, ear, larynx, and other organs. They constitute
-fifths to three-sevenths of the weight of the body.

s section an account is given of the gross anatomy of the musculature
to the skeleton and the skin, with the exception of certain of the muscles
more conveniently treated in connection with the organs to which they
ded. Thus, the muscles of the eye, the ear, the pharynx, the larynx,
ntrinsic muscles of the tongue are described in the sections devoted to
ctures.

ons to the skin.—Beneath the skin is a sheet of connective tissue, the
itanea. In this, in some regions of the body (the head, neck, and palm),
subcutaneous muscles are embedded. Superficial muscles of this kind
a panniculus carnosus, much more extensive in the lower mammals
an. The tela subcutanea is separated from the more deeply seated mus-
y areolar tissue, which, in most places, is loose in texture over the mus-
some regions, as over the upper part of the back, the tela subcutanea is
ited to the underlying musculature and is less freely movable. In
ubcutanea more or less fat is usually embedded. This constitutes the
s adiposus, which varies greatly in thickness in different parts of the
s a rule, it is much more developed over muscles than over those regions
e and joints lie beneath the skin. From the tela subcutanea of the eye-
, and scrotum fat is absent. The deeper layer of the tela subcutanea is
ss free from fat, and in it run the main trunks of the cutaneous nerves
ls. In some regions, as over the lower part of the abdomen, one or more
embranes are differentiated in this deeper layer.

tela subcutanea the term **superficial fascia** has been commonly applied, but since
o a confusion with the superficial fasciæ which immediately invest the muscles, it
er to restrict the term fascia to the membranes connected with the muscular system,
the term **tela subcutanea,** or subcutaneous tissue, for the layer of connective tissue
rlies the skin and is continuous over the whole surface of the body.

veral places where the skin overlies bony prominences well-marked
bursæ, or sacs (**bursæ mucosæ**), are developed in the tela subcutanea.
the skin and the subcutaneous tissue must be removed in order to study
es of various regions, the tela subcutanea and subcutaneous bursæ may
iently described in connection with the muscles, and brief references will,
be made to them in connection with the musculature of various regons.

le-fasciæ.—The musculature of the body, with the exception of some of
itaneous muscles, is ensheathed by fibrous tissue, which, in certain re-
ns distinct membranes, while in other regions it is delicate and not
be distinguished from the superficial connective tissue of the muscles,
ysium externum. The membranes, or **muscle-fasciæ,** are united to

various parts of the skeleton, either directly or by means of intermuscular septa, and, where strong, keep the underlying musculature in place. In some regions they are united to the muscles; in others they are separated from the underlying musculature by loose areolar tissue, which allows free movement between the surface of the muscles and the overlying fascia. The best example of a strong fascia of this nature is that which envelopes the extensor muscles of the thigh. Where the fasciæ are well developed, the main bundles of constituent fibers take a course directly or obliquely transverse to the direction of the underlying muscles. They may be composed of several successive layers of fibrous tissue, the fibers of one layer taking a different direction from those of the next layer.

The **function** of the fasciæ is the mechanical one of restraining or modifying muscle action. The direction of the main component fiber-bundles indicates the direction of the greatest stress to which the fasciæ are subjected. Indirectly the fasciæ promote the circulation of the blood and lymph in places where the vessels lie between the contracting muscles and the overlying fascia.

Intermuscular septa.—Muscle-fasciæ enclose not only the external layer of the musculature of the body, but also the various groups of more deeply seated muscles. In addition, between the individual muscles, and between the different layers and groups of muscles, there intervenes a greater or less amount of connective tissue, sometimes loose in texture, sometimes dense in structure. In these intermuscular septa run the chief nerves and blood-vessels of the region in which the musculature lies.

Gross structure of the muscles.—The muscles are composed of bundles of reddish fibers surrounded by a greater or less extent of white and glistening connective tissue. They are attached by prolongations of this tissue in the form of **tendons** or **aponeuroses** usually to the bony skeleton, but also in places to cartilages, as in the thorax and larynx; to the skin, as in the face; to mucous membranes, as in the tongue and cheeks; to the tendons of other muscles, as in the case of the lumbrical muscles; to muscle fasciæ, as in the case of the oblique and transverse muscles of the abdomen; and to other structures, as, for instance, to the eyeball.

The fleshy portion of the muscle is called the **belly**. The belly is usually attached at one extremity to a portion of the skeleton or to some other structure which serves as a support for its action on the structures to which its other extremity is attached. The attachment to the more fixed part is called the **origin** of the muscle; the attachment to the structure chiefly acted on is called the **insertion**. Thus the origin of the biceps muscle, the chief flexor of the forearm at the elbow, is from the scapula; the insertion is into the radius and into the fascia of the forearm. The part of the muscle attached to the origin is called the **head** of the muscle. The part attached to the insertion is sometimes called the **tail**, but this term is much less frequently used than the former.

The muscles vary greatly in **size** and **form**. Thus the stapedius muscle of the middle ear is a slender little structure, only a few mm. long, while the gluteus maximus muscle of the hip is a large, rhomboid structure often several cm. thick and with a surface area of over 500 square cm. The length of a muscle from origin to insertion may be much less than the width of the muscle, as in the intercostal muscles; or much greater than the width, as in most of the long muscles of the limbs. The thickness of a muscle is usually less than the width—so much so in some instances that the muscle is described as flat, sheet-like, or ribbon-like; while in other instances the belly is cylindrical. In flat muscles the general outline is usually quadrilateral or triangular. In triangular muscles in most instances one angle of the triangle marks the insertion of the muscle, while the opposite side marks the origin. In cylindrical muscles the belly usually has a somewhat fusiform shape, and grows smaller both toward the origin and the insertion of the muscle.

Some muscles are divided by tendons transverse to the long axis of the muscle. When one such tendon exists, the muscle is called **digastric** (fig. 379); when several, **polygastric**, e. g., rectus abdominis (fig. 419).

Two muscle-masses with separate origins may have a common insertion. Such muscles are usually designated **bicipital** muscles (biceps muscles of the arm and thigh). Other muscles have three heads (the triceps muscle of the arm) or four (the quadriceps muscle of the thigh). In the latter case special names are given to the four parts or muscles which constitute the quadriceps as a whole. In

bdivisions of the musculature on each side of the body into individual s, but also in describing muscles placed near the median line either as single s with bilateral halves or as paired muscles. In addition some muscles are nstantly present, and there are differences of opinion as to which of these less nt muscles should be classed with the normal musculature. The BNA izes 347 paired and two unpaired skeletal muscles, and 47 paired and two ed muscles belonging to the visceral system and organs of special sense. ıe skeletal muscles the head has 25 paired and one unpaired; the neck 16 the back 112 paired; the thorax 52 paired, one unpaired; the abdomen and 3 paired; the upper extremity, 52 paired; the lower extremity, 62 paired).

r **structure of muscles.**—While no attempt can be made here to describe in detail the croscopic features of muscle structure, some of the more general features of muscle ture may be briefly mentioned.

contractile cells of voluntary muscle are long, slender, multinucleated **'fibers'**, the pro- of which exhibits both cross and longitudinal striation. The longitudinal striation ı the presence of fibrils situated in the sarcoplasma. The cross striation is due to alter- ments of singly and doubly refracting substance in these fibrils. The length of these the human body varies from a few millimeters to sixteen centimeters or more, and the ıs from ten to eighty microns. Each muscle-fiber is surrounded by an especially differ- sheath, the **sarcolemma.** Outside of this is a layer of delicate connective tissue, the ium internum or **endomysium,** the fibers of which are in part inserted into the sarco- This connective tissue, which is especially developed at the ends of the fibers, serves to hem either directly to the structures on which the muscle acts or to the skeletal frame- the muscle.

ıe simplest mammalian muscles the muscle-fibers take a parallel course from tendon to and are not definitely bound into secondary groups. An example may be seen in fig. which represents two segments of the rectus abdominis muscle of a mouse. More often , the individual fibers do not run the entire distance from tendon to tendon, but instead erdigitate, and the interdigitating fibers are bound up into secondary and tertiary ıosing fiber-bundles by connective tissue, in which there is usually a considerable of elastic tissue. Fig. 370,b, represents diagrammatically this interdigitation of fiber- as seen in the abdominal musculature of one of the larger mammals.

ıost of the flat muscles of the body the fiber-bundles either take a nearly parallel course ıdon to tendon or they converge from the tendon of origin toward the tendon of insertion 370, c–e). The greater the distance from tendon to tendon, the more marked is the itation of the constituent fiber bundles.

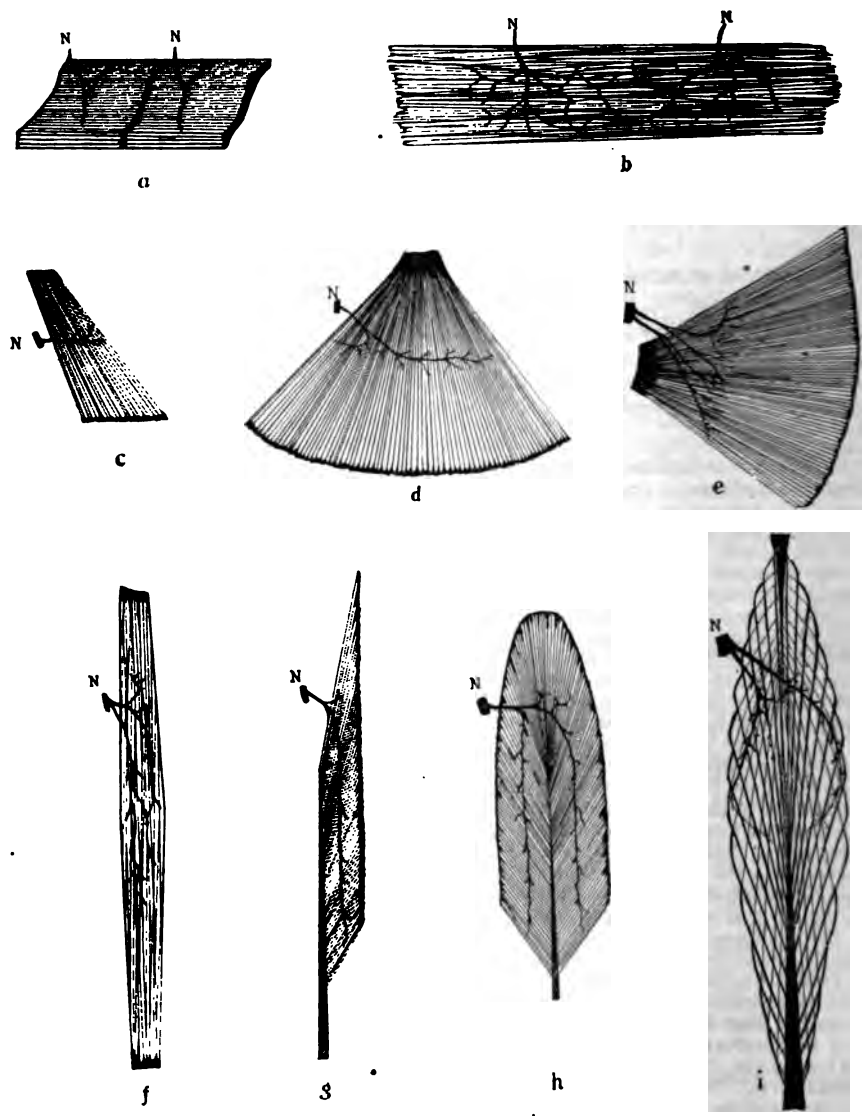
ongated muscles the tendons of origin and insertion may either arise near the extremities ıuscle or may extend for a considerable distance on the surface or within the substance of cle. In the former case the belly of the muscle is composed of bundles of interdigitating hich take a course parallel with the long axis of the muscle. This is shown diagrammatic- fig. 370, f. An example may be seen in the sartorius muscle of the thigh (fig. 442). he tendons extend far on the surface or within the substance of the muscle, the con- fiber-bundles take a course oblique to the long axis of the muscle. When they take a rom a tendon of origin on one side toward a tendon of insertion on the other, the muscle **unipenniform** (see fig. 370, g, and the extensor digitorum longus, fig. 446). In other s the fiber bundles converge from two sides toward a central tendon. Such a muscle **bipenniform** (see fig. 370, h, and the flexor hallucis longus, fig. 447). When there are endons in the muscle between which the fiber-bundles run obliquely, the muscle is called niform. In **fusiform** muscles the tendons usually either embrace the extremity of the ike a hollow cone, or they extend far on the surface or within the substance of the muscle. muscles the fiber-bundles take a curved course from one tendon to the other. The bundles ise highest on one tendon are inserted highest on one other, and the fiber-bundles of lowest ave the lowest insertion. This structure is diagrammatically shown in fig. 370, i. example may be found in the rectus femoris muscle (fig. 442).

y other arrangements of the fiber-bundles are found, and the arrangements here shown variously combined. In most muscles the architecture is decidedly complex. In the mplex muscles dense connective-tissue septa, or intramuscular fasciæ, serve to separate regions of the muscle from one another. In general there are groups of muscle fiber-

bundles surrounded by a greater amount of connective tissue, or perimysium internum, than that surrounding the individual fiber-bundles, and the latter are surrounded by a denser connective tissue than that surrounding the component muscle-fibers. The muscles are surrounded externally by a more or less dense sheet of connective tissue called the perimysium externum, or epimysium, which is continuous with the connective tissue within the muscle,

FIG. 370.—DIAGRAMMATIC OUTLINES TO ILLUSTRATE VARIOUS TYPES OF MUSCLE ARCHITECTURE AND THE RELATIONS OF THE MAIN NERVE BRANCHES TO THE FIBER-BUNDLES OF THE MUSCLE.

a. Two segments of the rectus abdominis muscle of a small mammal. b. Portion of sheet-like muscle with two nerve-branches and intramuscular nerve plexus. c. Typical quadrilateral muscle with nerve passing across the muscle about midway between the tendons. d and e. Two triangular muscles with different types of innervation. f. Long ribbon-like muscle with interdigitating fiber-bundles. g. Unipenniform muscle. h. Bipenniform muscle. i. Typical fusiform muscle. The main intramuscular nerve-branches are distributed to the fiber-bundles about midway between their origins and insertions. N. nerve.



the perimysium internum. In the following pages 'muscle fiber-bundle' is used to denote small groups of muscle-fibers, 'fasciculus' to denote large, more or less isolated, groups of fiber-bundles.

Embryonic development of muscles.—The voluntary muscles are of mesodermal origin. The muscles of the trunk arise chiefly from the myotomes (see p. 13), those of the head and limbs chiefly from the mesenchyme in these regions. New muscle-fibers are formed mainly before birth. After birth, growth of muscles depends on growth of individual muscle-fibers.

. Well-marked instances may be seen in the transverse muscle of the abdo- fig. 421), and the trapezius and latissimus dorsi muscles of the back (fig. 386). extent of development of these aponeuroses is generally inversely pro- ɔnal to the development of the muscle—the more extensively developed ıuscle is in a given individual, the less extensive the aponeurotic sheet.

ɜ terms facia and aponeurosis are often loosely and interchangeably used. It seems ɔ make a distinction by restricting the term fascia to membranous sheets of investment, oneurosis to broad tendons. The latter may, however, be inserted into and form a part former.

ost muscles are continued at one or both extremities into dense, tendinous ı which may be comparatively short and thick, like the tendon of Achilles 44), or very long and narrow, like the tendon of the palmaris longus (fig. 401). this latter case the tendon represents in part the remnants of musculature highly developed in the lower vertebrates. In most instances, however, ndons are structures specifically differentiated for definite functions and are ɔsed of bundles of parallel connectve-tissue fibrils held together by an inter- ; fibrous-tissue framework. The tendons usually contain a relatively small nt of elastic tissue.

ıe tendons are attached to the skeleton early in embryonic development. e bones enlarge the tendons become in part incorporated in the substance of ɔne and ossified.

ı some tendons **sesamoid bones** are developed in the neighborhood of joints ₩hich the tendons pass. Examples of these are the patella at the knee-joint 43) and the sesamoid bones of the thumb and great toe.

here muscles or tendons closely envelope a joint, there is usually formed a ınion between the connective tissue of the capsule of the joint and that of the le or the tendon. Special bands may develop in the direction of the pull ı muscle (lig. popliteum obliquum).

here tendons run for some distance across or beneath a fascia, they are ly either bound to the fascia by a special investment, as near the wrist and (figs. 397 and 445), or are fused with the fascia, as in the case of the ilio- band. Fibrous tracts in the fascia may indicate stress under muscle con- on (the lactertus fibrosus of the fascia of the forearm).

ften in broad aponeurotic attachments of muscles there is formed in the ten- ıear the attachment a fibrous archway [arcus tendineus] for the passage of -vessels, nerves, muscles, or tendons. The tendinous arch is either fastened ch ends to the bone, or at one end it is connected with a joint capsule or other

annulus fibrosus, may hold a tendon in place, as, for intance, the trochlea of the tendon of the superior oblique muscle of the eye.

Synovial bursæ [bursæ mucosæ].—Where there is freedom of action between muscles and tendons and the surrounding parts, there intervenes a loose connective tissue. In regions where the pressure is great or considerable friction would result were these conditions retained, there are developed special cavities with smooth surfaces and containing fluid. Most of these bursæ are developed from the intervening connective tissue at a period in embryonic life preceding muscular activity, but special bursæ may later be developed as the result of unusual pressure or muscular activity after birth. An instance of a bursa lying in a region of friction may be seen in the bursa intervening between the tendinous posterior surface of the iliopsoas muscle and the iliofemoral ligament. As an instance of a bursæ lying in a region of intermittent pressure may be cited that between the tendon of Achilles and the calcaneus.

Most synovial bursæ intervene between a tendon and a bone, a tendon and a ligament, or between two tendons (**subtendinous bursæ mucosæ**). Others lie between two muscles, a muscle and some skeletal part, or between a muscle and a tendon (**submuscular bursæ mucosæ**); or below a fascia (**subfascial bursæ mucosæ**). Subcutaneous bursæ have been referred to in connection with the tela subcutanea (see p. 353). Most bursæ are developed near joints. The bursæ may so expand during active life that they come to communicate with other bursæ or with a neighboring joint cavity.

Synovial sheaths [vaginæ mucosæ tendinum].—Synovial sheaths are developed about tendons where the latter are confined in osteofibrous canals, as in the fingers. The wall of the canal and the enclosed tendon, or tendons, are each covered by a smooth membrane which at the extremities of the canal is reflected from the wall to the tendon. Between the membrane covering the tendon and that lining the canal is a synovial cavity. An interesting feature of these tendon-sheaths is the presence of **mesotendons,** delicate bands of vascular connecive tissue which run in places from the osseous groove to the tendon and carry blood-vessels and nerves.

Trochleæ.—Where a tendon passes at an angle about a bone, the tissue in the groove in which the tendon runs frequently is composed of hyaline cartilage instead of bone. An example may be seen in the trochlear process of the calcaneus.

Nerves.—To each muscle of the body a nerve containing motor and sensory fibers is distributed. A few muscles receive two or more nerves. Sherrington has estimated that in the muscle-nerves of the cat two-fifths of the fibers are sensory and three-fifths motor. The muscles of the head and in part those of the neck are supplied by branches of the cranial nerves. The intrinsic muscles of the neck, back, thorax, and abdomen are supplied by branches which arise fairly directly from the spinal nerves. The muscles of the limbs are supplied by branches from nerve-trunks which arise from plexuses formed by the spinal nerves in the regions near which the limbs are attached.

The main nerve-trunks lie beneath the superficial muscles. They usually run in the intermuscular septa which separate the deeper groups of muscles from one another and from the superficial muscles. The nerve-branches which enter a given muscle usually pass in where the larger intramuscular septa approach the surface of the muscle, and then ramify through the perimysium internum, the smaller branches being distributed in the finer layers of connective tissue which surround and separate the primary muscle fiber-bundles, to the constituent muscle-fibers of which terminal branches are given. Special sensory end organs are distributed chiefly in the large intramuscular septa, in the tendons and in the muscles near the tendons. Simple sensory endings are found on the muscle-fibers.

The size of a nerve supplying a muscle is not proportional to the size of the latter, but rather to the complexity of movements in which the muscle plays a part.

Muscles receive their nerve supply early in development. During later development the muscle may wander a considerable distance from its place of origin and carry its nerve with it. The diaphragm, innervated by cervical nerves, is a good example.

The distribution of the motor nerves varies according to the architecture of the muscle, but in general it appears that the nerves are so distributed as to carry the main branches of distribution most directly to the middle of the constituent fiber-bundles. This is seen most clearly in muscles with comparatively short fiber-bundles, where the individual muscle-fibers run nearly or quite the entire distance from tendon to tendon (fig. 370 a, c, d, e, g, h, and i). When the distance is long, a marked plexiform arrangement is found (fig. 370, b and f). To each muscle fiber there is distributed a terminal nerve-fiber which passes through the sarcolemma and ends in a motor end organ (muscle plate). Occasionally there are two such nerve-fibers to one muscle-fiber.

ssels.—The muscles are richly supplied with blood. In many instances the
: blood-vessels accompany the larger nerve-trunks as they enter the muscle,
heir primary branches are distributed in the larger intramuscular septa.
ı, however, the main blood-vessels approach a muscle from a direction dif-
t from that taken by the nerves. Each muscle has, however, its own blood-
y. There is little anastomosis between the blood-vessels of a muscle and
of a neighboring structure, but the anastomosis between the vessels within
ıuscle is exceedingly rich. Veins, as a rule, accompany all but the smallest
es within the muscle. The veins are richly supplied with valves, so that
e contraction promotes the flow of blood through the muscle. Rich cap-
plexuses surround the muscle-fibers. The capillaries are of unusually
diameter.
ıring contraction, the blood is forced from the muscles; during expansion
hes in through dilated arteries which furnish five or six times as much
to muscles during exercise as that supplied to them during rest.
ıe connective-tissue sheaths, the larger intramuscular septa, and the tendons
scles are richly supplied with lymphatics. There are no lymphatics within
uscle-bundles or in small muscles.
menclature.—The names of the various muscles and their classification are
ıtisfactory than is desirable. The muscular system was first carefully
d in the human body, and names based sometimes upon the shape, structure,
r position, at other times upon the supposed function or other associated
were applied to the muscles found in various regions. Sometimes two or
ıames were applied to a muscle to indicate several of these factors. Thus
us and *triangularis* indicate the shape of the correponding muscles; *biceps*
ps indicates the origin by two or three heads; *rectus*, *obliquus*, and *trans-*
represent the direction taken by a muscle or its constituent fiber-bundles;
s and *minimus* indicate size; *sublimis* (superficial) and *profundus* (deep)
ent the relative positions occupied; *sterno-cleido-mastoid* indicates structures
ch the muscle is attached; *flexor* and *extensor* indicate function; and *sar-*
ndicates that the corresponding muscle was supposed to be of use to tailors.

e careful study has been devoted to the comparative anatomy of the muscles in various
ates, it has become apparent that a simple and more consistent nomenclature applicable
sponding muscles found in various animals would be of great value. A satisfactory
lature of this sort has not, however, as yet been devised and adopted in comparative
y, and the established usage of the terms now familiarly applied to the muscles of the
body makes it seem improbable that even if such a system were devised for compara-
ıtomy it could be brought into extensive use in human anatomy. For many of the
in the human body various synonyms have been in use in different countries. The
ical Congress assembled at Basil in 1895, to simplify the nomenclature of human ana-
dopted in large part the terms in familiar use in England and America. In the fol-
pages the terms approved by the Congress will be employed, but where they differ
lly from those previously in use, the synonym will be given in parentheses.
sification.—The muscles are usually treated strictly according to the region of the body
ı they are found. This method of consideration is still of value in a dissector's guide
ext-books of topographical anatomy. But in studying the muscles scientifically it is of
nce also to consider them in their more fundamental genetic relationships to one
and to the nervous system. Embryology and comparative anatomy have proved of the
value in revealing these relationships. Studies of this nature have revealed well-
relationships in the adult human musculature which are of practical as well as scientific
nce. The voluntary musculature may be broadly divided into that of the skeletal
e limbs, and the visceral orifices. The musculature of each of these divisions has a
t and in general simpler form in the lower than in the higher vertebrates, and in the
s of the higher vertebrates than in the adult. The musculature of the spinal region of
ly-axis of fishes, the tailed amphibia, and all vertebrate embryos is metamerically
ed; that is, it is divided along the axis of the body into a series of components corre-
g with the segmentation of the vertebral column. Although marked alterations take
the subsequent ontogenetic differentiation in higher vertebrates, traces of this primitive
ation are still to be found in the adult; in man, for instance, in the intercostal muscles
segments of the rectus abdominis. In the region of the head conditions are complex,
ı the concurrent presence of muscles which primitively correspond in nature with the
al spinal musculature, and muscles non-segmental in character, which surround the
orifices. This also is true of the anus and external genitalia, where, however, the con-
are simpler. Embryology and comparative anatomy have done much to clear up
features in both regions.
muscles of the limbs are metamerically arranged in no adult vertebrate. In some of the
rms a series of axial muscle-segments, myotomes, furnishes material from which the
ture of the limbs is differentiated. In the mammals this appears not to be the case, and
cles are differentiated from the non-segmental tissue of the limb-buds.

Where mammalian musculature is primitively segmental, each segment becomes associated with a corresponding spinal nerve or, in the head, with a nerve which corresponds in series with a spinal nerve. Even when subsequent differentiation brings about marked alterations in the axial musculature, the nerves maintain to a considerable degree a segmental distribution.

Into each of the limbs, where the intrinsic musculature is at no time segmental, there extends during embryonic development a series of segmental spinal nerves, so that in them, as in the region of the body axis, a certain segmentation in the nerve-supply can be made out in the adult. That part of the limb nearest the head in early embryonic development has its muscles supplied by the most cranial, that part nearest the caudal extremity of the body by the most caudal, of the nerves which supply the limb-musculature. There is here, however, considerable overlapping of the segmental areas.

Variation.—In man some variation in the arrangement of the muscles is met with in every individual, and often marked deviations from the normal conditions are found. The muscles vary in their mode of origin or insertion, and in the extent to which muscles of a given group are fused with one another or to which the chief parts of a complex muscle are isolated from one another. Some muscles, like the palmaris longus and the plantaris, are frequently entirely absent, and other muscles generally absent are frequently present.

In addition to these frequent variations there are others so rare that many authors prefer to speak of them as anomalies rather than variations. Sometimes muscles may be found doubled by longitudinal division, or two or more muscles normally present may be fused into a single indivisible muscle. Occasionally there occur muscles constantly present in some of the lower animals, but normally not met with in the human body (anomalies of reversion or of convergence). In such instances the muscle may be normally represented by a tendon or fascia. At times the anomalies are supposed to be not a reversion to an ancestral condition, but a distinct step in advance. This, however, is difficult to prove. At other times no phylogenetic relation is apparent, and the anomaly is looked upon as a monstrous sport or as the result of some pathological condition.

The nerve-supply of the muscles is of value in the study of muscle-variations. There is, however, not infrequent variation in the nerves with relation to the supply of the muscles.

Physiology.—From the standpoint of morphology the muscles are grouped according to their intimate relations to one another and to the peripheral nerves; relations, as noted above, that are made more clear by a study of comparative anatomy and embryology. From the physiological aspect a different grouping of the muscles is required, because muscles belonging morphologically in one group may have different physiological functions in the animal body. The chief features of the mechanical action of muscles may be briefly considered here.

Most muscles act on the bones as levers. In physics three types of levers are recognized. In levers of the first type (fig. 371, I) the fulcrum (F) lies between the place where power (P) is exerted on the lever and the point of resistance or load (L). Levers of this kind are frequently met with in the body. A good example is seen in the attachment of the skull to the vertebral column. The fulcrum lies at the region of attachment; the weight of the skull tends to bend the head forward, while the force exerted by the dorsal muscles of the neck serves to keep the head upright or to bend it back.

In levers of the second class (fig. 371, II) the point on which power is exerted moves through a greater distance than the point of resistance. Speed of movement is thus sacrificed to power. Levers of this type are exceedingly rare in the animal body. An example in the human body is the foot when the body is raised on the toes, if the contact of foot with ground be considered the fulcrum.

In levers of the third class (fig. 371, III) the point on which force is exerted moves a less distance than the point of resistance. Power is thus sacrificed to speed. This is the common form of leverage found in the body. A good example is found in the action of the muscles which flex the foream on the arm. The region in which the biceps and brachialis are attached is but a short distance from the elbow-joint or fulcrum, while the hand may be looked upon as the region of resistance to the force exerted. A movement of the point P through a short distance will cause L to move through a great distance.

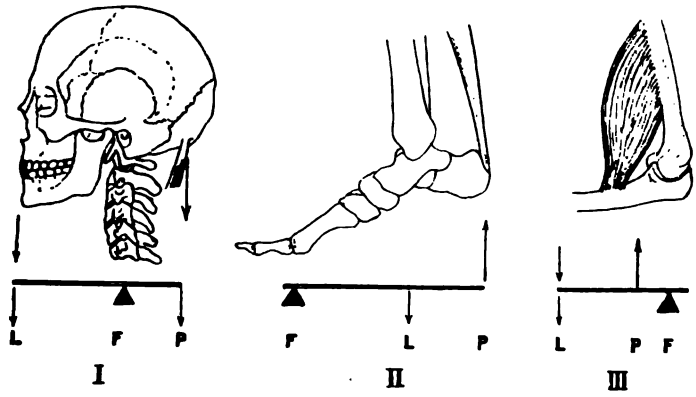
The more the angle between a muscle or its tendon and the bone on which it acts approaches a right angle, the greater is the power of movement exerted by the muscle. The arm in fig. 371, III, is in the position of greatest advantage for the action of the brachialis on the forearm. All boys know that it is easier to 'chin' oneself after the arm is partly bent than when hanging straight from a bar. Many of the muscles run nearly parallel with the parts on which they act, but the tendons before their attachment are usually either carried over a bony prominence or

some fascia or ligament acts as a pulley so that the tendon is inserted at an oblique angle. At other times a process for the attachment of the tendon projects from the bone and causes the force of the contracting muscle to be more advantageously exerted on the bone. It may, of course, readily be seen that the greater the distance of the attachment of a muscle from the joint on which it acts, the greater will be the power exerted by the muscle.

In considering the movements of the body, it is convenient to recognize two groups, simple and complex. To the former, which alone can be considered in a text-book of anatomy, belong such movements as flexion, extension, adduction, rotation, etc., while to the latter belong those associated movements which give rise to changes in the positions of the body as a whole or of extensive regions of the body.

In **flexion** the extremities of the trunk or limbs or special portions of these regions are bent near to one another; in **extension** the reverse movement is brought about. The parts are straightened or even bent beyond the straight position (over-extension).

FIG. 371.—THREE DIAGRAMS (AFTER TESTUT) TO ILLUSTRATE DIFFERENT TYPES OF LEVERS IN THEIR RELATIONS TO THE MECHANICAL ACTION OF THE MUSCLES.



In **abduction** transverse movements are made, a part being bent away from the median line of the body or limb; in adduction the reverse movement is brought about.

In **rotation** a part is turned on its longitudinal axis. The rotation of the femur at the hip-joint is called medial rotation when the toes are turned medialward, lateral rotation when the toes are turned lateralward. Rotation at the shoulder-joint is called medial when the thumb is turned forward and medialward toward the body, lateral when the reverse movement takes place. These movements are also carried out at the elbow-joint, but here medial rotation is called **pronation**, lateral rotation, **supination**. Fick prefers these terms also for the rotation at other joints as at the shoulder, hip and knee.

At the shoulder-joint the swinging of the arm toward the back is called extension; toward the front, flexion; and from the side, abduction. Moving the arm toward the mid-dorsal or mid-ventral line is called adduction.

Taking the body as a whole the musculature may be divided into two main divisions, an *expander division* and a *contractor division*. In general the extensors, abductors and lateral rotators expand, the flexors, adductors and medial rotators contract.

In the most expanded condition the head and spine are extended or even slightly hyperextended (flexed dorsally), and the limbs project laterally from the body with the backs of the hands and feet facing dorsalward, the palms and soles ventralward, and the digits spread out. In the fully formed human body it is not possible to put the lower extremity in the completely expanded position, although it is in this position early in embryonic development. As development proceeds the lower extremity is adducted and rotated medialward and the girdle is so fixed that full abduction becomes no longer possible. In many of the lower vertebrates full abduction is possible throughout life in the lower extremities just as it is throughout life in the upper extremities in man. Full extension of the spinal column in man is also hindered in the thoracic region by the thorax, and in the sacrococcygeal region by the osseous union of vertebræ with one another as well as by the attachment of the hip-girdles. The lumbar region in man is in a condition of permanent hyperextension.

In the fully contracted condition the head and spinal column are strongly flexed, and the digits are adducted, the various segments of the limbs are flexed and the limbs are adducted, flexed and rotated medialward toward the middle of the trunk. The body approaches a ball in form. It is the position taken by a gymnast when turning a somerset in the air, and is in marked contrast to the fully expanded condition which would be assumed could man fly like a bat or glide like a flying squirrel.

In general, the muscles which put the body or a part of the body into the expanded position form a distinct group as contrasted with those which put the body into the contracted position. The chief musculature which extends the head and trunk lies dorsolateral to the spinal column and is supplied by the dorsal divisions of the spinal nerves. The chief musculature which flexes the head and trunk lies ventrolateral to the spinal column and is supplied by ventrolateral divisions of the spinal nerves. The chief muscles which abduct, extend and rotate the limbs lateralward arise during embryonic development on the dorsal sides of the limb buds and are innervated by branches from the dorsal sides of the brachial and lumbosacral nerve plexus. The chief muscles which flex, adduct and rotate the limbs medialward arise on the ventral sides of the limb-buds and are supplied by nerves which arise from the ventral sides of the limb plexuses. To these general rules there are some exceptions, the most marked of which is at the hip-joint where rotation of the girdle has brought about a condition in which the primitive action of the flexor and extensor groups is partly reversed. The chief flexors (the iliopsoas and rectus femoris) belong to the dorsal division and some of the chief extensors (the hamstring muscles) belong to the ventral division. At the ankle-joint the exception is more apparent than real. What is usually called flexion at the ankle-joint is really hyperextension and the reverse movement is the nearest we can come to real flexion. In the extremely contracted positon of the body as a whole the feet are extended (flexed plantarward at the ankle joint.)

Muscles which produce a movement in a common direction are called **synergists**, while those whose contraction produces opposite movements are called **antagonists**; e. g., the flexors and extensors are antagonists. In the actual working of the muscular system, however, when a set of muscles is contracting to produce a movement, the antagonists are simultaneously relaxed. A more extended treatment of this subject is given on p. 533.

The relation of the internal architecture of a muscle to the movements to which its contraction gives rise is a complex subject, the details of which cannot be entered into here. In general it may be said that when the fiber-bundles run directly from one attachment to the other, as in fig. 370, a and f, the force exerted by the contraction of the individual muscle-fibers is most efficiently utilised and the extent of the movement varies directly as the length of the fibers, while the force exerted varies directly with the number of the fibers. In muscles with tendons of insertion relatively small in cross-section compared with the belly of the muscle, the power of the muscle is concentrated on a small area. Long tendons frequently take a course which improves the leverage.

In muscles of the types indicated in fig. 370, g, h, i, a certain amount of the extent of movement and of the force exerted by the contraction of the individual fibers is not effectively exerted on the parts moved by the muscles, as may be seen by applying to this action the laws of the parallelogram of forces. In such muscles, however, the great number of short muscle-fibers composing them makes possible the exertion of great power with some loss of speed of contraction in the muscle as a whole.

The direction of the movements which result from muscular contraction is in large part determined by the shape of the articular surfaces, none of which are to be looked upon as simple fulcra, but instead, during a given movement, the fulcrum shifts from one region to another of the joint.

In different muscles the extent of contraction of the constituent fiber-bundles during activity varies considerably. While usually the length of the contracted fiber-bundles is half that of those in the extended state, the amount of shortening in some muscles is only 25 to 35 per cent.

Functional activity is necessary for the full development or for the maintenance of development in muscles. Muscles atrophy if their nerve supply is injured or if they are passively prevented from contracting.

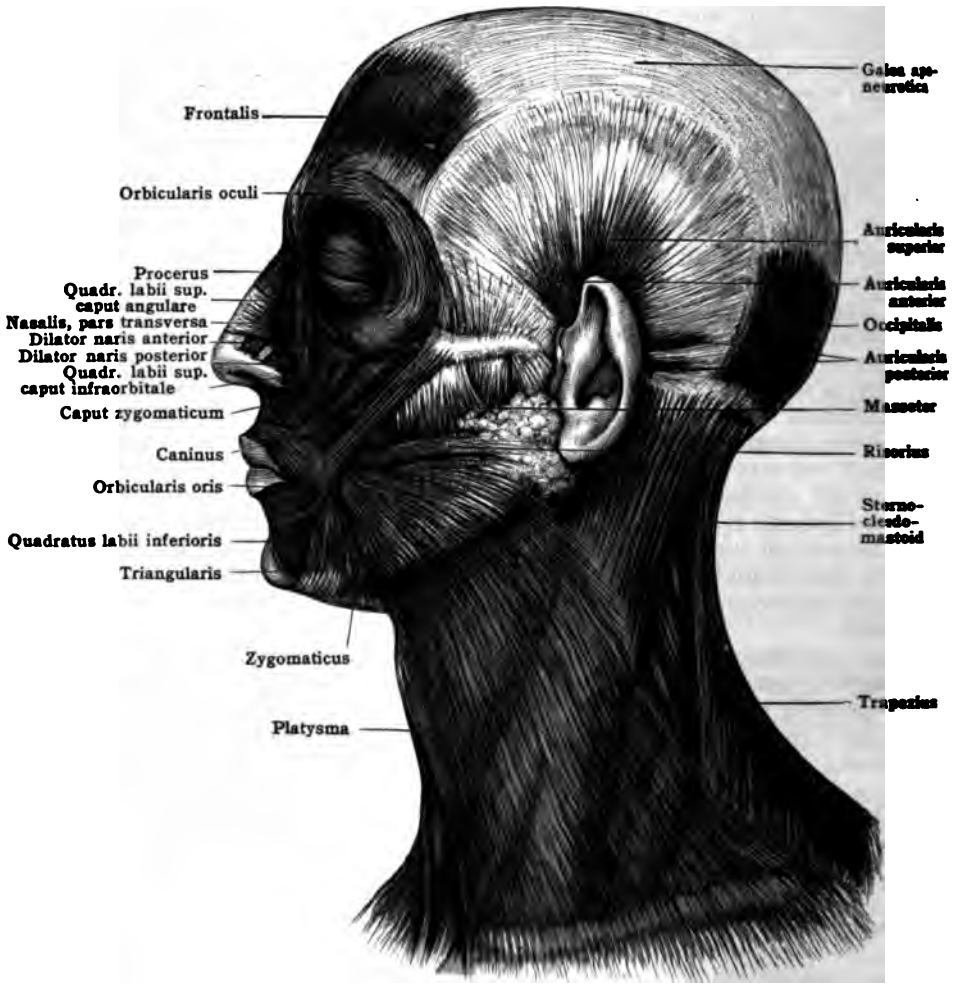
Order of treatment.—The muscles and fasciæ are here treated in the following order:—(1) those of the head and neck and shoulder-girdle (p. 363); (2) those of the upper extremity (p. 394); (3) those of the spine (p. 444); (4) those of the thorax and abdomen (p. 455); (5) those of the pelvic outlet (p. 472); (6) those of the lower extremity (p. 485). The reason for taking up the musculature in the order named is, that during embryonic development musculature belonging primitively to the head comes to overlap that of the neck; that of the neck spreads over the region of the back and thorax, and becomes attached to the shoulder-girdle; that of the arm extends over the region of the thorax, abdomen, and back; that of the back partially over the region of the thorax; while that of the abdomen enters into intimate relation with the pelvic girdle. So far as practicable the musculature of these various regions will be taken up according to fundamental morphological relationships.

Since a morphological grouping of the muscles does not accord perfectly with a physiological grouping, there is given at the end of this section a table showing what muscles are concerned in performing the simpler voluntary movements.

1. The facial group, p. 364.
2. The craniomandibular group, p. 373.
3. The suprahyoid musculature, p. 377.
4. The muscles of the tongue, p. 380.
5. The superficial shoulder-girdle musculature, p. 382.
6. The infrahyoid musculature, p. 384.
7. The scalene musculature, p. 388.
8. The prevertebral musculature, p. 389.
9. Anterior and lateral intertransverse muscles, p. 390.
10. Deep musculature of the shoulder girdle, p. 391.

The pectoral muscles and the latissimus dorsi, which extend from the skeleton of the limb to the front and side of the thorax and the lower part of the back, arise from the limb-bud during embryonic development, are innervated through the brachial plexus, and will, therefore, be taken up in considering the intrinsic musculature of the upper limb, p. 394.

FIG. 372.—THE SUPERFICIAL MUSCLES OF THE HEAD AND NECK.



THE FACIALIS MUSCULATURE

(Figs. 372, 375)

The muscles of this group are intimately connected with the scalp, with the skin of the face and neck, and with the mucous membrane lining the lips and the cheeks. Most of the muscles have an osseous origin and a cutaneous insertion, but there are exceptions. Both origin and insertion may be cutaneous, or the

ıent may be to an aponeurosis instead of directly to the skin. The nusculature about the mouth is attached to the mucous membrane.
muscles are composed of interdigitating muscle-fibers which are grouped lles that take a nearly parallel or slightly converging course and give rise muscle-sheets. The extent of development of the various muscles of the ınd their independence varies greatly in different individuals.

region from which the facial musculature originates in the embryo is, in the main at at of the hyoid arch immediately below the ear. From here the musculature spreads development of the facial nerve, dorsally to the occipital region behind the ear, caudal- er the neck, ventrally over the face, and upward toward the eye, forehead, and the side of l The course of the developn ent is indicated by the branches of the facial nerve. A ıt similar phylogenetic development is indicated by conditions found in the inferior ls and lower vertebrates. According to Ruge and Gegenbaur, the facial musculature looked upon as derived from two muscle-sheets, of which in man the deeper has dis- d in the region of the neck while it is differentiated into the deeper facial muscles in the f the head. The deeper layer of transverse fibers in the neck, the *sphincter colli*, is found al of the mammals. The complex development of the facial muscles in man is char- c of the human species, and is associated with the use of these muscles as a means of ɔn of the emotions, a physiological function superadded to the primitive function of and closing visceral orifices. (See Darwin: Expression of the Emotions in Man and .)

ıæ.—The skin of the head and neck is, in most regions, firmly fused with the **tela** ıea. This is composed of a dense fibrous tissue united by a looser areolar tissue to the ng structures. But a slight amount of fat is embedded in the subcutaneous tissue of ɔ, forehead, and nose Considerable fat may be embedded in the region of the cheeks, : of the neck, and the under surface of the chin (double chin). The constantly repeated f various muscles of the facialis group usually results by middle life in the production ınent wrinkles due to alterations in the structure of the tela subcutanea and the skin. subcutaneous muscles of the cranial vault and the neck are invested with fascial mem- That covering the cranial musculature externally is firmly fused to the subcutaneous f the scalp. That covering the subcutaneous muscle of the neck is less firmly fused ɜ subcutaneous tissue. In the facial region the more superficial muscles are so closely ɔd in the subcutaneous tissue that no distinct fasciæ intervening between the muscles skin can, as a rule, be distinguished. Of the deeper muscles of the facialis group, the ɔr alone possesses a distinct fascia. This muscle lies upon the mucous membrane of ral wall of the mouth, and is covered externally by a fascia continued into the fascia g the superior constrictor of the pharynx.
ɜ.—**Bursa subcutanea prementalis.** Between the periosteum at the tip of the chin overlying tissue. **Bursa subcutanea prominentiæ laryngeæ.** In front of the junction ght and left laminæ of the thyroid cartilage.

MUSCLES

ɜ muscles of the facialis group may be conveniently subdivided as follows:— **Cervical:** the platysma. (*b*) **Oral:** the orbicularis oris and the incisivus ıperioris and inferioris; the quadratus labii superioris and inferioris; the s, zygomaticus, risorius, and triangularis; and the buccinator. (*c*) **Mental sal:** the nasalis, depressor septi, and the dilatores naris. (*e*) **Periorbital:** ɔicularis oculi, corrugator, and procerus. (*f*) **Epicranial:** the frontalis and alis, with the galea aponeurotica. (*g*) **Auricular:** anterior, superior, and ior. With these the temporalis superficialis is also described.

(*a*) CERVICAL MUSCLE

ɜ **platysma** is a large, thin, quadrangular muscle which extends obliquely ıe chin, the corner of the mouth, and the lower part of the cheek across the ɔle and the neck to the upper part of the thorax and shoulder. The muscles ı side interdigitate across the chin. A short distance below the chin, in ɔk, the ventral margins diverge (fig. 372).

ɜn.—From the tela subcutanea by somewhat scattered bundles—(1) along a line extending e cartilage of the second rib to the acromion, and (2) along the dorsal margin of the

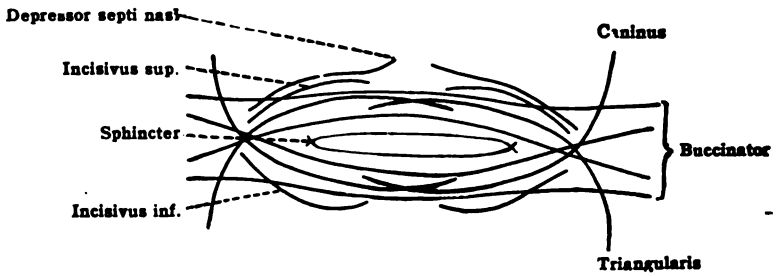
rtion.—Into—(1) the mental protuberance of the mandible and the inferior margin ıandible; and (2) into the skin of the lower part of the cheek and at the corner of the where it fuses more or less with the quadratus labii inferioris and the orbicularis oris.
e-supply.—The cervical branch (ramus colli) of the seventh cranial nerve forms beneath scle a plexus to which the cutaneus colli nerve contributes sensory branches.
tions.—The muscle is situated beneath the panniculus adiposus, to which in the neck it ery firmly attached. For the most part it is separated from the external layer of the

cervical fascia by loose areolar tissue. The main cutaneous rami of the cervical plexus and the external jugular vein lie beneath the muscle.

Action.—It wrinkles up the skin of the neck, depresses the corner of the mouth, and thus plays a part in expression of sadness, fright, and suffering. It aids the circulation by relieving pressure on the underlying veins.

Variations.—Either the facial or the thoracic development of the muscle may be more extensive than that described above. On the other hand, it may be less developed than usual, and rarely it is absent. Accessory slips have been seen going to the zygoma, the auricle, or the mastoid process, and to the clavicle and sternum. Rarely a deep transverse layer is found in man.

FIG. 373.—DIAGRAM TO ILLUSTRATE THE ARCHITECTURE OF THE ORBICULARIS ORIS. (After T. D. Thane.)



(*b*) ORAL MUSCLES
(Figs. 372–376)

The muscles of the mouth belonging to the facialis system include several *intralabial* muscles:—a sphincter, the **orbicularis oris**; a transverse, the **compressor labii**; and four deep submucous muscles which pass from the sides of the lips to the alveolar juga of the upper canine and lower lateral incisor teeth, the **incisivi labii superioris** and **inferioris.** From each corner of the mouth there radiate out several muscles; the **caninus** and **zygomaticus** upward to the maxilla and zygomatic bone; the **risorius** lateralward over the cheek; the **platysma** and the **triangularis** downward over the side of the jaw; and the **buccinator,** lateralward over the side of the oral cavity. From each of these, fiber-bundles are continued into the more peripheral and superficial portions of the orbicularis. In addition to these muscles there are two retractors or quadrate muscles, one of which, the **quadratus labii superioris,** extends to the bridge of the nose, the lower margin of the orbit, and the zygomatic bone from the upper lip medial to the angle; while the other, the **quadratus labii inferioris,** extends from a corresponding position in the lower lip to the side of the chin. The orbicularis oris, compressor labii, and incisive muscles close the lips; the other muscles open them and pull them in various directions. The buccinator, however, plays a part in the closing of the mouth by offering support for the orbicularis.

INTRALABIAL MUSCLES

The **orbicularis oris** (figs. 372–374) is a complex muscle which surrounds the oral orifice and forms the chief intrinsic musculature of the lips. Immediately about the orifice and on the deep surface of the muscle, is a fairly well-defined sphincter, although at the corners of the mouth the fiber-bundles of one lip cross those of the other and are inserted into the mucosa, and to a less extent into the skin. In the midline the fiber-bundles end partly in the perimysium, partly in the skin. About this sphincter area and between its outer margin and the skin is a complex musculature comprised partly of fiber-bundles prolonged from the muscles which radiate from the corners of the mouth. The more superficial portion of the muscle in the upper lip is composed of fiber-bundles from the triangularis (depressor anguli oris), the more superficial portion of that in the lower lip by fiber-bundles from the caninus (levator anguli oris). These fiber-bundles form commissures at the angles of the mouth and extend toward the median line, where many of them interdigitate with those of the opposite side, and are attached to the skin of the lips. The deeper portions are partly formed by fiber-bundles prolonged from the buccinator, the mandibular fiber-bundles of the latter muscle going mainly to the upper lip, the maxillary fiber-bundles mainly to the lower lip. These fiber-bundles are attached chiefly to the mucosa, near the corners of the mouth.

The **compressor labii,** or muscle of Klein, is composed of bundles of fibers which take a course transverse to those of the orbicularis, and pass obliquely from the skin surrounding the oral orifice toward the mucosa which bounds its inner margin. It is said to be best marked in infants.

The **incisivus labii superioris** is a small muscle-bundle which passes from the alveolar jugum of the upper canine tooth to the back of the orbicularis near the corner of the mouth.

The **incisivus labii inferioris** passes similarly from the alveolar jugum of the lower lateral or tooth to the back of the orbicularis in the lower lip.

-supply.—These muscles are supplied by the buccal branches of the facial nerve which
e orbicularis on the lateral border.
ions.—The main mass of intrinsic musculature of the lips is placed slightly nearer the
than the skin. On its deep surface lie the labial arteries.
n.—The orbicularis draws the upper lip downward, the lower lip upward. The
muscles draw the corners of the lips medialward, and the compressor flattens the lips.
r they serve to close the mouth. Acting separately they may draw different parts of
directions indicated by their structure. The circumferential portion of the orbicularis
ih the incisive muscles makes the lips protrude. The central portion of the orbicularis
ıe lips together, and when the buccinator also acts, draws them against the teeth. It
ɔortion of the muscle that has chiefly to do with nutritive functions. The more peri-
arts of the muscle are chiefly utilised in the expression of the emotions.

Retractors of the Lips or Quadrate Muscles.
(Fig. 372)

quadratus labii superioris is a thin, quadrangular muscle with three heads, all of which
rted into the skin and musculature of the upper lip. It includes the following:
The **caput zygomaticum** (zygomaticus minor) is long and slender and arises from the
rt of the external surface of the zygomatic bone beneath the lower border of the palpe-
tion of the orbicularis oculi. It passes obliquely forward over the caninus and orbicularis
cles, and extends to a cutaneous and muscular insertion in the upper lip medial to the
f the mouth. It lies medial to the zygomaticus.
The **caput infraorbitale** (levator labii superioris), a broad, flat muscle, arises from the
ital margin of the maxilla, where it is concealed by the orbicularis oculi. It extends
r forward over the caninus and beneath the caput angulare to the skin and musculature
teral half of the upper lip.
The **caput angulare** (levator labii superioris alæque nasi) arises from the root of the nose,
is fused with the frontalis. As it descends it divides into two fasciculi, one of which is
l to the skin and the alar cartilage of the nose; the other passes obliquely downward
caput infraorbitale to the skin and musculature of the lateral half of the upper lip.
-supply.—The zygomatic ramus of the facial nerve sends branches to enter the deep
of each of the divisions of the muscle.
ns.—It raises the lateral half of the upper lip and the wing of the nose. It is of value
ation, serves to express the emotion of discontent, and comes into play in violent weep-

ations.—The caput zygomaticum is often absent. It may be fused with the zygoma-
ajor). It may be doubled. Its origin may extend to neighboring structures. The
ads, though more stable, vary considerably, especially in the extent of their fusion with
ing muscles.
quadratus labii inferioris (depressor labii inferioris) is a thin, rhomboid muscle which
low the canine and bicuspid teeth from the base of the mandible, between the mental
ance and the mental foramen, and extends obliquely upward in a medial direction to the
ris oris, through which its fiber-bundles pass. Its more medial fibers cross at their
with those of the muscle of the other side. It is attached to the skin and mucosa of
r lip. It is essentially a part of the platysma, and is superficially united to the skin
here covered by the triangularis (depressor anguli oris). It crosses the mental vessels
res and a part of the mentalis (levator menti).
-supply.—The mandibular branch of the facial sends twigs into its deep surface near
al border.
n.—It draws down and everts the lower lip. It is an antagonist of the mentalis
menti). It plays a part in the expression of terror, irony, great anger, and similar
s.

Muscles of the Angle of the Mouth
(Figs. 372, 373, 374, 375, 376)

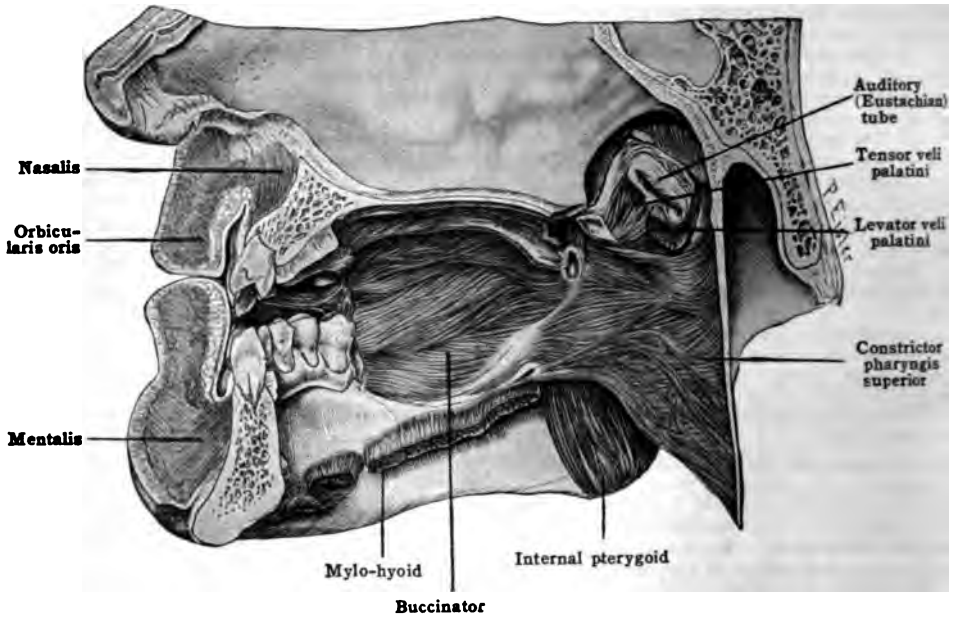
caninus (levator anguli oris) is a flat, quadrilateral muscle which arises from the canine
the maxilla and runs beneath the quadratus (levator) labii superioris to the corner of
th, where it becomes attached to the skin and sends some fasciculi into the orbicularis of
r lip. Between the caninus and the quadratus labii superioris there is a certain amount
areolar tissue through which the infraorbital vessels and nerves run. Its deep surface
over the canine fossa, the buccinator muscle, and the mucosa of the lip. The external
y (facial) artery passes over its inferior extremity.
zygomaticus (z. major) is a long, ribbon-shaped muscle which arises by short tendinous
s from the zygomatic bone near the temporal suture under cover of the orbicularis oculi.
s obliquely to the corner of the mouth, where it is attached to the skin and mucosa.
ly of the muscle is subcutaneous and is usually surrounded by fat. It crosses the
r and buccinator muscles and the anterior facial vein.
risorius is a thin, triangular, subcutaneous muscle which extends across the middle of
k and lies in a more superficial plane than the platysma, with which it is often fused. It
ɔm the tela subcutanea above the parotid fascia. Its fibers converge across the masseter
oward the angle of the mouth and are attached to the skin and mucosa in this vicinity.
bove the anterior facial vein and external maxillary artery.
platysma has been described above.
triangularis (depressor anguli oris) is a broad, flat, well-developed, subcutaneous muscle
rises from the base and external surface of the body of the mandible below the canine,
and first molar teeth. From here its fibers converge toward the corner of the mouth,
ıey are in part inserted into the skin and in part are continued into the orbicularis or

of the upper lip. It overlies the buccinator and the quadratus (depressor) labii inferioris muscles. Not infrequently (58 out of 92 bodies—LeDouble) some fasciculi are continued into the neck as the **transversus menti**, a fibromuscular band formed by the interdigitation of the slips prolonged from each side below the chin and superficial to the platysma. Santorini described the transversus menti as an independent though inconstant muscle. According to Eisler the true transversus menti muscle is to be distinguished from aberrant slips of the triangularis or of the platysma in this region. In one instance Eisler found a slender nerve emerging through the platysma and passing to this muscle.

Nerve-supply.—The zygomatic branch of the facial nerve supplies the canine (levator anguli oris) and zygomatic (major) muscles. Branches enter the middle of the deep surface of the latter muscle and the superficial surface of the former near its lateral border. The risorius is supplied by branches from the buccal rami of the facial nerve, which enter its deep surface. The triangularis (depressor anguli oris) is supplied by the buccal branch through branches which enter its deep surface near the posterior margin.

FIG. 374.—BUCCINATOR MUSCLE AND PTERYGOMANDIBULAR RAPHÉ, AS SEEN FROM THE BUCCAL SIDE. (AFTER EISLER.)

The alveolar processes of both jaws have been removed in the region of the molar teeth. The soft palate and its muscles have been removed.



Action.—The caninus (levator anguli oris) and zygomatic (z. major) muscles raise the corner of the mouth, the former at the same time drawing it medially, the latter, laterally. The caninus gives rise to expression of bitterness or menace. The zygomaticus is active in smiling or laughing. When contracted greatly it elevates the cheek and the lower eyelid and produces crow's-foot wrinkles at the corner of the eye. The risorius draws the angle of the mouth laterally. In spite of its name it is not used to express pleasure, but instead gives rise to an expression of pain. The triangularis (depressor anguli oris) depresses the corner of the mouth and draws it laterally, giving rise to the expression of grief.

Variations.—The risorius is very inconstant in its development, and in its relations to neighboring muscles, and is not infrequently quite small. The zygomaticus is rarely absent. Its origin may extend to the temporal or masseteric fasciæ. It may be doubled throughout its length or at one extremity. Frequently the triangularis is divided into three fasciculi.

The **buccinator** (figs. 373, 374) arises from—(1) the molar portion of the alveolar process of the maxilla; (2) the buccinator crest of the mandible, and (3) the pterygomandibular raphe of the buccopharyngeal fascia. This narrow fibrous band, which separates the buccinator from the superior constrictor of the pharynx, extends from the pterygoid hamulus to the buccinator crest of the mandible. The fiber-bundles of the muscle are divisible into four sets. The most cranial extend directly into the orbicularis of the upper lip. The next pass through the commissure at the corner of the lips into the orbicularis of the lower lip; the third through the commissure into the orbicularis of the upper lip, and the fourth directly into the orbicularis of the lower lip. The muscle is attached chiefly to the mucosa of the lips near the angle of the mouth. Some fiber-bundles extend to the more medial portion of the mucosa and some through the the orbicularis to the skin.

Nerve-supply.—By the buccal branch of the facial nerve through filaments which enter the posterior half of its outer surface.

Relations.—The muscle is covered externally by the thin buccopharyngeal fascia; internally by the mucosa of the mouth. Above its outer surface lie the zygomatic (z. major), risorius, and

masseter muscles. Between the last and the buccinator lies a large pad of fat (the buccal fat pad). The parotid duct passes forward over the muscle, and slightly in front of its center pierces it and passes into the mouth. It is crossed by the external maxillary (facial) artery and anterior facial vein and by the buccal artery and nerve.

Actions.—It draws the corner of the mouth laterally, pulls the lips against the teeth, and flattens the cheek. It is of use in mastication, swallowing, whistling, and blowing wind-instruments.

Variations.—Occasionally it consists of two laminæ, a condition found in many mammals. It may be continuous in part with the superior constrictor of the pharynx, as in the cat.

(*c*) MENTAL MUSCLE

The **mentalis** (levator menti) (fig. 374) is a short, thick muscle which arises from the alveolar jugum of the lower lateral incisor tooth and the neighboring region of the mandible under cover of the quadratus (depressor) labii inferioris and beneath the oral mucosa, where this is reflected from the lips to the gums. It extends to the chin, where it is fused with the muscle of the opposite side and is inserted into the skin of the chin.

Nerve-supply.—The mandibular branch of the facial nerve sends terminal twigs into this muscle.

Actions.—It draws up the skin of the chin and thus indirectly causes the lower lip to protrude. It is of use in articulation, in forcing bits of food from between the gums, and in the expression of various emotions (muscle of pride).

Variations.—It varies greatly in size and generally is fused with the platysma.

(*d*) NASAL MUSCLES
(Figs. 372 and 375)

Toward the nasal apertures several muscles converge. Those extending from above elevate and dilate, those from below depress and contract, the nostrils. To the former belongs the **pars transversa** of the **nasalis** (compressor naris), a triangular muscle extending from the bridge of the nose to the nasolabial sulcus; the **caput angulare** of the **quadratus labii superioris** (levator labii superioris alæque nasi), which arises from the root of the nose and sends a fasciculus to the wing of the nose; and the **dilatores naris,** described below; to the latter, the **pars alaris** of the **nasalis** (depressor alæ nasi), which extends from the alveolar juga of the upper lateral incisor and canine teeth to the dorsal margin of the nostril; and the small **depressor septi nasi.**

The **nasalis** consists of two parts, the pars transversa and the pars alaris. The **pars transversa** (compressor naris) is triangular. It lies on the side of the nose above the wing. Its fiber-bundles arise from an aponeurosis which overlies the bridge of the nose, is adherent to the skin, and is not closely attached to the underlying cartilage. From this aponeurosis the fiber-bundles converge toward the back of the wing, where they are attached to the skin along the line which separates the wing from the cheek (nasolabial sulcus). Its insertion is covered by the nasal process of the caput angulare (levator labii superioris alæque nasi) of the quadratus labii superioris (p. 367), with which its fibers interdigitate. An attachment (origin) is also described by many as taking place in the lower part of the canine fossa of the maxilla.

The **pars alaris** (depressor alæ nasi) (figs. 374, 375), is a small quadrangular muscle situated below the aperture of the nose, between this and the alveolar portion of the maxilla. It is covered by the mucosa of the gum, by the orbicularis oris and the quadratus (levator) labii superioris, and laterally is fused with the pars transversa (compressor naris). It arises from the alveolar juga of the lateral incisor and the canine teeth. Its fiber-bundles extend vertically to the skin of the dorsal margin of the nostril, from the dorsal part of the cartilage of the wing to the septum.

The **dilator naris posterior** is a thin, triangular muscle which lies on the side of the wing of the nose. It arises from the skin of the nasolabial groove and is attached to the inferior border of the wing of the nose.

The **dilator naris anterior** is a very small, thin muscle which runs from the lower margin of the cartilage at the front of the wing of the nose to the skin. It is not usually clearly marked.

Nerve-supply.—The muscles of this group are supplied by the infraorbital and buccal branches of the facial nerve.

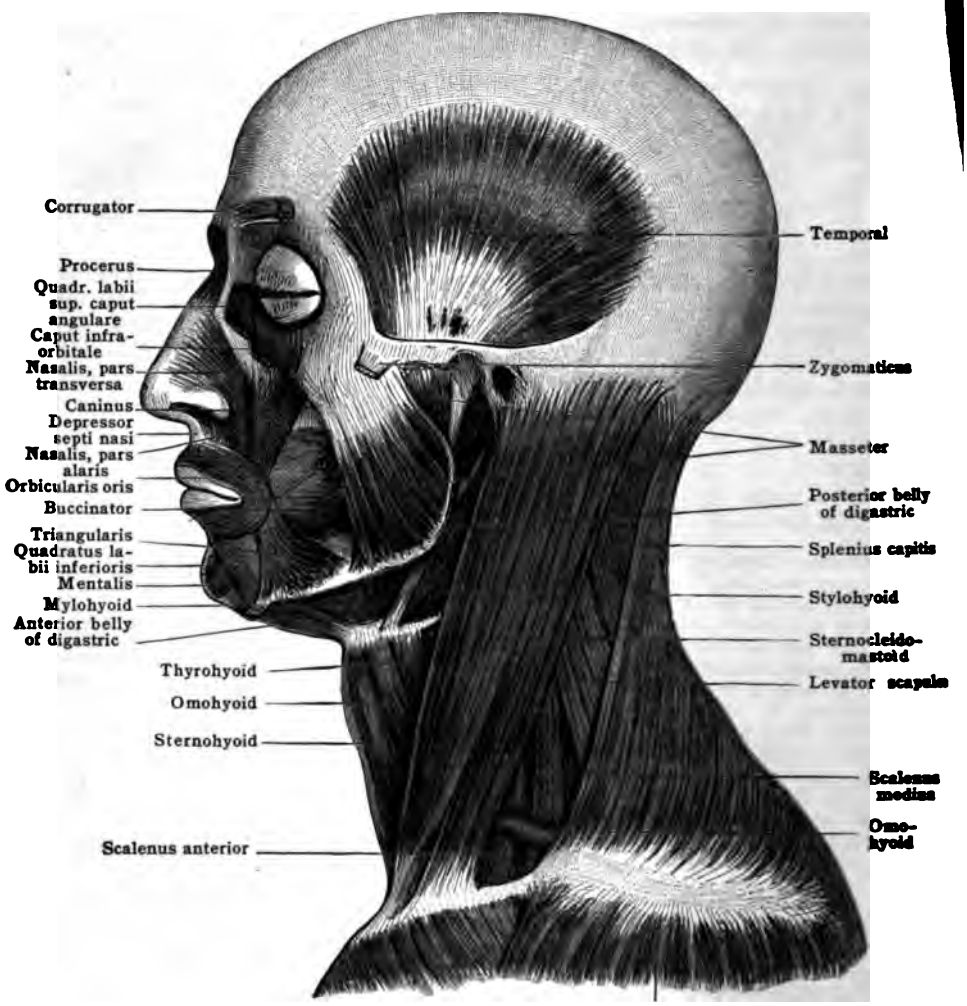
Actions.—The transverse portion of the nasalis (compressor naris) acts with the angular head (levator labii superioris alæque nasi) of the quadratus labii superioris in drawing the lateral margin of the wings of the nose laterally and upward, and gives rise to the expression of sensuality. (Poirier.) This accords with the electrical experiments of Duchenne. However, acting in conjunction with the alar portion, the transverse portion of the nasalis may constrict the nostrils. The alar portion (depressor alæ nasi) of the nasalis and the depressor septi nasi draw down the nostril. The former tends to contract it from side to side, the latter from front to back, and at the same time to depress the tip of the nose. They play a part in the expression of anger and of pain. The functions of the other muscles are indicated by their names.

Variations.—The muscles of the nose vary considerably in extent of development, and one or more may be absent. Authors differ considerably in their description of several of the muscles. The **anomalus** is a longitudinal muscle strip occasionally found running from the frontal process to the body of the maxilla near the lateral margin of the nasal aperture.

(e) PERIORBITAL MUSCLES
(Figs. 372 and 375)

The muscles which encircle the orbit constrict the entrance of the orbit so as to shut out light and protect the eye against foreign bodies. To these belong the orbicularis oculi, the corrugator, and the procerus. The **orbicularis oculi** is a large, flat, elliptical mucle which lies in the eyelids and over the bone surrounding the orbit. **Three parts** are recognized: a **palpebral,** an **orbital** and a **lacrimal.** The quadrangular **corrugator** extends from the nasal portion of the frontal bone to the skin of the middle half of the eyebrow; the narrow **procerus** (pyramidalis nasi) from the bridge of the nose to the skin at the root. The muscles which

FIG. 375.—THE DEEPER MUSCLES OF THE FACE AND NECK.



have an antagonistic action are the levator palpebræ superioris and the epicranius. The levator palpebræ is described in the chapter on the EYE (see Section IX), the epicranius in the following subsection.

The **orbicularis oculi.**—The **palpebral portion** arises from the anterior surface and margins of the lateral portion of the medial palpebral ligament (tendo oculi), and from the covering of the lacrimal sac. The fiber-bundles spread out as they pass into the eyelids and again are concentrated toward their insertion into the outer surface of the lateral palpebral ligament. Many of the fiber-bundles interdigitate here without being inserted into the ligament. The muscle in each eyelid lies between the tarsal plate and the skin, separated from both by loose tissue. The superficial muscle-fibers nearest the margin of the lids constitute the ciliary muscle, or muscle of Riolan. They are very small fibers and probably act on the eyelashes and Meibomian glands.

orbital portion arises by a superior origin from the medial palpebral ligament (tendo
ne nasal portion of the frontal bone, and the anterior lacrimal crest of the maxilla and
ferior origin from the medial palpebral ligament and the medial portion of the inferior
ne orbit. The fiber-bundles form a flat ring which surrounds the orbit for a consider-
ance, especially inferiorly. The muscle is adherent to the overlying skin. It lies over
s surrounding the margin of the orbit and over the attachments of several of the facial
attached to these bones. With these muscles some of the fiber-bundles are usually
ous.

lacrimal portion (tensor tarsi or Horner's muscle) arises from the posterior lacrimal
the lacrimal bone and passes down on the dorsal surface of the lacrimal sac and the
palpebral ligament (tendo oculi). It bifurcates and furnishes a fasciculus attached to
sal plate. Some of the fiber-bundles surround the lacrimal canaliculi and some surround
s of the tarsal glands and the roots of the eyelashes.

corrugator arises from the frontal bone near the frontonasal suture. It extends ob-
upward and lateralward to be inserted into the skin of the medial half of the eyebrow.
r-bundles of insertion interdigitate with those of the frontalis. The muscle lies rela-
ep. It is covered by the procerus (pyramidalis nasi), the frontalis, and the orbicularis.
lie the supraorbital vessels and nerves.

procercus (pyramidalis nasi) overlies the nasal bone. It arises from the lateral cartilage
se through a fibrous membrane and also directly from the nasal bone, and is attached
in over the root of the nose, where its fibers interdigitate with those of the frontalis.

-supply.—The muscles of this group are supplied by temporal and infraorbital branches
cial nerve which enter the deep surfaces near the lateral margins.

n.—The palpebral portion of the orbicularis closes the eyelids, of which the upper
nore freely than the lower. It also serves to dilate the lacrimal sac and allow the
flow away readily. The tensor tarsi probably contracts the sac and forces the tears
nose. The upper half of the orbital portion of the orbicularis contracts and depresses
ie overhanging the orbit, and stretches the skin of the forehead. The corrugator draws
of the brow downward and medially, thus aiding the preceding muscle. It causes the
cular furrows characteristic of frowning. The procerus (pyramidalis nasi) draws
skin of the forehead and wrinkles the skin across the root of the nose. The lower half
bital portion of the orbicularis raises the skin of the cheek, causing the wrinkles seen to
rom the corner of the eye. The whole set of muscles comes into play in the forcible
of the eyes. In case of violent expiratory efforts, as in shouting, sneezing, coughing,
eye is thus usually forcibly closed. The pressure thus exerted on the eyeball prevents
lent flow of blood to the vessels of the eye. Pressure is thought at the same time to
ed on the lacrimal gland so as to cause the excessive flow of tears often experienced at
es.

ations.—The muscles of this group vary in extent and differentiation, and may be more
used with one another or with neighboring muscles. The orbital portion of the or-
, the corrugator, and the procerus have been found absent.

(*f*) THE EPICRANIAL MUSCULATURE
(Fig. 372)

epicranius (occipitofrontalis) is formed of the two **frontal** muscles, which
ach side of the forehead, the two **occipital** muscles, which occupy corre-
ig positions on the occipital bone, and of the epicranial aponeurosis, the
poneurotica, which extends between these. The occipital muscles arise
ne supreme nuchal line and are inserted into the galea aponeurotica. The
muscles arise from the latter and are inserted into the skin near the eye-
The chief function of these muscles is to elevate the brows. The
and the intervening aponeurosis lie between two layers of fascia, the ex-
of which is fused to the skin, while the internal moves freely over the peri-
, to which it is loosely attached. Hemorrhages and abscesses spread freely
n the deep layer of fascia and the periosteum.

frontalis is a large, thin muscle with convex upper and concave lower border. It arises
epicranial aponeurosis midway between the coronal suture and the orbital arch, and is
into the skin of the eyebrow and of the root of the nose. The medial fiber-bundles take
l direction; the lateral converge obliquely toward the brow. The medial margins of
les of each side are approximated near the attachment. The more medial fiber-bundles
inuous with those of the procerus (pyramidalis nasi) and the angular portion (levator
erioris alæque nasi) of the quadratus labii superioris; the more lateral interlace with
the corrugator and orbicularis muscles. The branches of the vessels and nerves of the
egion pierce the muscle and are distributed between it and the skin.

occipitalis, flat and quadrangular, lies on the occipital bone above the supreme nuchal
rises by tendinous fibers from the lateral two- thirds of this line and from the posterior
he mastoid process of the temporal bone, and is inserted into the epicranial aponeurosis.
lial fiber-bundles run sagitally, while the lateral run obliquely forward. The occipital
id nerve lie between the muscle and the skin. The lateral border of the muscle comes
t with the posterior auricular muscle. The muscles of each side are usually separated
p of aponeurosis.

galea aponeurotica (epicranial aponeurosis) is a fibrous membrane which extends be-
e occipital muscles and from them anteriorly to the frontal muscles. In the area be-

tween these two sets of muscles it is composed largely of sagitally running fibers into which coronal fibers radiate from the region of the muscles of the ear. Between the two occipital muscles the aponeurosis is attached to the supreme nuchal line and external occipital protuberance. Laterally the fascia covering it is continued as a special investment of the auricular muscles, beyond which it is attached to the mastoid process, the zygoma, and to the external cervical and the masseteric fasciæ.

Nerve-supply.—The frontalis is supplied by the temporal branches of the facial nerve, the occipitalis by the posterior auricular branch. The branches enter the deep surface of each of these muscles near its lateral border.

Action.—The occipitalis serves to draw back and to fix and make tense the epicranial aponeurosis. The frontalis, with its aponeurotic extremity fixed, elevates the brows and throws the skin of the forehead inso transverse wrinkles as in the expression of attention, surprise, or horror. When both muscles contract forcibly there is, in addition, a tendency to make the hair stand on end because the hair-bulbs of the occipital region slant forward, those of the frontal region backward. The frontalis when fixed below pulls the scalp forward.

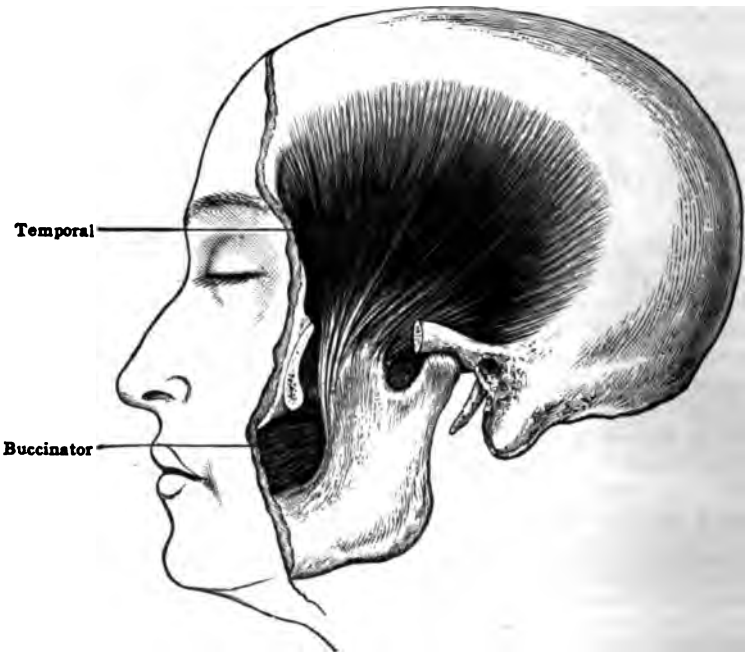
Variations.—The occipitalis is occasionally absent, a condition normal in ruminants. The muscles of the two sides may be fused in the median line (normal in dogs). It may be fused with the posterior auricular. The frontalis is rarely missing. The frontalis may send slips to the medial or lateral angles or the orbital arch of the frontal bone, to the nasal process of the maxilla or to the nasal bone. The fiber-bundles of the frontalis may interdigitate across the median line.

The **transversus nuchæ**, or occipitalis minor, is a small muscle, frequently present (27 per cent., Le Double), which runs from the occipital protuberance toward the posterior auricular muscle, with which it may be fused. It may lie over or under the trapezius.

(*g*) AURICULAR MUSCLES
(Fig. 372)

The intrinsic muscles of the auricle are described in Section IX. There are three 'extrinsic' auricular muscles which converge from regions anterior, superior, and posterior to the auricle and are inserted into it.

FIG. 376.—THE TEMPORAL MUSCLE.



The **auricularis anterior** (attrahens aurem) is a small, flat, triangular muscle which arises between the two layers of the fascia of the galea aponeurotica, extends over the zygomatic arch, and is inserted into the front part of the helix. The fiber-bundles converge from the origin toward a tendon of insertion. The area of origin of this muscle is often marked by a fibrous band tangential to its component fibers. From this band muscle fiber-bundles radiate but toward the frontal region of the skull. To the muscle formed of these radiating fibers the names **epicraniotemporalis** (Henle), **temporalis superficialis** (Sappey) and **auriculofrontalis** (Gegenbaur) have been given.

The **auricularis superior** (attollens aurem) is a large, thin, triangular muscle which, from its tendinous insertion on the eminence of the triangular fossa of the ear, radiates upward into the fascia of the galea aponeurotica, between the layers of which it takes origin near the temporal ridge. It lies over the temporal fascia and the periosteum of the parietal bone.

he auricularis posterior (retrahens aurem) is a thin, band-like muscle which extends over nsertion of the sternocleidomastoid from the base of the mastoid process and the apo- is of the sternocleidomastoid muscle to the convexity of the concha, where it has a ten- n insertion. It is usually composed of two fasciculi, and is contained between two layers scia derived from the galea aponeurotica.

erve-supply.—The auricularis anterior and superior are supplied by the temporal branch e facial, the auricularis superior and posterior by the posterior auricular branch. The of supply run to the deep surface of the muscles.

elations.—The superficial ascending branch of the auriculotemporal nerve usually runs rficial to the anterior and superior auricular muscles. The superficial temporal vessels run st beneath these muscles and the lateral expansion of the galea aponeurotica, then between wo fascial layers which enclose the muscles. Their branches of distribution finally come between the muscles and aponeurosis and the skin. The posterior auricular artery and usually run under cover of the auricularis posterior.

ction.—The anterior muscle is a protractor, the superior an elevator, and the posterior a ctor of the ear, but usually in man they are inactive.

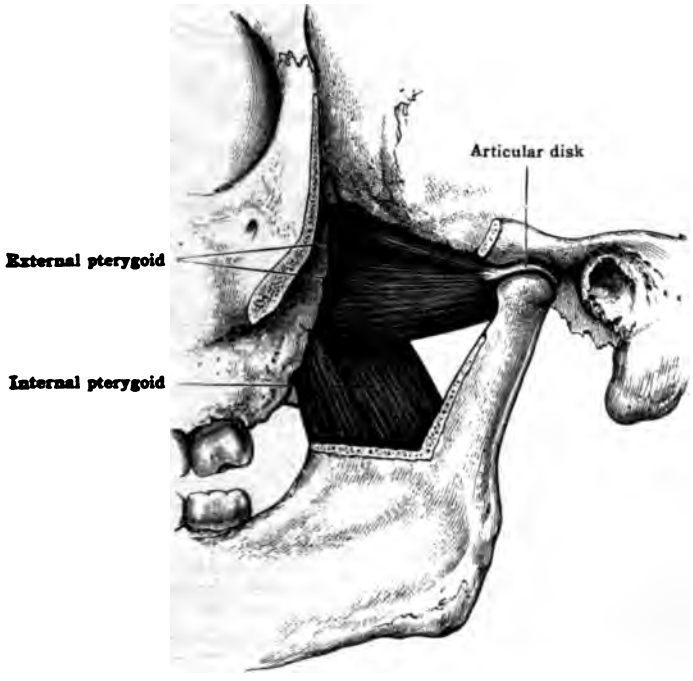
ariations.—These muscles vary much in development. The most constant of them is perior. The posterior frequently is increased in size and may be fused with the occipitalis, originally was probably an ear muscle From the anterior muscle a special deep fascicu- occasionally isolated. Each of the muscles is occasionally, though rarely, absent, the ior most frequently. An inferior auricular muscle is very rarely found in man, though nt in many of the lower mammals. A slip of the posterior auricular may run beneath the the parotid fascia.

2. CRANIOMANDIBULAR MUSCULATURE

(Figs. 375–378C)

The craniomandibular muscles, or muscles of mastication, pass from the base e skull to the lower jaw. They are represented in the selachians by a single le mass, the adductor mandibulæ (Gegenbaur), but in the higher vertebrates

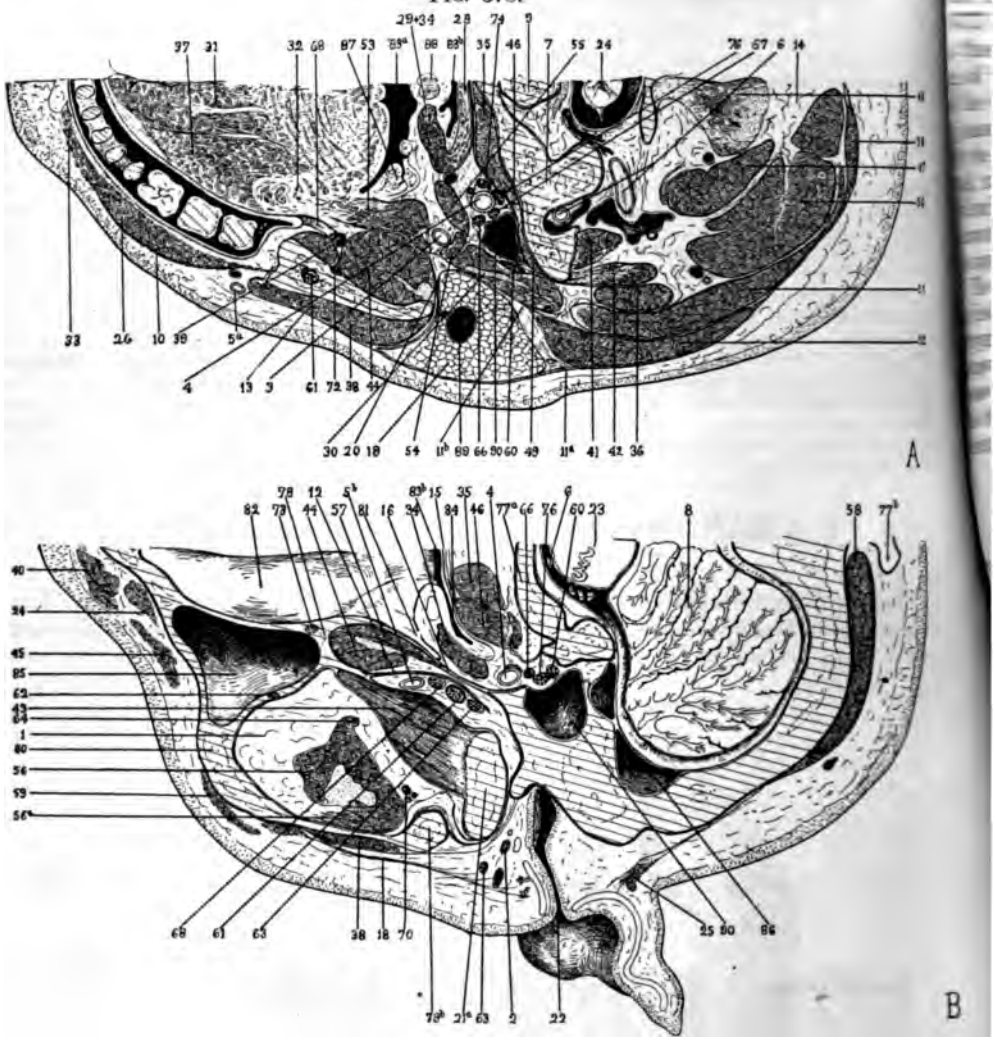
FIG. 377.—THE PTERYGOID MUSCLES.

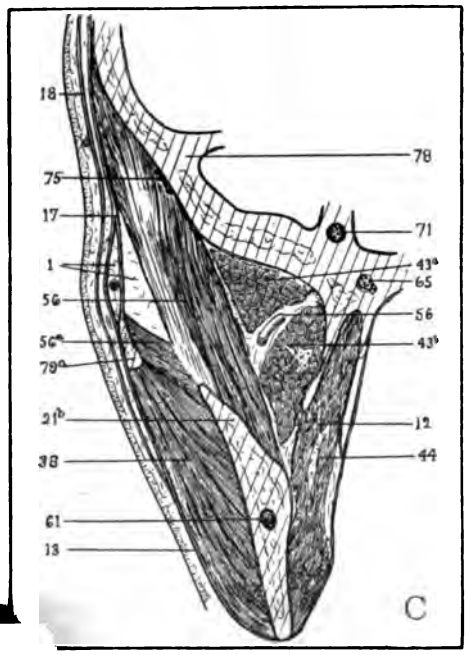


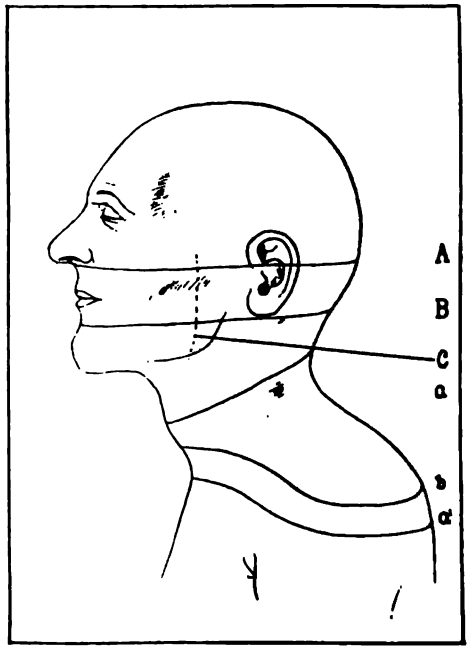
muscle mass becomes variously subdivided during embryonic development. muscles are innervated by the masticator nerve (motor root of the tri- inal cranial nerve, the nerve of the mandibular arch). In man four muscles ecognized, the temporal, masseter, and internal and external pterygoids.

The **temporal** and **masseter** muscles are situated on the lateral surface of the , partly under cover of muscles of the facialis group. The **temporal** muscle 376), which resembles the quadrant of a circle, arises from the temporal and is inserted into the coronoid process of the mandible; the thick, quad- eral **masseter** (fig. 375) muscle arises from the zygomatic arch and is inserted

FIG. 378.







ıto the lateral surface of the ramus and angle of the mandible. The **pterygoids** ig. 377) are more deeply seated. The cone-shaped **external pterygoid** arises om the lateral side of the pterygoid process and lower surface of the great ing of the sphenoid and is inserted into the condyloid process of the mandible nd the capsule of the joint. The thick, quadrilateral **internal pterygoid** parallels he masseter. It arises from the pterygoid fossa of the sphenoid and is inserted nto the inner side of the angle of the mandible. It will be noted that the temporal, masseter, and internal pterygoid muscles have an approximately vertical pull and adduct the lower jaw, while the external pterygoid has an approximately horizontal pull and draws the jaw forward and, when acting on one side, toward the opposite side.

The first three muscles act in the main on the joint between the condyle and the disk, about an axis passing transversely through the condyle. The external pterygoid, on the other hand, acts chiefly on the joint between the disk and the temporal bone. When both of the latter muscles act, the axis of movement passes transversely from the base of the articular tubercle on one side to that of the other. When only one muscle contracts, the approximate axis is vertical, through the condyle of the opposite side of the mandible (fig. 454).

FASCIÆ

The temporal fascia arises from the temporal line of the frontal bone and from the superior emporal line of the parietal and the periosteum immediately below this. It extends to the ygomatic arch. In its inferior quarter the fascia divides into two lamellæ, one of which passes o the outer, the other to the inner, surface of the arch, but at the superior margin of the arch hese two lamellæ are united by dense fibrous tissue. Between the two lamellæ above the rch lies a fatty areolar tissue in which the middle temporal artery often runs. The outer surıce of the fascia is covered by the superficial temporal and anterior and superior auricular uscles, and by a thin layer of fascia from the galea aponeurotica, with which, toward the zygoıatic arch, it becomes merged The superficial temporal artery and auriculotemporal nerve ross it.

IG. 378.*—A AND B ARE TRANSVERSE SECTIONS AND C (AFTER TESTUT), A FRONTAL SECTION THROUGH THE LEFT SIDE OF THE HEAD, IN THE REGIONS INDICATED IN THE DIAGRAM.

and *b* in the diagram indicate the regions through which pass sections A and B, fig. 382; and a^1, section A, fig. 388.

. Adipose tissue. 2. Arteria temporalis superficialis. 3. A. carotis externa. 4. A. carotis interna. 5*a*. A. maxillaris externa (facial). 5*b*. A. maxillaris interna. 6. A. vertebralis. 7. Atlas. 8. Cerebellum. 9. Epistropheus (axis). 10. Fascia buccopharyngea. 11. F. cervicalis, *a* (superficial layer), *b*, deep parotid process. 12. F. interpterygoidea. 13. F. masseterica. 14. F. nuchæ. 15. F. pharyngobasilaris. 16. F. pharyngis lateralis. 17. F. temporalis. 18. Galea aponeurotica. 19. Glandula parotica. 20. Ligamentum stylomandibularis. 21*a*. Mandible, capitulum; *b*, coronoid process. 22. Meatus acusticus ext. 23. Medulla oblongata. 24. Medulla spinalis (spinal cord). 25. Musculus auricularis posterior (retractor auris). 26. M. buccinator. 27. M. caninus (levator anguli oris). 28. M. constrictor pharyngis medius. 29. M. constrictor pharyngis superior. 30. M. digastricus. 31. M. genioglossus. 32. M. hyoglossus. 33. M. incisivus labii inferioris. 34. M. levator veli palatini. 35. M. longus capitis (rectus capitis anticus major). 36. M. longissimus capitis (trachelomastoid). 37. M. longitudinalis inferior. 38. M. masseter. 39. M. mylohyoideus. 40. M. nasalis (alar portion). 41. M. obliquus capitis inferior. 42. M. obliquus capitis superior. 43. M. pterygoideus externus —*a*, superior fasciculus; *b*, inferior fasciculus. 44. M. pterygoideus internus. 45. M. quadratus (levator) labii superioris. 46. M. rectus capitis anterior (minor). 47. M. rectus capitis posterior major. 48. M. rectus capitis posterior minor. 49. M. rectus capitis lateralis. 50. M. semispinalis capitis (complexus). 51. M. splenius capitis. 52. M. sternocleidomastoideus. 53. M. styloglossus. 54. M. stylohyoideus. 55. M. stylopharyngeus. 56. M. temporalis (*a*, fasciculus from zygoma). 57. M. tensor veli palatini. 58. M. trapezius. 59. M. zygomaticus (major). 60. Nervus accessorius (spinal accessory). 61. N. alveolaris inferior (dental). 62. N. alveolaris posterior superior (dental). 63. N. auriculotemporalis. 64. N. buccinatorius. 65. N. canalis pterygoidei (Vidian nerve). 66. N. glossopharyngeus. 67. N. hypoglossus. 68. N. lingualis. 69. N. mandibularis. 70. N. massetericus. 71. N. maxillaris. 72. N. mylohyoideus. 73. N. palatinus. 74. Sympathetic trunk. 75. N. temporalis profundus. 76. N. vagus. 77. Os occipitale—*a*, basilar portion; *b*, external protuberance. 78. Os sphenoidale. 79. Os temporale—*a*, processus zygomaticus; *b*, tubercle. 80. Os zygomaticum (malar). 81. Pharyngeal orifice of tuba auditiva (Eustachian tube). 82. Palatum durum (hard palate). 83. Pharynx—*a*, oral portion; *b*, nasal portion. 84 Pharyngeal recess. 85. Sinus maxillaris (antrum of Highmore). 86. Sinus transversus (lateral). 87. Tonsilla palatina. 88. Uvula. 89. Vena facialis posterior (temporomaxillary). 90. V. jugularis interna.

*This and the following series of cross-sections are taken from a thin, not very muscular, lult male. The fasciæ are represented in most instances disproportionately thick.

The **masseteric fascia** represents essentially a continuation of the temporal fascia from the inferior margin of the zygomatic arch over the masseter muscle which it covers. It is less thick than the temporal fascia, but is firm and strong. It is attached posteriorly to the posterior margin of the mandible, inferiorly to the inferior margin, and anteriorly to the body and to the anterior margin of the ramus and the coronoid process of the mandible. In part it extends over the fat pad of the cheek to the buccinator fascia. The parotid gland, covered by the parotid extension of the external cervical fascia, extends over the posterior portion of this fascia. The **parotid fascia** becomes fused to its external surface at the anterior margin of the gland. Over it lie the parotid duct, the transverse facial artery, branches of the facial nerve, the zygomatici (major), risorius, and platysma muscles.

The pterygoid muscles are each surrounded by a delicate membrane. In addition an **interpterygoid fascia** separates the two muscles. This arises from the sphenoidal spine and follows the internal surface of the external pterygoid to the mandible. Medially it is attached to the lateral lamella of the pterygoid process; posteriorly and laterally it presents a free margin which forms with the neck of the mandibular condyle, an orifice for the passage of the internal maxillary artery, the auriculotemporal nerve, and several veins. Its posterior margin is strengthened into the sphenomandibular ligament, which runs from the spine of the sphenoid to the lingula of the mandible.

The pharyngeal region is separated from the pterygoid by a dense membrane, the **lateral pharyngeal fascia.** This extends from the depth of the pterygoid fossa to the prevertebral fascia, and separates the tensor veli palatini from the internal pterygoid muscle. It is attached above along a line extending from the external margin of the carotid canal to the internal margin of the oval foramen.

The **sigmoidal septum** is a thin membrane which occupies the incisura mandibulæ and separates the masseter from the external pterygoid muscle.

MUSCLES

The **temporalis** (figs. 376 and 378C).—**Origin.**—(1) From the whole of the temporal fossa with the exception of that part formed by the body and temporal process of the zygomatic (malar) bone; and (2) from the fascia covering the fossa. **Insertion** is into the tip, posterior and anterior borders, and the whole internal surface of the coronoid process of the mandible and the anterior portion of the medial surface of the ramus.

In *structure*, the muscle is thin near its superior margin, but becomes thick as its insertion is approached. The fiber-bundles arising from the medial surface of the fossa and from the fascia converge upon the medial and lateral surfaces and the margins of a thick, broad tendon which begins very high in the muscle, becomes visible laterally some distance above the zygomatic arch, and is inserted into the tip, edges, and internal surface of the coronoid process. On the anterior and posterior margins of the tendon the insertion of fiber-bundles continues to the coronoid process, while medially the insertion of the fiber-bundles is continued on the medial surface of the coronoid process and often on the ramus as far as the body of the bone.

Nerve-supply.—Usually three branches from the anterior branch of the mandibular division of the trigeminal nerve curve upward over the temporal surface of the great wing of the sphenoid and enter the deep surface of the muscle. The posterior and middle nerves pass above the external ptergyoid; the anterior, which springs from the buccinator nerve, passes between the two heads of the external pterygoid before curving upward.

Relations.—The muscle is covered by the temporal fascia and the zygomatic arch. Below the temporal fossa the pterygoid muscles and the buccinator lie medial to it. The temporal fossa in front of the muscle is filled with a fatty areolar tissue and this also extends between the muscle and the temporal fascia. Fatty tissue likewise lies between the muscle and the buccinator. Medial to the muscle run the deep temporal vessels and nerves, the buccinator nerve and the sphenomandibular ligament. The masseteric nerve passes lateralward behind and below the tendon.

The **masseter** (figs. 375 and 378C) is composed of two layers. The **superficial layer** arises by an aponeurosis from the anterior two-thirds of the lower border of the zygomatic (malar) bone. The fiber-bundles arise from the deep surface of this aponeurosis and its tendinous prolongations pass obliquely downward and backward, and are inserted into the lower half of the external surface of the ramus, into the angle, and into the neighboring portion of the body of the mandible—the more anterior directly, the posterior by means of an aponeurosis. The **deep layer** arises from the lower border and internal surface of the zygomatic arch. The fiber-bundles pass nearly vertically downward, and are inserted upon the upper half of the external surface of the ramus. The origin and insertion are by tendinous bands, to which the fiber-bundles are attached in a multipenniform manner. The two layers are fused near the origin and insertion and in front. From the temporal surface of the zygomatic bone and the neighboring part of the deep layer of the temporal fascia there arises a fasciculus which is separated by a pad of fat from the main body of the temporal muscle, and is inserted into the lateral surface of the lower extremity of the tendon of the temporal muscle and into the anterolateral surface of the tip of the coronoid process. This fasciculus, sometimes described as a part of the temporal muscle, is innervated by the masseteric nerve.

Nerve-supply.—The branch arises in common with the posterior nerve to the temporal muscle from the motor root of the trigeminal (the masticator nerve). It passes above the external pterygoid, through the mandibular (sigmoid) notch, and enters the deep surface of the muscle near the dorsal margin.

Relations.—It is covered by the masseteric fascia (see above). It lies upon the ramus of the jaw and ventrally is separated by a pad of fat from the buccinator muscle. At the mandibular (sigmoid) notch the sigmoid septum separates it from the external pterygoid muscle. The parotid gland partly overlaps its posterior border.

pterygoideus externus (figs. 377 and 378C) consists of two fasciculi. Each is thick and ular. The superior is flattened in a horizontal, plane. At their hey are separated by a narrow cleft. Near the insertion they become more or less fused. perior fasciculus arises by short tendinous processes from the infratemporal (pterygoid) nd from the neighboring portion of the under surface of the great wing of the sphenoid. er-bundles converge toward the insertion, which takes place by short tendinous processes (1) the capsular ligament in front of the articular disk and (2) the upper third of the front neck of the condyle. The inferior fasciculus is the larger. It arises by short tendinous es from the lateral surface of the lateral lamina of the pterygoid process, from the pyrami- ocess of the palate bone, and from the adjacent portions of the maxillary tuberosity. er-bundles converge toward their insertion into a depression on the front of the neck of ndyle.

ve-supply.—A branch from the masticator nerve (motor root of the trigeminus) ap- es the muscle near the upper border of the medial surface of the superior fasciculus and ranches to both portions.

ations.—It is partly covered by the maxillary fasciculus of the internal pterygoid and by mporal and masseter muscles. Medial to it lies the chief fasciculus of the internal ptery- uscle. The masseteric and the posterior and middle temporal nerves usually pass above uscle, the anterior temporal and the buccinator nerves and frequently the internal maxil- tery between the two fasciculi. The internal maxillary vessels usually pass below the order of the muscle and across its external surface; and the auriculotemporal, lingual, ferior alveolar (dental) nerves cross the deep surface of the muscle.

e pterygoideus internus (fig. 377).—*Origin.*—From (1) the pterygoid fossa, and (2) from axillary tuberosity and the pyramidal process of the palatine, where these adjoin.

ucture and Insertion.—From the medial and lateral laminæ of the pterygoid process arise aponeuroses and from the palatine bone at the lower margin of the fossa, and from axillary tuberosity and palatine bone in front of the external pterygoid, there arise short s. From these aponeuroses and tendons and directly from the fossa the fiber-bundles nearly parallel course downward, backward, and outward, and are inserted in part in a enniform manner into the lower half of the internal surface of the ramus of the mandible. sertion extends to the mylohyoid ridge. The muscle is divided at its origin into two li by the margin of the external pterygoid.

ve-supply.—The internal pterygoid nerve arises from the back of the mandibular nerve e foramen ovale. It passes near or through the otic ganglion. and thence to the medial of the muscle near the dorsal edge. Both the buccinator and lingual nerves are also ed as sending filaments to this muscle.

ations.—Laterally the muscle is covered by the interpterygoid fascia and the spheno- ular ligament, the external pterygoid, temporal, and masseter muscles, and the ramus mandible. The inferior alveolar (dental) and lingual nerves and the corresponding run across this surface. Medial to the muscle lie the lateral pharyngeal fascia, the tensor latini muscle, and the superior constrictor of the pharynx.

ion.—The muscles of this group adduct the lower jaw and carry it forward and backward tate it. The elevation is produced by the masseter, temporal, and internal pterygoid s. The suprahyoid muscles and the external pterygoid are the feeble antagonists. rward movement of the jaw is produced by the simultaneous action of the two external oids (slightly by the superficial layer of the masseter, and the anterior fibers of the tem- while the inferior posterior portions of the temporal muscles carry the jaw at the tem- scoidal joint somewhat backward. Oblique lateral rotatory movements are produced by the action of one of the external pterygoids. The alternate action of these two s associated with the elevating action of the other muscles of the group, gives rise to the g movement of the molar teeth. Purely lateral movements of the jaw may be produced internal pterygoids, acting alternately.

riations.—The temporal muscle may have a more extensive cranial origin than usual. be formed of two superimposed layers. It may be more or less fused with the external oid, or send a fasciculus to the coronoid process. The masseter may be completely l into two fasciculi, a condition normal in many mammals. A special fasciculus may rom the temporomandibular articulation or from the zygomatic (malar) bone. Its t fibers may be fused with the temporal muscle. The two fasciculi of the external oid may be distinct, as in the horse. It has been seen fused with the temporal and with gastric muscle. The internal pterygoid may send a fasciculus to the masseter. It may rigin to the styloglossus. Inconstant fasciculi (*accessory pterygoids*) extending from the f the sphenoid to the pterygoid process represent perhaps remnants of the muscles which the movable pterygoids possessed by many inferior vertebrates.

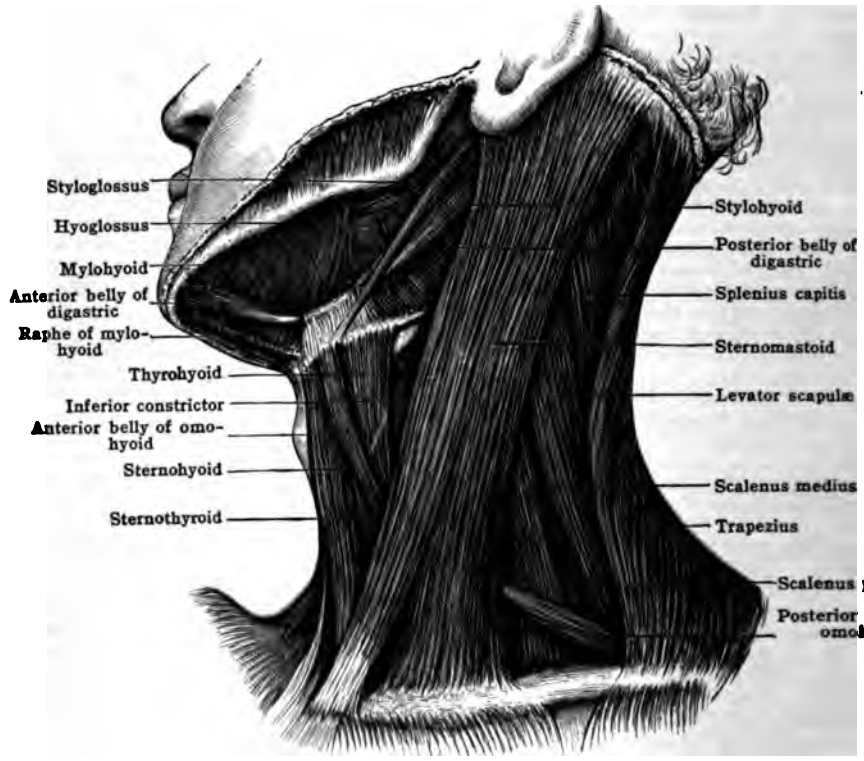
3. SUPRAHYOID MUSCULATURE

(Fig. 379)

om the hyoid bone there extend to the base of the skull on each side four es which form a fairly well-defined group. They are situated external to usculature of the tongue and pharynx. They elevate the hyoid bone and : and depress the mandible. The anterior part of this musculature pulls oid bone and larynx forward and opens up the pharynx, and therefore is of swallowing. The most superficial of the group is the slender, fusiform **yoid,** which arises from the styloid process of the temporal bone and is d into the body of the hyoid. Immediately behind this is the flattened

posterior belly of the **digastric,** which extends from its origin in the mastoid notch to a tendon that runs between two divisions of the tendon of the stylohyoid and is inserted into the hyoid bone by an aponeurotic process. From the digastric tendon the flat, triangular anterior belly is continued to the back of the anterior portion of the inferior margin of the mandible. Internal to this anterior belly the thin, quadrangular **mylohyoid** arises from the inner surface of the body of the mandible and is inserted into a median raphe extending from the mandible to the hyoid. Still more internally the triangular **geniohyoid** extends from the hyoid to the mental spine of the mandible. The last two muscles form the muscular floor of the mouth. The motor innervation of the posterior belly of the

FIG. 379.—ANTERIOR AND LATERAL CERVICAL MUSCLES.



digastric and of the stylohyoid is from the facial nerve, the sensory innervation probably from the glossopharyngeal. The mylohyoid and the anterior belly of the digastric are supplied by the masticator (fifth) cranial nerve; the geniohyoid from the hypoglossal by a branch, the fibers of which are possibly derived through anastomosis from the first cervical nerve.

From the morphological standpoint, therefore, the stylohyoid, and the posterior belly of the digastric belong to the facialis group; the anterior belly of the digastric and the mylohyoid to the group of mandibular muscles, and the geniohyoid to the muscles of the tongue innervated by the hypoglossal; or, if we consider the nerve-fibers of the nerve to the genio-hyoid as derived from the first cervical nerve, to the same group as the infrahyoid muscles. It is convenient, however, to follow the usual custom of considering these muscles as a suprahyoid group.

FASCIÆ

The muscles of this group lie internal to that portion of the external cervical fascia which extends above the hyoid bone. This fascia, which is described on p. 382, comes into contact merely with the tendon, the anterior belly, and to a slight extent with the posterior belly of the digastric muscle. Above the tendon it sends inward a process which curves down internal to the tendon, and is inserted into the external surface of the hyoid bone. The individual muscles of the group are covered by delicate adherent membranes. An aponeurotic membrane usually extends between the anterior bellies of the digastric muscle of each side.

MUSCLES
(Fig. 379)

The stylohyoideus.—*Origin.*—From the lateral and dorsal part of the base of the styloid process by a rounded tendon which soon becomes a hollow cone to the internal surface of which the fiber-bundles of the muscle are attached. *Structure and Insertion.*—The fiber-bundles are inserted on both sides of a slender tendon which divides to let the tendon of the digastric pass through and then is attached to the ventral surface of the body of the hyoid bone near its junction with the great cornu.

Nerve-supply.—From the facial nerve as it emerges from the stylomastoid foramen a small twig is given off which enters the proximal third of the deep surface of the muscle. The glossopharyngeal nerve also gives to it a small twig, probably sensory.

Relations.—It descends immediately in front of the posterior belly of the digastric. Externally lie the parotid and submaxillary glands. Medially it crosses the internal and external carotid artery, the hypoglossal nerve, the stylopharyngeus muscle, the superior constrictor of the pharynx, and the hyoglossus muscle. The posterior auricular artery passes between it and the posterior belly of the digastric and the external maxillary artery crosses over it.

The digastricus.—**The posterior belly** arises by tendinous processes from the mastoid (digastric) notch of the temporal bone. The fiber-bundles form a ribbon-like belly which converges on the intermediate tendon. This begins as a semiconical laminar process on the outer surface of the muscle a short distance above the hyoid bone. **The anterior belly** arises by short tendinous processes from the digastric fossa of the mandible. This attachment is often described as an insertion. The fibers converge on both surfaces of the flattened anterior end of the intermediate tendon. **The intermediate tendon** lies a variable distance above the hyoid bone, usually less than a centimeter. It curves upward toward each belly of the muscle. It is united to the outer surface of the body and to the base of the great cornu of the hyoid bone by an aponeurotic expansion from its inferior margin Other expansions are usually continued into the interdigastric aponeurotic membrane Occasionally the intermediate tendon of the digastric is bound to the hyoid bone by a fibrous loop which allows the tendon free play.

Nerve-supply.—The facial nerve near the stylomastoid foramen gives off a branch which enters the proximal third of the anterior margin of the muscle. From this a ramus may be continued through the muscle to the glossopharyngeal nerve The anterior belly is supplied by a branch of the nerve to the mylohyoid muscle This enters the middle of the lateral part of the deep surface Very rarely the vagus may supply the anterior belly, the hypoglossal, the posterior belly.

Relations.—The posterior belly of the digastric lies internal to the mastoid process and the longissimus capitis (trachelomastoid), splenius, and sternocleidomastoid muscles. Posteriorly near its origin are the rectus capitis lateralis and obliquus cap. sup. muscles, the occipital artery and the spinal accessory nerve. It helps to form the deep wall of the cavity in which the parotid gland is placed. Internally it crosses the origin of the styloid muscles, the carotid arteries, the internal jugular vein, and the hypoglossal nerve. The intermediate tendon of insertion lies below the inferior margin of the submaxillary gland, and crosses the hypoglossus and mylohyoid muscles. The relations to the stylohyoid muscle have been described above The anterior belly lies on the mylohyoid and is covered by the external cervical fascia and the platysma.

The mylohyoideus.—*Origin.*—From the mylohyoid ridge of the mandible. *Structure and Insertion.*—Its fiber-bundles take an oblique course and are inserted into—(1) a median raphe extending from the middle of the ventral surface of the hyoid bone nearly or quite to the posterior aspect of the inferior margin of the mandible, and (2) into the ventral surface of the hyoid bone. Some of the fiber-bundles may cross the median line. The muscles of the two sides form a sheet with a downward convexity which lies between the inner surface of the body of the mandible and the hyoid bone. On the diaphragm thus formed rests the tongue.

Nerve-supply.—From the mylohyoid branch of the inferior alveolar (dental) nerve several filaments enter the under surface of the muscle.

Relations.—The mylohyoid muscle is covered externally by the submaxillary gland, the anterior belly of the digastric, and the external cervical fascia. It is crossed by the submental artery. With the geniohyoid and the genioglossus muscles it helps to bound a compartment in which are lodged the sublingual gland, the duct of Wharton, and the deep portion of the submaxillary gland. Its deep surface also faces the styloglossus and hyoglossus muscles, the lingual and hypoglossal nerves, and to a slight extent the buccal mucosa.

The geniohyoideus (fig. 380).—*Origin.*—By short tendinous fibers from the mental spine of the mandible. *Structure and Insertion*—The fiber-bundles diverge and are inserted into the ventral surface of the body of the hyoid bone. Usually a special fasciculus goes to the great cornu of the hyoid bone.

Nerve-supply.—The hypoglossal nerve sends a filament to the middle third of the deep surface of the muscle. The nerve-fibers are thought to be derived chiefly from the first cervical nerve.

Relations.—It lies between the genioglossus and mylohyoid muscles. It adjoins its fellow of the opposite side and is often fused with it. Lateral to it lie the sublingual and submaxillary glands and the hypoglossal nerve.

Action.—The muscles of this group all elevate the hyoid bone and, through this, the larynx and inferior part of the pharynx, and thus play a part in the act of swallowing. The stylohyoid and posterior belly of the digastric serve also to draw the hyoid bone in a dorsal direction; the ventral belly of the digastric and the geniohyoid, in a ventral direction. The digastric geniohyoid, and mylohyoid depress the mandible, when the hyoid bone is fixed. The digastric acting on one side rotates the jaw toward that side. The two digastrics may retract the jaw. The posterior belly of the digastric has a slight power to bend the head backward.

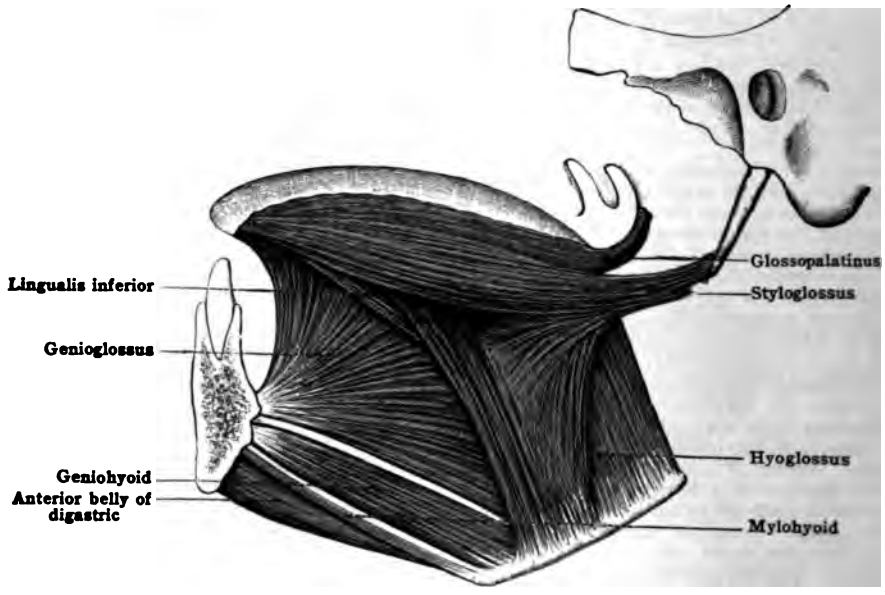
Variations.—The stylohyoid tendon frequently passes entirely in front of and less frequently

entirely behind the digastric muscle. Its insertion may be of greater extent than usual. A special fasciculus to the lesser cornu is not very infrequent; more rarely one extends to the angle of the jaw or to other regions. The muscle may arise from the petrous portion of the temporal or from the occipital bone, as in some lower vertebrates. It may be doubled or absent or fused with the posterior belly of the digastric. The anterior belly of the digastric may be missing; the posterior belly may be inserted into the angle of the jaw. The intermediate tendons of the digastric of each side may be connected by a fibrous arch. The anterior bellies of the muscles of each side may be united by a fasciculus or fused. The anterior belly is frequently doubled. The posterior belly may be divided by a tendinous inscription. Fasciculi may pass from either belly to neighboring structures. The mylohyoid may not extend quite to the hyoid bone. It may be more or less fused with neighboring muscles. Rarely it is absent. The geniohyoid is frequently more or less fused with the muscles of the tongue or with the geniohyoid of the opposite side. A considerable number of infrequently found muscles have been described superficial to the stylohyoid and digastric muscles. Most of them are innervated by the glossopharyngeal nerve or by the facial nerve.

4. MUSCLES OF THE TONGUE
(Fig. 380)

The tongue is a flexible organ, composed chiefly of various muscles, some of which lie entirely within its substance, while others extend to be attached to neighboring parts of the skeleton. To the former the term **intrinsic,** to the latter the term **extrinsic,** is frequently applied. In this section the extrinsic

FIG. 380.—SIDE VIEW OF THE MUSCLES OF THE TONGUE.



muscle will alone be taken up. The intrinsic muscles are described in the section on the DIGESTIVE SYSTEM. Certain pharyngeal and palatal muscles which are continued into the tongue are described in connection with the pharynx. The extrinsic musculature of the tongue is concealed below by the suprahyoid musculature and the sublingual gland. It is covered on the free surface of the tongue by the mucosa.

The musculature of the tongue is supplied by the hypoglossal nerve, which is in series with the motor roots of the spinal nerves. It is, primitively at least, derived from the ventral portion of myotomes in series with the spinal myotomes.

Four extrinsic muscles are recognized on each side. The **styloglossus** is a slender muscle, which arises from the styloid process and is inserted into the side of the tongue. It is cylindrical near its origin, flat and triangular near its insertion. The thin, quadrilateral **hyoglossus** arises from the body and great cornu of the hyoid bone and is inserted into the dorsum of the tongue. The **chondroglossus** arises from the lesser cornu of the hyoid bone and joins the superior and inferior longitudinal muscles of the tongue. The **genioglossus** (geniohyoglossus), which forms the main part of the body of the tongue, arises from the

ne of the mandible, from which the fiber-bundles radiate out toward the
th of the dorsum of the tongue and to the hyoid bone.
the mucous membrane of the tongue is a dense layer of fibrous tissue,
l fascia. In the body of the tongue there is a sagittal septum linguæ,
arates the two genioglossus muscles. A transverse fibrous lamella,
ssal membrane, helps to unite the tongue to the hyoid bone. Delicate
s invest the free portions of the extrinsic muscles of the tongue.

MUSCLES

loglossus.—This *arises* from the front of the lower end of the styloid process of
l bone and from the upper part of the stylomandibular ligament. *Insertion.*—It
ly downward, forward, and medially, with slightly diverging fiber-bundles, to the
in of the tongue, where it gives rise near the anterior (glossopalatine) arch to two
he larger, lateral, longitudinal fasciculus runs superficially along the lateral margin
e to the tip. The fiber-bundles are attached to the overlying mucosa and under-
ilature. The smaller, inferior, transverse fasciculus gives rise to diverging fiber-
ch pass medially through the hyoglossus into the base of the tongue. The most
these diverging bundles may extend to the hyoid bone.
glossus.—This *arises* from—(1) the lateral part of the ventral surface of the body
bone and (2) from the upper border of the great cornu. The fiber-bundles take a
llel course upward, diverging, however, slightly. Near the upper margin of the
the tongue they curve medianward and interlace with the intrinsic musculature of
The dorsal fiber-bundles pass transversely, the middle obliquely, the ventral longi-
They are inserted into the fibrous tissue which forms the skeletal framework of the

ndroglossus is a small muscle which arises from the lesser cornu of the hyoid bone
se to fasciculi which join the longitudinalis inferior and the longitudinalis superior
ue described in Section X.
loglossus.—This *arises* from the mental (genial) spine of the mandible partly
tly by means of a short, triangular tendon. The more inferior fiber-bundles radiate
ip of the tongue; the intermediate extend directly toward the dorsum of the tongue,
are *inserted* into the lingual fascia and skeletal framework. The inferior curve
nserted on the median part of the superior border of the hyoid bone.
pply.—Twigs from the hypoglossal nerve enter the lateral surfaces of the muscles
).
-The chief of the muscles, the genioglossus, performs various services according to
ch contracts. The anterior portion serves to withdraw the tongue into the mouth
the tip; the middle portion to draw the base of the tongue forward, depress the
ion of the tongue, and make the tongue protrude from the mouth; the inferior fibers
ie hyoid bone and carry it forward. The styloglossus retracts the tongue, elevates
nd raises the hyoid bone and base of the tongue. The hyoglossus draws down the
ongue and is also a retractor. The chondroglossus aids in both these movements.
).—The main portion of the tongue is composed of the two genioglossus muscles
parated in the median line by the lingual septum. The genioglossus is covered
r the geniohyoid and the mylohyoid muscles; along the lateral margin of the tongue
opalatinus, the styloglossus, the longitudinalis inferior, and the glossopharyngeus
l posteriorly by the hyoglossus, and the chondroglossus. Below it forms a part of
wall of the space in which the sublingual gland is lodged. Over the dorsum and tip
ie it is covered by the mucosa. This likewise covers laterally, in the region of the
tongue, the styloglossus, hyoglossus, and the longitudinalis inferior. The lingual
between the hyoglossus and the genioglossus, and along the boundary between the
is inferior and the genioglossus to the tip of the tongue. The lingual vein, which
to the hyoglossus muscle, takes a similar although much more irregular course.
haryngeal nerve passes down medial to the styloglossus muscle to the root of the
ie lingual nerve passes along the lateral margin of the tongue external to the stylo-
glossus, and inferior longitudinal muscles. The hypoglossal nerve lies lateral to
portion of the hyoglossus muscle and then sinks into the genioglossus.
glossus muscle is covered laterally below the free portion of the tongue by the mylo-

5. SUPERFICIAL MUSCULATURE OF THE SHOULDER GIRDLE AND THE EXTERNAL CERVICAL FASCIA
(Figs. 379, 386)

The **sternocleidomastoid** is a strong, band-shaped muscle, bifurcated below, which arises from the medial third of the clavicle and the front of the manubrium and is inserted into the mastoid process of the temporal bone and the neighboring part of the occipital. The large, flat, triangular **trapezius** arises from the occipital bone and the spines of the cervical and thoracic vertebræ and is inserted into the lateral third of the clavicle and into the acromion and spine of the scapula. The two muscles lie in a well defined layer of fascia which ensheaths the neck beneath the platysma, the *external cervical fascia*. Both muscles bend the head and neck toward the shoulder, and rotate and extend the head. The sternocleidomastoid also elevates the thorax and flexes the neck. The trapezius draws the scapula medially and rotates the inferior angle lateralward. The upper part of the muscle elevates, the lower part depresses, the scapula.

These two superficially placed muscles represent differentiated portions of a musculature found in elasmobranchs and in the amphibia and all higher vertebrates. In sharks this musculature is associated with the musculature of the branchial arches, and, like them, is innervated by the vagus nerve. In the higher vertebrates it is innervated by the vagus or by the spinal accessory nerve, developed in connection with the vagus. To this innervation by a cranial nerve, innervation by cervical nerves is added in those higher vertebrates in which the musculature is more extensively developed. In the human embryo the muscles migrate from their origin in the upper lateral cervical region to the positions found in the adult.

FASCIÆ

The **fasciæ** of the neck and the relations of the muscles are shown in cross-section in figs. 378, 382, and 1090.

The **tela subcutanea** of the head and neck in the upper dorsal region is thick, fibrous, and closely adherent to the underlying muscle fascia. Ventrally in the cervical region it contains the platysma.

The **external cervical fascia** (fig. 381) lies beneath the subcutaneous tissue and the platysma, completely invests the neck and extends cranialward over the parotid gland to the zygoma and the masseteric fascia. The trapezius lies between two closely adherent laminæ of the fascia. From the ventral margin of the trapezius it is continued as a thin but strong membrane across the posterior triangle of the neck, between this muscle and the sternocleidomastoid, and is attached below to the clavicle. It invests the sternocleidomastoid with two adherent laminæ and extends from the ventral margin of this muscle across the anterior triangle to the mid-line where it is continued into that of the opposite side. In this triangle the fascia is bound to the hyoid bone, and is thus divided into a submaxillary and an infrahyoid portion. The infrahyoid portion is simple and is attached below to the front of the manubrium. The submaxillary portion is attached to the inferior margin of the mandible. It covers the submaxillary gland and along the inferior margin gives rise to a strong, membranous process which passes inward below the gland and, after extending around the tendon of the digastric muscle, becomes united to the superior margin of the hyoid bone. This process ventrally becomes fused with the perimysium of the ventral belly of the digastric. Dorsally it extends over the posterior end of the submaxillary gland and becomes attached to the angle of the jaw. Here it is strengthened by fibrous tissue which extends in from the ventral margin of the sternocleidomastoid and serves to separate the parotid from the submaxillary gland. This 'mandibular process' is continued into the stylomandibular ligament.

The **parotid gland** is enclosed between two laminæ of the external cervical fascia. These are continued over the gland from the fascial investment of the sternocleidomastoid, and unite anteriorly to become fused to the masseteric fascia along the anterior margin of the gland. They unite below the inferior margin of the gland, and are continued into the mandibular process mentioned above. The external layer, which is the thicker and stronger, is attached above to the cartilage of the auditory canal and to the zygoma. The inner lamina is attached above to the base of the temporal bone. It is incomplete and is more or less fused to the posterior belly of the digastric muscle, the styloid process, and the muscles arising from this process. Beween the styloid process and the angle of the jaw this lamina is strengthened to form the stylomandibular ligament.

In the back beyond the spine of the scapula, the fascia arising from the investing adherent fascial sheath of the trapezius muscle is continued laterally across the fascia investing the infraspinatus muscle, and becomes fused with the most superficial layer of this fascia and more distally with that of the latissimus dorsi muscle. Near this lateral line of fusion it is usually closely adherent to the tela subcutanea.

MUSCLES

The **sternocleidomastoideus** (fig. 379)—*Origin.*— By a medial (sternal) head from the front of the manubrium and by a lateral (clavicular) head from the upper border of the medial third of the clavicle. Between the two origins there intervenes a triangular area covered by the external cervical fascia. Its *insertion* is (1) on the anterior border and outer surface of the mastoid process, and (2) on the lateral half of the superior nuchal line of the occipital bone.

tructure.—The tendons are comparatively short, the longest being that on the anterior ce of the sternal attachment. The fiber-bundles of the muscle take a nearly parallel se from origin to insertion. Five fasciculi may be more or less clearly recognized. In a rficial layer—(1) a superficial sternomastoid;(2) a sterno-occipital; and (3) a cleido-occipital. deep layer—(4) a deep sternomastoid and (5) a cleidomastoid.

FIG. 381.—FASCIÆ OF THE NECK. (After Eisler.) The superficial fascia has been removed laces in order to show the deeper fasciæ; the sternocleidomastoid has been partly removed; submaxillary gland, almost wholly; the parotid gland, as far as the duct.
1. Submaxillary space. 2. Parotid space. 3. Sternocleidomastoid. 4. Supraclavicular a. 5. Suprasternal space. 6. External jugular vein. 7. Anterior jugular vein. 8. Me- colli vein. 9. N. occipitalis minor. 10. N. auricularis magnus. 11. Deltoid. 12. Proc. coideus. 13. Fascia coracoclavicularis.

Nerve-supply.—(1) From the spinal accessory nerve, which gives it branches during its rse through the deep portion of the muscle, and (2) by branches from the anterior primary isions of the second and sometimes the third cervical nerves. These branches enter the deep face of the upper half of the muscle.
Action.—To bend the head and neck toward the shoulder and rotate the head toward the osite side. When both muscles act, the neck is flexed toward the thorax and the chin is ed; or, with fixed head, the sternum is raised, as in forced respiration. When the head is t back, the two muscles may further increase the hyperextension.

Relations.—The muscle and its sheath are covered externally by the tela subcutanea, which here contains the platysma and the external jugular vein, as well as the superficial branches of the cervical plexus. Beneath the muscle lie the sternohyoid, sternothyroid, omohyoid, levator scapulæ, scaleni, splenius, and digastric muscles, the cervical plexus, the common carotid artery, internal jugular vein and the vagus nerve. The spinal accessory nerve usually runs through its deep cleidomastoid portion.

Variations.—There is considerable variation in the extent of independence of the main fasciculi of the muscle. In many of the lower animals the cleidomastoid portion of the muscle is quite distinct from the sternomastoid portion, and this condition is frequently found in man. The cleido-occipital portion of the muscle is that most frequently absent (Wood found it present in 37 out of 102 instances). The clavicular portion of the muscle varies greatly in width. The sternal head has been seen to extend as far as the attachment of the fifth rib. Slips from the muscle may pass to various neighboring structures. The main fasciculi of the muscle may be doubled. Sometimes one or more tendinous inscriptions cross a part or the whole of the superficial layer of the muscle.

The **trapezius** (fig. 386).—*Origin.*—By a flat aponeurosis from the superior nuchal line and external protuberance of the occipital bone, the ligamentum nuchæ, and the vertebral spines and supraspinous ligament from the seventh cervical to the twelfth thoracic vertebra. The aponeuroses of the right and left muscles are continuous across the middle line. Between the middle of the ligamentum nuchæ and the second thoracic vertebra, the aponeuroses give rise to an extensive quadrilateral tendinous area. At the distal extremity of the muscle they are also well developed.

Structure and insertion.—The superior fiber-bundles pass obliquely downward, lateralward and forward to the posterosuperior aspect of the lateral third of the clavicle; the middle-fiber bundles, transversely to the medial edge of the acromion and the upper border of the spine of the scapula; the lower fiber-bundles, obliquely upward and laterally to terminate through a flat triangular tendon on a tubercle at the medial end of the spine of the scapula.

Nerve-supply.—The external branch of the spinal accessory nerve descends for a distance near the superior border of the trapezius muscle and then along the ventral surface. Soon it gives rise to ascending branches for the superior portion of the muscle and descending branches for the middle and inferior portions. The main branches of distribution run about midway between the origin and insertion of the fiber-bundles. The branches from the (second) third and fourth cervical nerves anastomose with the trunk of the spinal accessory, sometimes as it passes along the margin of the muscle, at other times within the substance of the upper portion of the muscle.

Action.—When the whole muscle contracts, it draws the scapula toward the spine and turns it so that the inferior angle points laterally, the lateral angle upward. In addition the upper portion draws the point of the shoulder upward, and with the scapula fixed extends the head, bends the neck toward the same side, and turns the face to the opposite side. The lower portion of the muscle tends to draw the scapula downward and inward and at the same time to rotate the inferior angle of the scapula lateralward.

Relations.—It is covered merely by skin and fascia. It lies external to the semispinalis, splenii, rhomboidei, latissimus dorsi, levator scapulæ, supraspinatus, and a small portion of the infraspinatus muscles.

Variations.—The lower limit of attachment of the muscle may be as high as the fourth thoracic vertebra. The right and left muscles are seldom symmetrical. The upper attachment may not extend to the skull. The clavicular attachment may be much more extensive than normal or may be missing. The attachments to the scapula show considerable variations. Occasionally the cervical and thoracic portions are separate, a condition normal in many mammals. Ventrally the trapezius may become continuous with the sternocleidomastoid in the neck, or send a fasciculus to it or to the sternum. Aberrant fasciculi are not infrequent. Rarely a transverse tendinous inscription is found in the cervical or in the thoracic portion of the muscle. Sometimes a fasciculus is sent into the deltoid. The innervation of either the sternocleidomastoid or the trapezius may be by cervical nerves only. The *omocervicalis* (*levator claviculæ*) is a fasciculus frequent in the lower mammals, but rarely found in man. It usually extends from the acromial end of the clavicle to the atlas and axis, but may extend to more distal cervical vertebræ. It is innervated by a ramus from the cervical branches to the trapezius. The *supraclavicularis proprius* is a muscle rarely found. It extends on the cranial surface of the clavicle from the sternal to the acromial end and is innervated by the third cervical nerve. It is said to make tense the superficial layer of the cervical fascia.

A bursa is often found between the base of the spine of the scapula and the tendon of insertion of the thoracic portion of the trapezius. Another bursa is also frequently found between the insertion of the transverse portion and the supraspinous fascia.

6. INFRAHYOID MUSCULATURE

(Figs. 379 and 382)

The four infrahyoid muscles constitute a well-defined group of muscles which depress the hyoid bone, the larynx, and the associated structures. They lie beneath the sternocleidomastoid muscle and the external cervical fascia. Two strata may be recognized. In the superficial stratum are comprised the **omohyoid**, a narrow, ribbon-like digastric muscle which arises from the superior margin of the scapula and is inserted into the hyoid bone; and the thin, quadrangular **sternohyoid**, which arises from the superior margin of the sternum and

nedial end of the clavicle and is inserted into the hyoid bone. Between
two muscles is an aponeurotic membrane which constitutes the main part
ıe middle layer of the cervical fascia, and represents possibly a retrograde
ion of a single muscle, of which the two above named are but the ventral and
al margins. Beneath this superficial musculature the thin, quadrangular
hyoid descends from the hyoid bone to the thyroid cartilage, and the
on-like sternothyroid arises from the dorsal surface of the manubrium and is
ted into the thyroid cartilage.
All these muscles are supplied by branches from the ansa hypoglossi. The
e-fibers arise from the first three cervical nerves.

he muscles of this group are derived from the ventral portions of the ventrolateral divi-
of the first three cervical myotomes, and correspond with the rectus abdominis muscle,
is derived from the ventral portions of the eighth to the twelfth thoracic myotomes.
musculature is characterised by metameric segmentation, which may be more or less ob-
l, and by a general longitudinal direction taken by the component fiber-bundles. The
e of the fibers in the omohyoid may be looked upon as a secondary condition due to the
ıg laterally of the distal attachment of the muscle. Musculature of this nature is not
ed from the lower cervical and upper thoracic myotomes in man, but in some of the lower
rates it forms a continuous ventral band. Even in man occasional traces of this ventral
ılature may, however, be seen as muscular and aponeurotic slips on the upper part of the
cic wall, above the ribs and the aponeurosis of the external intercostal muscles.

FASCIA
(Figs. 382 and 388)

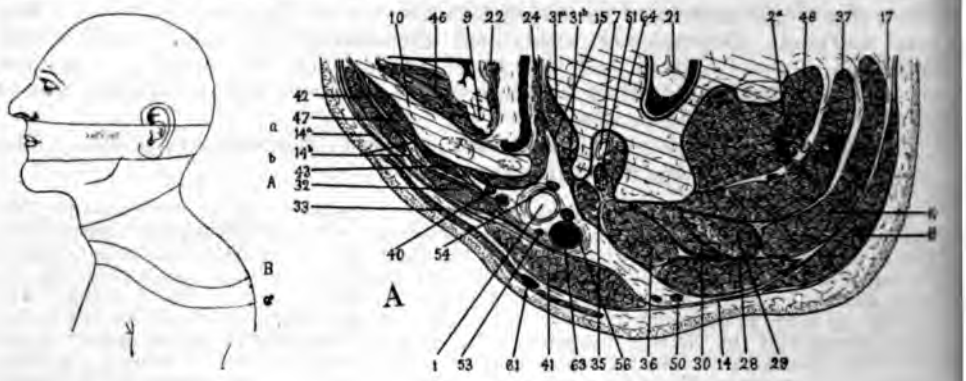
he middle cervical fascia is composed of two laminæ. Of these, the superficial, which
aths the sternohyoid and omohyoid muscles and fills in the intervening area, is much the
ger and better differentiated. The more delicate deep lamina ensheathes the thyrohyoid
ternothyroid muscles, and laterally extends out to become fused with the superficial
a. It is also more or less closely bound to the sheath which covers the internal jugular
carotid artery, and vagus nerve.
ıe middle cervical fascia is attached above to the hyoid bone. Beyond the lateral edge
omohyoid it becomes fused with the deep lamina of the external layer of the cervical
, beneath the sternocleidomastoid. Posterior to this muscle it usually terminates along
anial margin of the omohyoid in the areolar tissue of the neck. Its distal attachment
place into the dorsal surface of the upper margin of the sternum, and from here a process
t over the left innominate vein to the pericardium. Lateral to the sternum the fascia is
ıed for some distance to the inner margin of the clavicle, and gives rise to processes, one of
extends to the fascia of the subclavius muscle, while the others pass on each side of the
ıvian vein to the first rib. Still more laterally the fascia is fused along the lower margin
scapular belly of the omohyoid to the underlying dense, fatty areolar tissue.

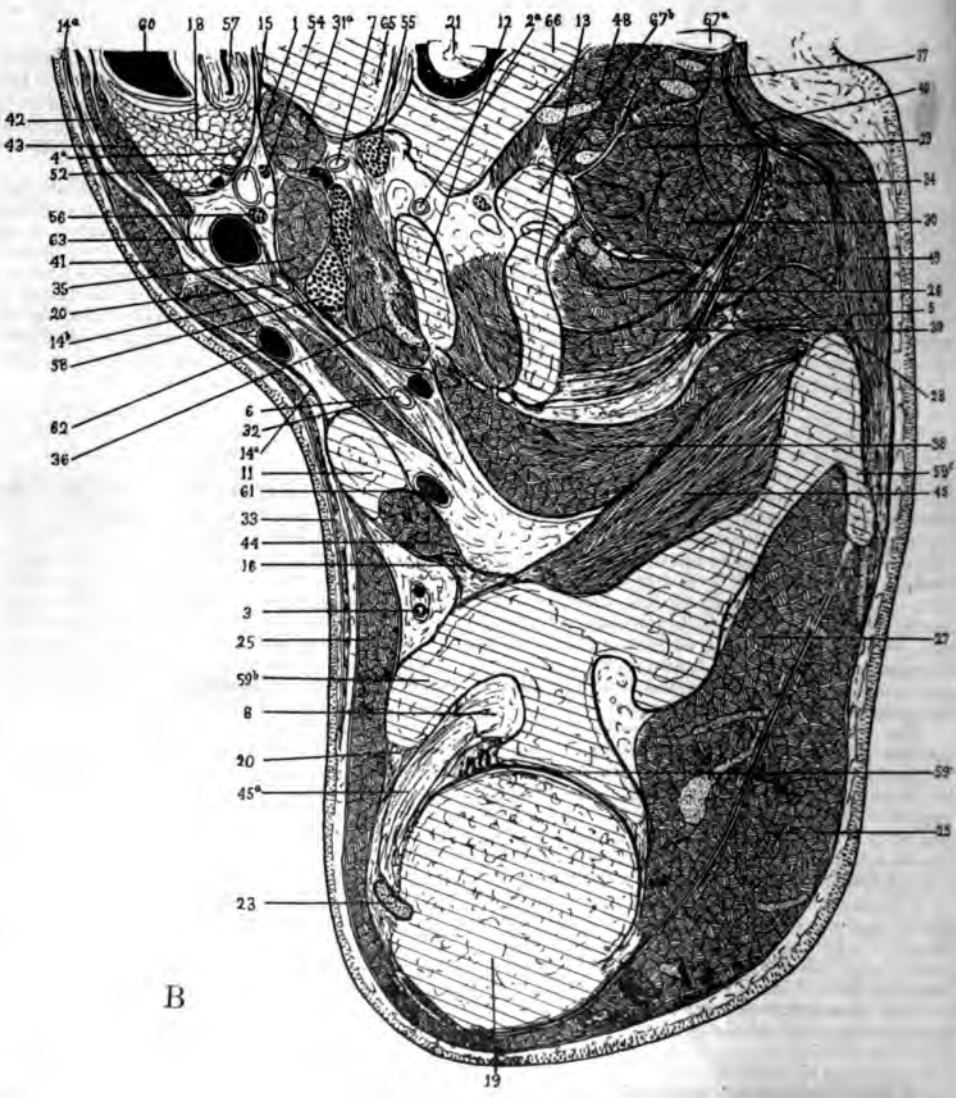
INFRAHYOID MUSCLES
(Figs. 379 and 382)

ıe sternohyoideus.—*Origin.*—From (1) the deep surface of the medial extremity of the
ıle; (2) the costoclavicular (rhomboid) ligament; and (3) the neighboring part of the
ım. The origin may extend to the cartilage of the first rib. *Structure and insertion*—
iber-bundles take a nearly parallel course upward. The muscle belly, however, contracts
ly in width and increases slightly in thickness and slants somewhat toward the median
The insertion takes place directly upon the inferior margin of the body of the hyoid
l to the midline. Not infrequently a tendinous inscription near the junction of the middle
nferior thirds more or less completely divides the muscle into two portions. A second
ption is sometimes found at the level of the oblique line of the thyroid cartilage. *Nerve-*
y.—One or more branches from the ansa hypoglossi enter the lateral margin of the muscle.
ıently one goes to the upper third, another to the lower third, of the muscle.
ıe omohyoideus.—*Origin.*—From the superior margin of the scapula near, and occa-
ly also from, the superior transverse ligament of the scapula. *Insertion.*—The lower
r of the hyoid bone lateral to the sternohyoid muscle. *Structure.*—The inferior belly of
ıuscle near its origin is thick and fleshy. It contracts as it passes ventrally across the
rior triangle of the neck. Beneath the sternocleidomastoid it is attached to a short ten-
rom which, as it bends upward toward the hyoid bone, the superior belly takes origin and
e expands toward the insertion. The tendon of attachment is short. The fiber-bundles
ch bellies take a nearly parallel course. The central tendon of the muscle is held in place
strong process in the middle layer of the cervical fascia. This process is attached to the
l surface of the clavicle and to the first rib. *Nerve-supply.*—The superior belly is sup-
by a branch which enters its deep surface near the medial margin somewhat below the
r; the inferior by a branch which enters the proximal third of its deep surface. These
hes arise from the ansa hypoglossi.
he sternothyroideus.—*Origin.*—Partly directly, partly by tendinous fibers, from—(1)
orsal surface of the manubrium from the middle line to the notch for the first rib; (2) the
l surface of the cartilage of the first rib. Occasionally also from the back of the cartilage
second rib or from the clavicle. *Structure and insertion.*—The fiber-bundles take a nearly
al course upward and slightly lateralward. The muscle is inserted by short tendinous

FIG. 382, A and B.—TRANSVERSE SECTIONS THROUGH THE LEFT SIDE OF THE NECK AND SHOULDER IN THE REGIONS INDICATED IN THE DIAGRAM.

a and *b* in the diagram indicate sections A and B of fig. 378. *a'* that of section A, fig. 388.





fibers into the oblique line on the lamina of the thyroid cartilage. A transverse tendinous inscription near the upper border of the interclavicular ligament not infrequently divides the belly of the muscle more or less completely into two parts. Sometimes a second transverse inscription is found at the level of the lower margin of the thyroid cartilage. *Nerve-supply.*—By one or two branches from the ansa hypoglossi, which enter the ventral surface of the muscle near the lateral margin. One branch usually goes to the upper, another to the lower, third of the muscle.

The **thyrohyoideus.**—*Origin.*—From the oblique line on the lamina of the thyroid cartilage. *Structure and insertion.*—The fiber-bundles take a parallel course and are inserted on the inferior margin of the lateral third of the body of the hyoid bone and the external surface of the great cornu. Many figer-bundles are continuous with those of the sternothyroid.

Nerve-supply.—By a branch of the hypoglossal which enters the muscle near the middle of its lateral border. The fibers are said to be derived from the first cervical nerve.

Action.—The sternohyoid and omohyoid depress the hyoid bone; the sternothyroid depresses the thyroid cartilage; and the thyrohyoid approximates the bone to the cartilage. The omohyoid tends to draw the hyoid bone somewhat laterally. In this is aided by the posterior belly of the digastric and the stylohyoid and is opposed by the sternothyroid and thyrohyoid muscles, and the anterior belly of the digastric.

Relations.—The muscles of this group lie beneath the external cervical fascia. The sternocleidomastoid muscle crosses the omohyoid, the sternohyoid, and sternothryoid muscles. The latter two muscles extend for a distance behind the manubrium of the sternum. The omohyoid is partly covered by the trapezius, crosses the scalene muscles, the brachial plexus, the internal jugular vein, carotid artery, and the sternothyroid and thyrohyoid muscles. The sternohyoid extends over the sternothyroid muscle, the thyroid gland, cricothyroid muscle, and the thyroid cartilage. The sternothyroid lies over the innominate vein, the trachea, and thyroid bland. It is partly covered by the sternohyoid and omohyoid muscles. The thyrohyoid is largely covered by the omohyoid and sternohyoid muscles, and lies upon the hyothyroid membrane and the upper part of the thyroid cartilage.

Variations.—The muscles vary in extent of development and may be more or less fused with one another. The sternal attachment of the sternohyoid is more frequently absent than the clavicular attachment. The region between the omohyoid and sternohyoid may be composed of muscle instead of fascia. Each of the muscles may be longitudinally divided into two distinct fasciculi, may send fasciculi to one another or to the middle layer of the cervical fascia, or may have an abnormal origin or insertion. The omohyoid is the one of the group most frequently absent. One of the bellies is much more frequently absent than both. The intermediate tendon of the omohyoid may be reduced to a tendinous inscription for even disappear entirely. The inferior attachment may take place on the scapular spine, the acromion, the coracoid process, or even the first rib or clavicle. An extra fasciculus from the clavicle is found in 3 per cent. of instances. (Le Double.). Not very infrequently a muscle innervated by a branch of the *descendens hypoglossi* is found extending from the sternum to the clavicle behind the origin of the sternocleidomastoid. It may also extend from the sternum or clavicle in various directions upward toward the head.

BURSÆ

The **bursa m. sternohyoidei** is in constantly found between the lower margin of the hyoid bone and median hyothyroid ligament and the sternohyoid muscle and external cervical fascia. It is better developed in men than in women and is found either on each side of the median line or fused in the median line.

The **bursa m. thyrohyoidei** is frequently found between the greater cornu of the hyoid bone and hyothyroid membrane and the thyrohyoid muscle.

1. Arteria carotis communis. 2*a*. A. cervicalis profunda. 2*b*. A. cervicalis superficialis 3. A. thoracoacromialis (acromial branch). 4*a*. A. thyreoidea inferior. 4*b*. A. thyreoidea superior. 5. A. transversa colli. 6. A. transversa scapulæ. 7. A. vertebralis. 8. Bursa m. subscapularis. 9. Cartilago arytenoidea. 10. Cartilago thyreoidea. 11. Clavicle 12. Costa I. 13. Costa II. 14. Fascia cervicalis—*a*, superficial layer; *b*, middle layer. 15. Deep or prevertebral layer. 16. Fascia coracoclavicularis. 17. Fascia nuchæ. 18. Glandula thyreoidea. 19. Humerus. 20. Ligamentum coracohumerale. 21. Medulla spinalis (spinal cord). 22. Musculus arytenoideus transversus. 23. M. biceps brachii, tendon long head. 24. M. constrictor pharyngis inferior. 25. M. deltoideus. 26. M. lliocostalis. 27. M. infraspinatus. 28. M. levator scapulæ. 29. M. longissimus capitis (trachelo-mastoid). 30. M. longissimus cervicis. 31*a*. M. longus colli. 31*b*. M. longus capitis (rectus capitis anticus major). 32. M. omohyoideus. 33. M. platysma. 34. M. rhomboideus minor. 35. M. scalenus anterior. 36. M. scalenus medius. 37. M. semispinalis capitis (complexus). 38. M. serratus anterior. 39. M. serratus posterior superior. 40. M. splenius. 41. M. sternocleidomastoideus. 42. M. sternohyoideus. 43. M. sternothyreoideus. 44. M. subclavius. 45 M. subscapularis; *a*, tendon. 46. M. thyreoarytenoideus (and vocalis). 47. M. thyreohyoideus. 48. M. transversospinales. 49. M. trapezius. 50. Nervus accessorius. 51. N. cervicalis IV. 52. N. laryngeus inferior. 53. N. descendens hypoglossi. 54. Sympathetic trunk. 55. N. thoracalis I. 56. N. vagus. 57. Esophagus. 58. Plexus brachialis. 59. Scapula—*a*, glenoid cavity; *b*, coracoid process; *c*, spine. 60. Trachea. 61. Vena transversa colli. 62. V. jugularis externa. 63. V. jugularis interna. 64. Vertebra cervicalis V. 65. Vertebra cervicalis VII. 66. Vertebra thoracalis I, arch. 67. Vertebra thoracalis II—*a*, spine; b, transverse process.

7. SCALENE MUSCULATURE

(Figs. 379 and 383)

The three muscles which form this group constitute a triangular mass which extends in front of the levator scapulæ and intrinsic dorsal musculature and behind the prevertebral musculature from the first two ribs to the transverse processes of the cervical vertebræ. They cover laterally the apex of the pleural cavity. They bend the neck ventrolaterally and rotate it toward the opposite side, and fix the first two ribs or raise the thorax. In front lies the **scalenus anterior,** which extends from the first rib to the fourth to sixth vertebræ. Behind this the **scalenus medius** extends from the first rib to the lower six vertebræ. The most dorsal of the group, the **scalenus posterior,** extends from the second rib to the fifth and sixth vertebræ.

These muscles are supplied by direct branches of the cervical nerves. They are probably derived from the lateral portions of the cervical myotomes. According to Gegenbaur, the two more ventral are homologous with intercostal muscles, the dorsal with the levatores costarum. It is to be noted, however, that the anterior muscle lies in front of the brachial plexus, *i.e.*, in a position similar to that of the subcostal musculature. The scalene musculature is morphologically closely related to the deep shoulder-girdle musculature, p. 391.

FASCIA

(Figs. 382, 388)

From the front of the bodies of the cervical vertebræ the prevertebral fascia is continued laterally over the longus colli and the scalene muscles, and extends dorsally into the fascia covering the levator scapulæ. Between the muscles fascial processes are sent in to become attached to the cervical vertebræ. Inferiorly the fascia extends to the outer surface of the thorax.

SCALENE MUSCLES

(Fig. 383)

The **scalenus anterior.**—This *arises* from the ventral part of the inferior border of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, usually also from the third, rarely from the seventh, by means of long, slender tendinous processes. From each tendon arises a fasciculus composed of nearly parallel fiber-bundles. The fasciculi soon fuse to form a muscle-belly which contracts somewhat toward the insertion. This takes place by means of a tendon which sends a fibrous lamina a short distance upward on the outer surface of the muscle. The tendon is *inserted* into the scalene tubercle on the upper surface of the body of the first rib.

The scalenus medius.—This *arises* usually from the third to the seventh, sometimes from all seven or from merely the last four or five cervical vertebræ. The origin take place from the posterior part of the lateral border of the transverse processes by means of a slender tendon from each of the upper and directly by a muscular fasciculus from each of the lower vertebræ. The fasciculi become combined into a compact muscle-belly which is *inserted* in a manner similar to the scalenus anterior into the upper surface of the first rib behind the subclavian groove. The insertion usually extend to the second rib.

The **scalenus posterior** *arises* by short tendons from the posterior tubercles of the transverse processes of the fifth and sixth cervical vertebræ. The origin may extend as high as the fourth vertebra, for as low as the seventh. It is *inserted* by a short tendon into the lateral surface of the second rib. Occasionally it extends to the third rib.

Nerve-supply.—The scalenus anterior is innervated by branches from the fifth, sixth, and seventh cervical nerves; the middle by the fourth, fifth, sixth, seventh, and eighth cervical nerves; the posterior by the seventh or eighth nerves.

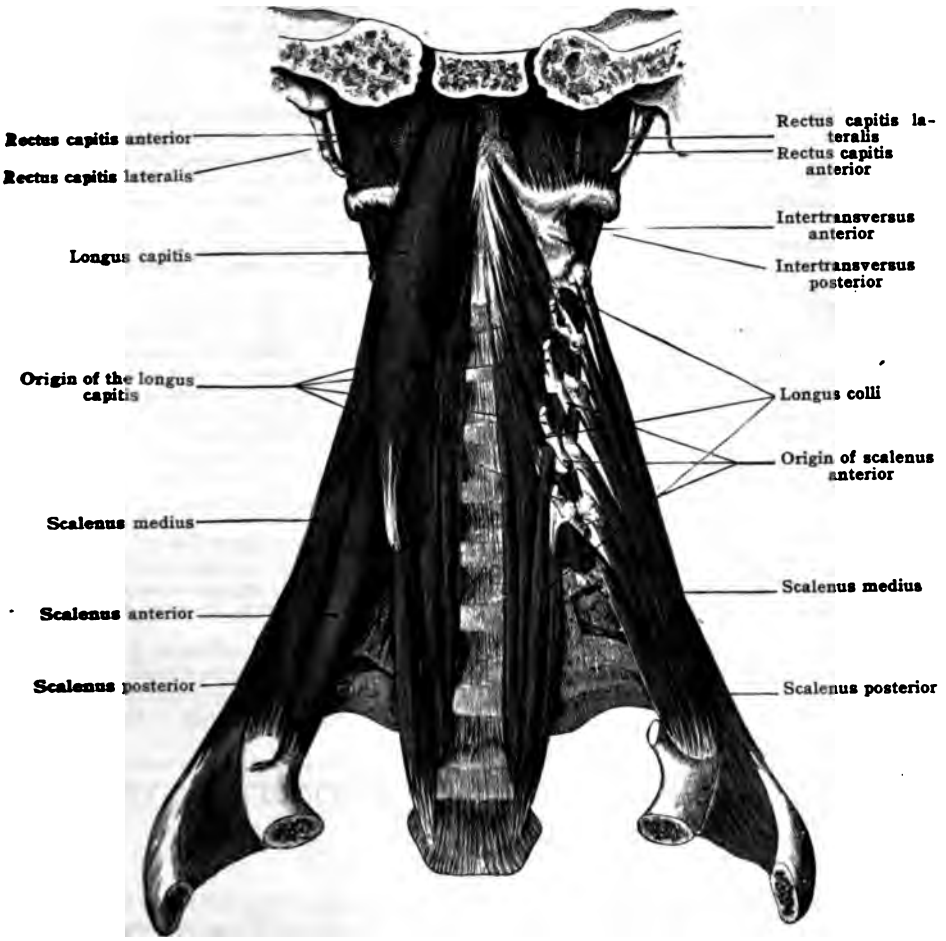
Action.—With the thorax fixed the scalene muscles bend the neck to the side and slightly forward and turn it slightly toward the opposite side. With the neck fixed they serve to lift the first two ribs and are of use in enforced inspiration. In quiet inspirations they serve to fix the first two ribs.

Relations.—The longus colli lies medial to the scalenus anterior. Dorsally the scalene muscles; medially the pharynx, thyroid gland, and trachea; ventrolaterally the sternocleidomastoid, infrahyoid, and subclavius muscles and the clavicle bound a space filled with dense fatty areolar tissue in which are contained the subclavian and carotid arteries, the subclavian and internal jugular veins, the vagus, phrenic, and sympathetic nerves, and numerous smaller blood-vessels and nerves. The main branches of the lower five cervical nerves pass laterally between the scalenus anterior and medius. The subclavian artery passes behind, the subclavian vein in front, of the attachment of the scalenus anterior. The scalenus medius above and the scalenus posterior below enter into relations dorsally with the levator scapulæ and the intrinsic dorsal musculature, from which they are separated by fascial septa.

Variations.—The scaleni present numerous variations in the extent of the costal and vertebral attachments. The degree of fusion of the various fasciculi likewise varies so much that different authors have described varying numbers of muscles into which the scalenus mass should be subdivided. A muscle frequently present is the **scalenus minimus.** This arises

from the anterior tubercle of the sixth or sixth and seventh cervical vertebræ, and is inserted into to the first rib behind the sulcus for the subclavian artery. It sends a process (Sibson's fascia) to the pleural cupola and serves to make the pleura tense. Zuckerkandl found it in 22 out of 60 bodies on both sides; 12 times on the right side only, 9 times on the left. It is innervated by the eighth cervical nerve. When absent, a ligamentous band takes its place. An *intertransversarius lateralis longus*, may extend from the posterior tubercles of the 3–5 transverse processes to the tip of the seventh transverse process and divide the muscle fasciculi near their origin into dorsal and ventral divisions.

FIG. 383.—THE DEEP VENTRAL MUSCLES OF THE NECK.



8. THE PREVERTEBRAL MUSCULATURE

(Fig. 383)

This deep-seated musculature extends along the ventrolateral surfaces of the three upper thoracic and the cervical vertebræ to the skull. It is composed of two muscles. **The longus colli** arises from the bodies of the first three thoracic and last three cervical vertebræ, and from the transverse processes of the third to the sixth cervical vertebræ. It is inserted into transverse processes and bodies of the cervical vertebræ. **The longus capitis** (rectus capitis anterior major) arises from the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ and is inserted into the basilar process of the occipital bone. These muscles flex, abduct, and rotate the head and neck. All of them are supplied by direct branches from the anterior divisions of the cervical nerves. They are probably specialized from the ventrolateral portions of the cervical myotomes Similar muscles are found in all vertebrates with well-developed necks. The rectus capitis anterior (minor) represents an anterior cervical intertransverse muscle.

FASCIA

The muscles are firmly bound to the vertebral column by the prevertebral fascia described in connection with the scalene muscles and by the septa which extend in between the muscles of this group and between them and the scalenus anterior.

MUSCLES

(Fig. 383)

The **longus colli.** This muscle may be compared to a triangle, the base of which extends from the anterior tubercle of the atlas to the body of the third thoracic vertebra and the apex of which is the transverse process of the fifth cervical vertebra. The complex construction of the muscle makes it advisable to consider it as divided into three parts.

The **superolateral portion** consists of fasciculi which arise from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ and from the body of the third thoracic and become fused into a belly which is inserted into the anterior tubercle of the atlas.

The **medial portion** is formed of muscle fasciculi which arise from the anterolateral parts of the bodies of the first three thoracic vertebræ and the last three cervical vertebræ by tendinous processes. These fasciculi fuse into a belly which terminates by three flat tendinous fasciculi on the anterolateral surfaces of the bodies of the second, third, and fourth cervical vertebræ.

The **inferolateral portion** is applied to the inferior lateral surface of the medial portion. It arises from the lateral parts of the bodies of the first three thoracic vertebræ and is inserted by tendinous processes into the transverse processes of the fifth and sixth cervical vertebræ.

Nerve supply.—By branches from the second to sixth cervical nerves which supply the various constituent fasciculi of the muscle.

The **longus capitis** (rectus capitis anterior major).—Origin.—By cylindrical tendons from the tips of the anterior tubercles of the third, fourth, fifth, and sixth cervical vertebræ. The tendons send up aponeurotic expansions on the outside of the fasciculi which arise from them. These fasciculi fuse into a dense muscle belly to which is usually added a fasciculus from the longus colli. The [illegible] the impression on the inferior surface of the basilar portion of the occipital bone [illegible] lateral to the pharyngeal tubercle. [illegible]

[illegible]

Variations. [illegible]

ANTERIOR AND LATERAL INTERTRANSVERSE

.—To flex the head laterally.
ns.—In front lie the anterior primary division of the suboccipital nerve and the ugular vein. Behind the muscle lie the superior oblique and the longissimus capitis nastoid) muscles and the atlanto-occipital joint.

EEP MUSCULATURE OF THE SHOULDER-GIRDLE

(Figs. 379, 384, 385, 419)

his group belong four muscles which arise in the lateral cervical region mbryonic development and become secondarily attached to the vertebral of the scapula. One of these muscles, the band-like **levator scapulæ**), remains in the cervical region. It extends beneath the sternocleido-, the trapezius, and the intervening fascia from the transverse processes st four cervical vertebræ to the medial angle of the scapula. A second, , quadrilateral **serratus anterior** (magnus) (figs. 384, 385), comes to lie the scapula and wanders with this to the thoracic region. It arises, in the om the first nine ribs and is inserted into the vertebral margin of the

The flat, quadrangular **rhomboideus major** and **rhomboideus minor**) arise from the spines of the last cervical and first four or five thoracic , pass obliquely downward across the deep dorsal muscles beneath the s and are inserted into the vertebral margin of the scapula. The third venth cervical nerves supply this set of muscles. The levator scapulæ is by the third and fourth cervical nerves, the rhomboids by the fifth capular), the serratus anterior by the fifth to the seventh (long thoracic The muscles of this group elevate the scapula, rotate it, and draw it d (rhomboidei) or forward (serratus anterior). When all contract to-ney raise the thorax.

vator scapulæ and the serratus anterior (magnus) are two differentiated parts of a nich is a continous mass in many of the lower mammals. A muscle corresponding mboideus is found in some of the reptiles and many of the higher vertebrates. In ie mammals it has a more extensive cervical attachment than in man.

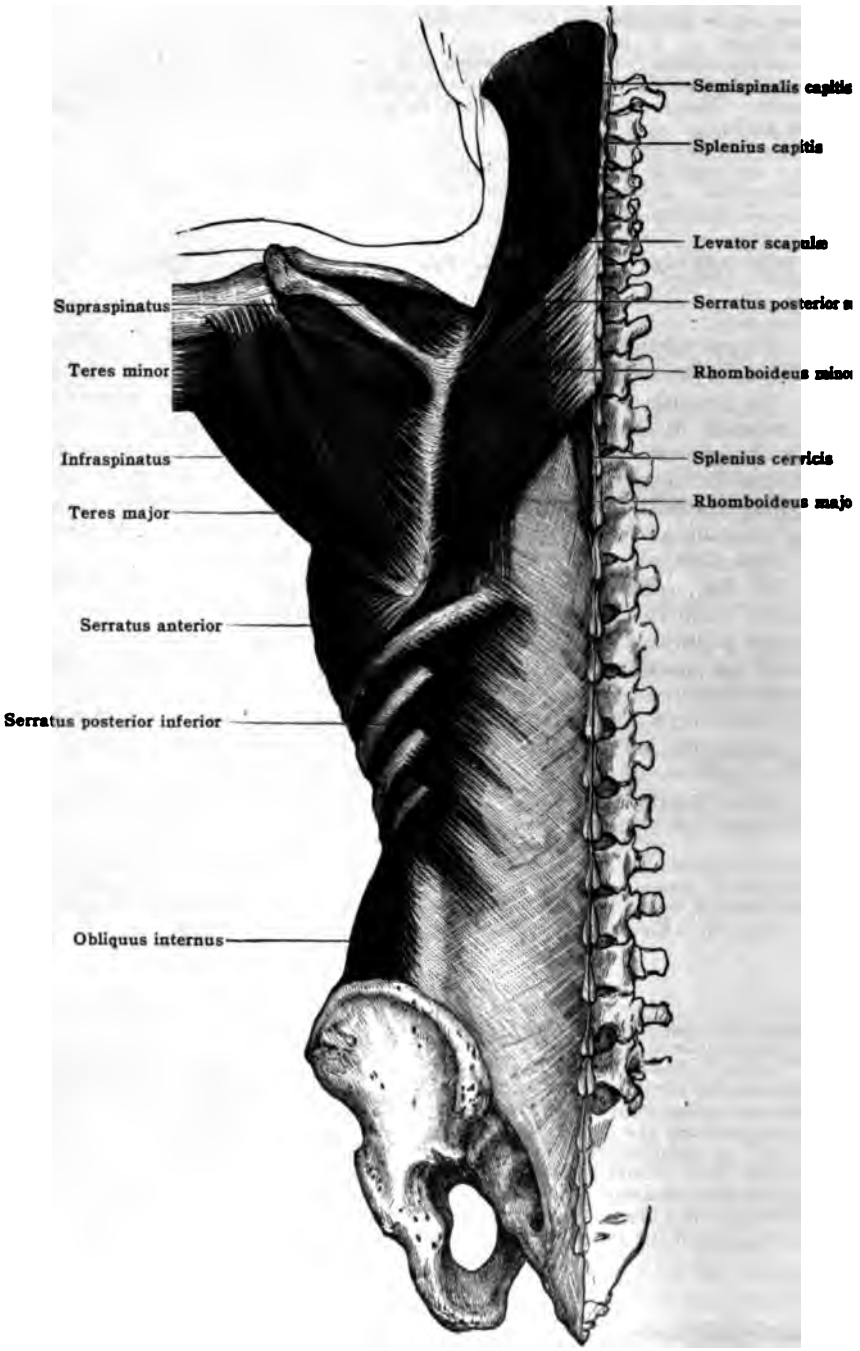
FASCIÆ

scia investing these muscles are shown in cross-section in fig. 388.
vator scapulæ is invested by fascial membranes, the external and stronger of which ied dorsally from the fascial investment of the scalene muscles. The thinner layer p surface lies next the fascial investment of the intrinsic muscles of the back. Cranial-n the rhombbid muscles the fascial investment of the levator scapulæ is fused dorsally **fascia** covering the splenius cervicis. Where the dorsal margin of the levator comes

spines the muscles arise by an aponeurosis which varies in width. The attachment to the ula is by short tendinous processes. The attachment of the rhomboideus major is firm ward the inferior angle of the scapula.

Nerve-supply.—The dorsal scapular nerve, which usually arises chiefly from the cervical nerve, enters the superior margin of the rhomboideus minor and then courses down

FIG. 384.—LEVATOR SCAPULÆ AND RHOMBOID MUSCLES.



near the deep ventral surface of the two muscles and about midway between the tend origin and insertion.

Action.—The two muscles drawn the scapula upward and medialward toward the spi rotate it so as to depress the shoulder.

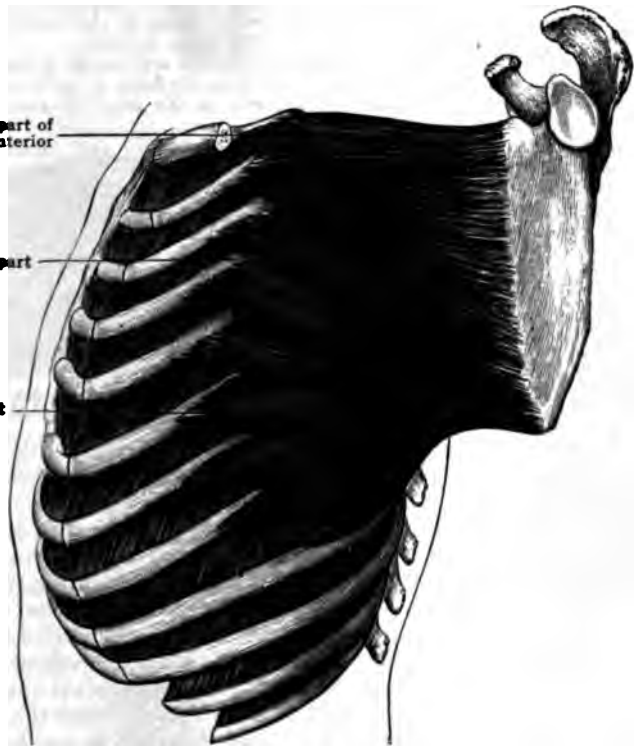
Relations.—Over the muscles lies the trapezius. Under them lie the serratus po rior and the splenius cervicis, the longissimus dorsi, the iliocostalis, levatores co

and external intercostal muscles. The descending ramus of the transverse cervical artery descends on the deep surface. Blood-vessels for the trapezius pass to this muscle between the two rhomboids.

Variations.—There is much variation in the extent of the vertebral attachment. The minor is frequently, the major occasionally, absent. The two rhomboids are frequently fused with one another or may be divided into several distinct fasciculi. Frequently (80 per cent., Balli) a fasciculus extends obliquely on the deep surface of the *R.* major from the cranial part of the origin to the distal part of the insertion. Slips may be sent to the latissimus dorsi or the teres major. An accessory slip may pass between the trapezius and splenius muscles to the occipital bone (**occipito-scapularis**). A muscle corresponding to this fasciculus is normally found in many mammals.

The **levator scapulæ** (figs. 384, 419).—*Origin.*—By short tendons from the dorsal tubercles of the transverse processes of the first four cervical vertebræ, between the attachments of the splenius cervicis and scalenus medius muscles. The tendons from the third and fourth cervical vertebræ are fused for a short distance with those of the longissimus cervicis. *Structure and*

FIG. 385.—SERRATUS ANTERIOR.



insertion.—The fibers run in parallel bundles in a dorsolateral direction downward to the vertebral border of the scapula opposite the supraspinous fossa. The fiber-bundles are inserted directly into the periosteum. As a rule, the flat fasciculi arising from the different vertebræ are easily separated.

Nerve-supply.—By rami chiefly from the third and fourth cervical nerves. These rami enter the ventral margin of the muscle and extend obliquely across the dorsal surface of the constituent fasciculi about midway between the tendons of origin and insertion. Frequently anastomosing branches pass between the nerves. The lowest fasciculus is usually supplied by branches from the nerve to the rhomboid muscles (dorsal scapular).

Action.—Draws the scapula upward and tends to rotate it so that the inferior angle approaches the spine. When the scapula is fixed, the muscle serves to bend the neck laterally and slightly to rotate it toward the same side and extend it.

Relations.—Externally the sternocleidomastoid and, in part, the splenius capitis cover it above; the trapezius, below; and the external cervical fascia, its middle portion. Internally lie the splenius cervicis, longissimus and iliocostalis cervicis (transversalis cervicis), and serratus posterior superior muscles and the ramus descendens of the transversa colli artery. In front lie the scalene muscles.

Variations.—The number of cervical vertebræ from which the muscle springs varies from two to seven. The most constant are the slips of origin from the first two vertebræ. The muscle may send slips to the temporal or the occipital bone or to the trapezius, the serratus anterior (magnus), serratus posterior superior, and other muscles, or to the clavicle, first or second rib, etc. Often the parts of the muscle running to each vertebra are separated for the whole distance. A bundle of fibers that appears to be a detached slip of the levator scapulæ may run from the first two or from lower cervical vertebræ to the lateral end of the clavicle and

to the acromion. This represents the **levator claviculæ** found normally in many vertebrates. According to Le Double, it is innervated by a branch from the cervical branches to the trapezius group.

The **serratus anterior** (magnus) (figs. 385, 419).—*First Part.*—The origin is by two digitations from the first and second ribs and from a fibrous arch uniting these two attachments. The fiber-bundles converge to be inserted on an oval space on the costal surface of the scapula near its medial angle. *Second Part.*—This arises by two or three digitations from the second, third, and sometimes the fourth ribs. The fiber-bundles spread out into a thin sheet which is inserted along the vertebral border of the scapula. *Third Part.*—This, the strongest part of the muscle, arises by digitations from the fourth or fifth to the eighth or ninth ribs. The attachments of the digitations are longest on the upper border of each rib They interdigitate with the attachments of the external oblique muscle of the abdomen. The fiber-bundles converge to be inserted on the large oval space on the costal surface near the inferior angle of the scapula.

Nerve-supply.—From the proximal portions of the anterior divisions of the fifth, sixth, seventh, and sometimes the eighth cervical nerves branches arise which fuse into the long thoracic nerve. This nerve usually passes laterally through or behind the scalenus medius muscle, courses along the outer surface of the serratus anterior midway between the origin and insertion, and gives rise to numerous twigs to supply the various divisions. The fibers to the upper portion come mainly from the fifth cervical nerve; those to the middle from the fifth and sixth; and those to the lower from the sixth and seventh.

Action.—The muscle holds the scapula against the thorax and draws it forward and laterally and, by its highly developed inferior portion, rotates the bone so as to raise the point of the shoulder. It is of especial importance in abduction of the arm. It also aids, to a slight degree, in forced inspiration.

Relations.—Superficial to the muscle lie the pectoralis major and minor, subscapularis, teres major, and latissimus dorsi muscles, the subclavian and axillary vessels, and the brachial plexus. Between the latissimus dorsi and pectoral muscles it is covered by skin and fascia inferiorly, and superiorly by the fatty areolar tissue of the axillary fossa. Under it lie the external intercostal, serratus posterior superior, and the lower extremity of the scalenus medius and posterior muscles.

Variations.—The digitations may extend to the tenth or only to the seventh rib. The muscle may be continuous with the levator scapulæ as it is in the carnivora, or some of its upper digitations may be wanting. Slips may be continued into neighboring muscles. The lower digitations may be partially replaced by digitations innervated by intercostal nerves.

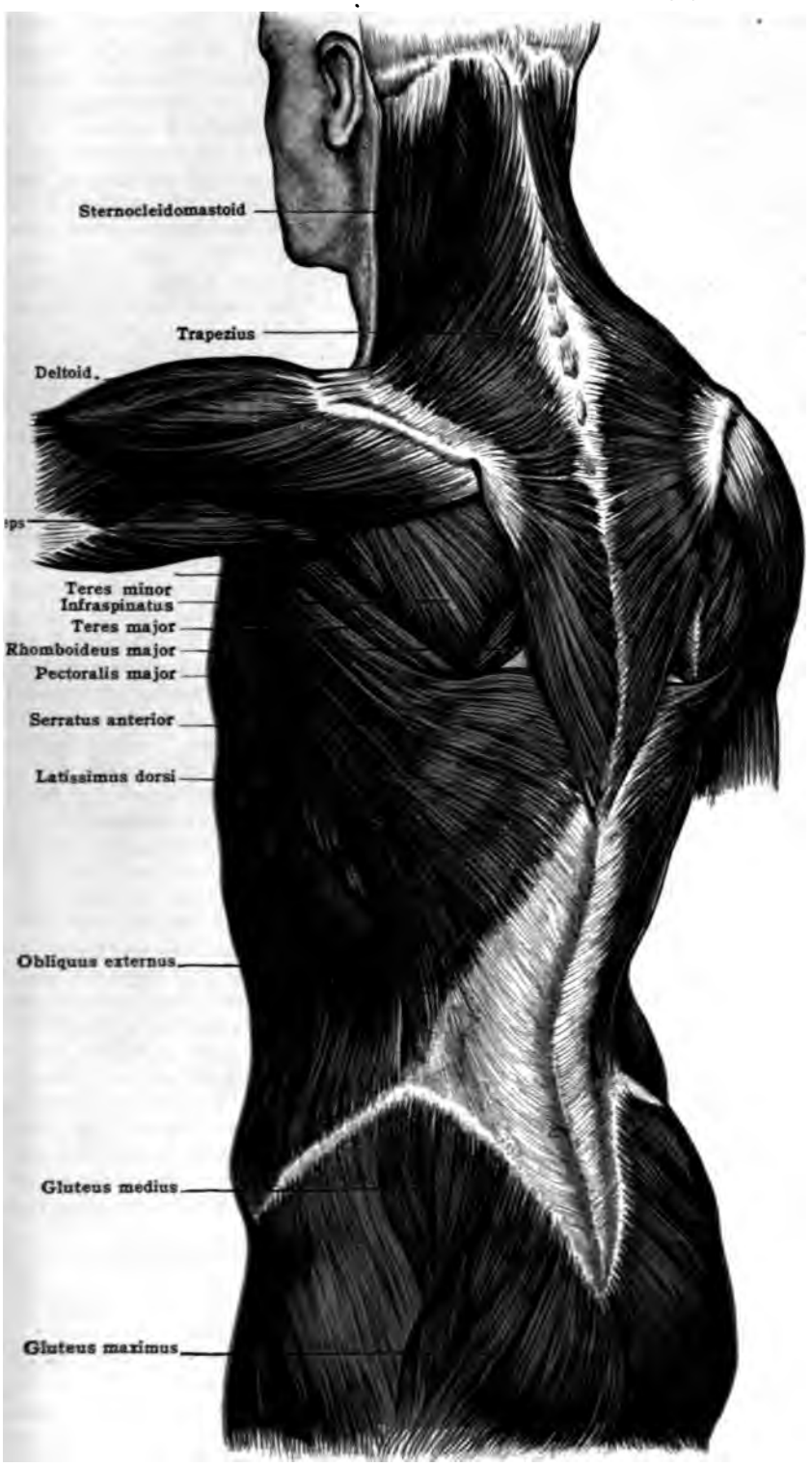
II. MUSCULATURE OF THE UPPER LIMB

The upper limbs in man, relieved of the function of locomotion which is their chief office in most of the lower mammals, have become endowed with great freedom of movement which permits their developing many important functions. Primitively of value in climbing, in seizing food, preparing it for eating and carrying it to the mouth, in attack and defense, their importance has been greatly increased through the invention and use of tools, at first simple but constantly increasing in complexity. They are also used as a means of social expression, as seen primitively in the shrugging of the shoulders, or in the varied movements of the arms which accompany heated discourse, and as finally developed in the art of writing. In order to understand the muscles which are called into play in the performance of these varied functions it is necessary to consider the various types of movement which take place at each of the joints. Since, however, most muscles act on more than one joint and the different parts of a muscle may act differently on the same joint, it is convenient to take up the muscles of each region of the limb in groups, based not so much upon the action of the muscles on any one joint as upon the development of the group and the innervation of the muscles composing it.

Physiology.—Movement of the scapula is of essential importance in the movements of the arm. The scapula is kept against the thorax by muscular attachments and atmospheric pressure, but it may be moved forward, backward, upward, and downward, and may be rotated so that the glenoid fossa, with which the head of the humerus articulates, is pointed forward when the arms are carried forward, lateralward when the arms are abducted, upward when the arms are raised high and somewhat downward when the arms are carried backward, thus greatly increasing the extent of movement in these various directions. The acromioclavicular and sternoclavicular joints both allow limited movements in various directions so that they resemble physiologically limited ball and socket joints. The part played by the superficial and deep shoulder-girdle muscles in the various movements has been described above in connection with these groups of muscles. The action of these muscles is aided by the pectoral muscles, (fig. 391) and by the latissimus dorsi (fig. 386) described below. These muscles depress the scapula. The upper sternal part of the pectoralis major, however,

ɾ alone elevates the scapula; the lastissmus dorsi draws the scapula back-
, the pectoral muscles draw it forward.
t the humeroscapular or shoulder-joint the arm may be carried outward or
cted, bodyward or adducted, forward or flexed and backward or extended.

FIG. 386.—FIRST LAYER OF MUSCLES OF THE BACK.



The last is much more limited in degree than the other two. The arm may also be partially rotated at this joint. These various movements are brought about by the scapulohumeral muscles (figs. 386, 387, 394) and by the latissimus dorsi (fig. 386) and the pectoralis major (fig. 391), assisted by the muscles of the arm which arise from the scapula. They are produced in association with the movements of the scapula described above. At the ulnohumeral joint the movements are relatively simple, consisting of flexion and extension. Extension is produced at the elbow by the dorsal muscles of the arm (fig. 394), flexion is produced not only by the ventral muscles of the arm, which are inserted into the radius and ulna (fig. 395), but also by the more superficial of both the main groups of muscles of the forearm. The pronation of the forearm, whereby the palm is turned downward, and supination, whereby it is turned upward, take place in the joints between the radius and ulna at each extremity and between the radius and the lower end of the humerus. At the upper radioulnar joint the radius is turned on its long axis, at the lower joint it is carried about the lower end of the ulna. Pronation is produced chiefly by muscles belonging to the ulnovolar group of forearm muscles (fig. 401); supination is produced by the biceps of the arm (fig. 395) in conjunction with some of the muscles of the radio-dorsal group of the forearm (fig. 398). At the wrist joints (radiocarpal, intercarpal), the movements are those of flexion, extension, radial abduction and ulnar abduction. Volar flexion takes place chiefly at the radiocarpal joint, dorsal flexion at the intercarpal joint (Frohse). Extension is produced by those muscles of the radiodorsal group of the forearm which send tendons to the wrist and digits, flexion by the corresponding muscles of the ulnovolar group, radial abduction is produced by the radial carpal extensor muscles (fig. 398), and ulnar abduction by the ulnar carpal extensor and flexor (fig. 401). The varied movements of the thumb and fingers, flexion, extension, abduction, and adduction are produced partly by muscles of the two chief groups of forearm muscles, partly by the intrinsic muscles of the hand. Of chief interest here are the free movements of the metacarpal of the thumb and the limited movements of the other metacarpals, that of the little fingers being the most movable, as seen in spreading or cupping the hand. In flexion and extension of the metacarpal of the thumb the movement is such as to bring the thumb into opposition to the fingers. In the metacarpophalangeal joints those of the fingers admit of much greater freedom of movement, flexion, extension, abduction, and adduction, than that of the thumb. The interphalangeal joints are pure hinge joints and permit merely flexion and extension.

Divisions.—The muscles described in this section as the muscles of the upper limb are all differentiated from the blastema of the embryonic limb bud. Most of them are differentiated in connection with the skeleton of the limb and extend between the various bones which compose it, but a few grow out from the limb bud over the trunk and become secondarily attached at one extremity to the trunk, while the other extremity remains attached to the skeleton of the limb. Thus the pectoral muscles (fig. 391), extend from the limb bud over the front of the thorax and the latissimus dorsi extends over the side and back of the trunk as far as the iliac crest (fig. 386). The muscles of the limb may be divided into two great divisions, a dorsal division, innervated by nerves arising from the back of the brachial plexus (supra- and subscapular, axillary and radial nerves) and a ventral division innervated by nerves arising from the front of the plexus (subclavian, anterior thoracic, musculocutaneous, median and ulnar). The former, which correspond with the musculature on the back of the shark's fin, are in the main extensors; the latter, which correspond with the musculature on the front of the shark's fin are in the main flexors. The bellies of the muscles of each division are found in the region of the shoulder and thorax, the arm, the forearm, and the hand.

The **shoulder muscles** belong to the dorsal division, the **pectoral** to the ventral division. In the **arm** the **dorsal division** is represented by the triceps and anconeus (fig. 394). The **ventral division** is made up of the coracobrachialis (fig. 396); the biceps (fig. 395); and the brachialis (fig. 396). The two main divisions of the musculature of the **forearm** give rise to the prominences on each side of the elbow-joint. Their peculiar arrangement with respect to the humerus is because in man, as in most tetrapods, the normal position of the forearm is one of pronation and in this position the back of the forearm is in line with the

icondyle, the front with the ulnar epicondyle. The dorsal or extensor springing from the lower end of the humerus (fig. 398), get the most rchase when attached to the radial epicondyle, and the ventral or flexor (fig. 401), the most direct purchase when attached to the ulnar epicondyle. divisions of the musculature may therefore here be designated the radio- nd the ulnarvolar or volar divisions. The main bulk of the muscula- ound in the upper part of the forearm. At the wrist numerous tendons r to the wrist, palm and digits. This arrangement facilitated move- the hand. In the **hand**, all intrinsic muscles belong to the **volar** division.

.—The muscle fasciæ of the upper extremities are well developed. The deltoid imus dorsi are contained in a fascial sheet which extends between them. The deeper hich arise from the scapula are covered by strong fasciæ. Of the pectoral muscles the major is covered by a delicate fascia, while the subclavius and pectoralis minor are within the dense *costocoracoid membrane* (fig. 389) which extends into the fascia the axillary fossa. The latter (fig. 390), is thin and is intimately fused to the tela a. The muscles of the arm are enveloped in a cylindrical sheath which in the lower e arm is united to the humerus by intermuscular septa.

forearm near the wrist and on the back of the hand the tela subcutanea contains The antibrachial fascia forms a cylindrical enclosure for the muscles of the forearm. wrist it becomes strengthened dorsally to form the dorsal ligament of the carpus annular ligament). This ligament converts the grooves on the back of the radius s for the tendons of the extensors of the wrist and fingers. On the back of the hand s the fascia is intimately connected with these tendons. On the volar side near the fascia is strengthened to form the volar ligament of the carpus. Beneath the ligament ansverse ligament of the carpus which extends from the pisiform and hamate bones to sities of the navicular and greater multangular bones. It completes an osteofibrous the tendons of the long flexors of the fingers. On the palm of the hand the fascia is nd to the bones by intermuscular septa, which separate the thenar and hypothenar om a central palmar region. On the volar sides of the fingers the fascia forms the gaments of the flexor tendons.

A. MUSCULATURE OF THE SHOULDER

(Figs. 386–388, 394, 419)

muscles belonging to this group are the deltoid, the teres minor, the infra- raspinatus, the latissimus dorsi, the teres major, and the subscapularis. **deltoid** (fig. 386) is a large, shield-shaped muscle which covers the shoul- arises from the spine of the scapula, the acromion, and lateral third of the and is inserted into the deltoid tubercle of the humerus. It abducts nd extends the arm.

teres minor, infra- and supraspinatus form a group of muscles (fig. 394) rise from the back of the scapula, pass over the capsule of the shoulder- s which their tendons are adherent, and, under cover of the deltoid, are l into the top and the dorsal margin of the great tubercle of the humerus. nd-like **teres minor** arises from the upper two-thirds of the axillary border scapula, and has the lowest insertion on the tubercle. The triangular **natus** (fig. 394) arises from the whole infraspinous fossa except the axillary and is inserted above the teres minor. The pyramidal **supraspinatus** 4) arises under cover of the trapezius from the supraspinous fossa, and highest insertion on the tubercle. The teres minor, supraspinatus and natus act as lateral rotators of the arm, the supraspinatus also as an or.

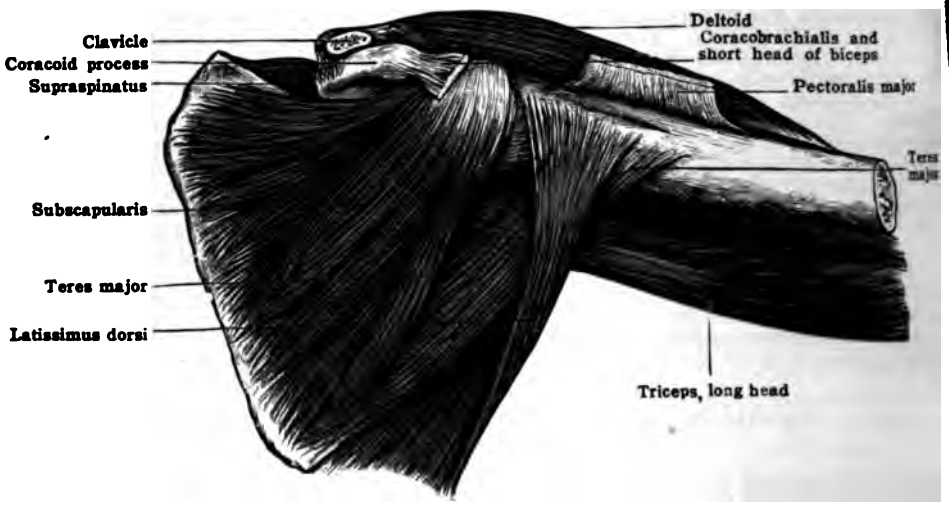
latissimus dorsi, the teres major, and the subscapularis form a group of attached to the lesser tubercle of the humerus and to the crest which distally from this on the medial side of the intertubercular (bicipital)

The **latissimus dorsi** (figs. 386, 387) is a large, flat, triangular muscle, rises from an aponeurosis covering the lumbar and the lower half of the regions of the back and from the posterior part of the iliac crest, and is l into the intertubercular (bicipital) groove. The **teres major** (figs. 7) is a thick, ribbon-shaped muscle which arises from the dorsal surface of rior angle of the scapula and is inserted behind the latissimus dorsi into tal two-thirds of the crest of the small tubercle of the humerus. The **ularis** (fig. 387) is a thick, triangular muscle which extends from the ular fossa to the small tubercle of the humerus. These muscles adduct and rotate it medialward. The latissimus dorsi is also the chief extensor rm.

Near their humeral attachments these two groups of muscles are separated below by the long head of the triceps. The supraspinatus is separated from the subscapularis by the base of the coracoid process and by the intertubercular (bicipital) groove. The tendons of the latissimus dorsi, teres major, and subscapularis are crossed ventrally by the main vessels and nerves of the arm and by the short head of the biceps and the coracobrachialis.

The supra- and infraspinatus muscles are supplied by the suprascapular nerve. The deltoid and the teres minor are supplied by the axillary (circumflex). The subscapularis, the teres major, and the latissimus dorsi are supplied by subscapular nerves. That to the latissimus dorsi is called the thoracodorsal nerve.

FIG. 387.—FRONT VIEW OF THE SCAPULAR MUSCLES.



The deltoid in many of the mammals and the lower vertebrates is represented by separate scapulohumeral and cleidohumeral portions. The cleidomastoid in some mammals is continued into the deltoid. The teres minor, which is innervated by the same nerve, may be looked upon as a derivative of the deltoid although in man it is anatomically more intimately connected with the infraspinatus. The teres major may be looked upon as a specialised portion of the more primitive latissimus dorsi. The comparative anatomy of the shoulder muscles throughout the vertebrate series is a somewhat intricate subject, owing to the great variations exhibited in the form and attachment of the shoulder girdle.

The muscles of this group show more or less marked resemblances to certain muscles of the lower limb. The deltoid and the teres minor probably represent the tensor fasciæ latæ, the gluteal fascia, and the upper part of the gluteus maximus; the latissimus dorsi and teres major, the lower portion of the gluteus maximus; and the subscapularis, the gluteus medius and minimus, and the piriformis. The subscapular and axillary nerves, which supply the arm muscles mentioned, therefore represent in the main the nerves to the gluteal muscles, and the gluteal branch of the posterior cutaneous nerve of the thigh. The infraspinatus muscle probably represents the iliacus; the supraspinatus possibly the pectineus muscle of the lower limb.

FASCIÆ

(Figs. 382, 388, 389, 390, 393)

The **tela subcutanea** covering the regions occupied by these muscles contains considerable fat. In most regions it is not readily separable into two distinct layers. In the neighborhood of the shoulder-joint it is adherent to the underlying musculature and the axillary fasciæ. Over the acromion there is a well-marked subcutaneous bursa, **bursa subcutanea acromialis.**

Muscle fasciæ.—The deltoid and latissimus dorsi muscles are throughout the greater part of their extent superficially placed. They are covered by an adherent fascial layer, which above is attached to the clavicle and to the spine of the scapula. Ventrally it is continued over and fuses with the fascia covering the pectoralis major, serratus anterior, and external oblique muscles. On the back it extends as a thin sheet between the dorsal margin of the deltoid and the upper margin of the latissimus dorsi, and is continued dorsally into the fascial investment of the rhomboid muscles. The lateral fascial extension of the trapezius becomes fused to the dorsal surface of this sheet. Toward the armpit the fascial investment of the deltoid and latissimus dorsi muscles is continued into the axillary fascia, and on the back of the arm it is continued into the fascial investment of the triceps.

The supraspinatus muscle lies beneath the trapezius. It is covered by a dense adherent fascial layer which is separated from the trapezius by loose connective tissue which usually contains a considerable amount of fat.

ıfraspinatus and the two teres muscles lie beneath the musculofascial layer composed ltoid, the latissimus dorsi, and the fascial sheet described above. Each of the three ıas a special fascal investment which is bound to the scapula about the region of attach- the muscle to the bone Where two of the muscles adjoin, their fasciæ give rise to ular septa. Septa of this nature are found between the infraspinatus and each of the scles, and between the teres minor and the teres major. The intermuscular septum the infraspinatus and teres minor muscles is often incomplete. The fascia covering major is so delicate as hardly to deserve the name, except near the origin of the muscle. spine the fascia covering the deep surface of the deltoid is often fused to that covering spinatus.

ubscapularis muscle is invested by a moderately dense fascia which is bound to the long the periphery of the attachment of the muscle. For a short distance this fascia ith the fascial investment of the teres major near the origin of the latter muscle, so that ıuscular septum is formed. From the ventrolateral margin of the fascia covering the laris muscle a sheet of fascia is contained below the axillary fascia into the fascia cover- ɜrratus anterior (magnus).

SHOULDER MUSCLES

leltoideus (figs. 386, 387, 391).—*Origin.*—Fleshy from the lateral border and upper f the acromion and from the ventral border and upper surface of the lateral third of the and tendinous from the spine of the scapula. Some fiber-bundles also at times arise deep fascia of the muscle where it overlies and is fused to the fascia of the infraspinatus ear the spine.

ion.—Into the deltoid tuberosity of the humerus by a strong tendon arising from s tendinous bands within the muscle (fig. 395).

ure.—In structure the deltoid muscle is complex. Three portions may be recognized: cular, an acromial, and a spinous. The first and last are composed of long fiber-bundles ke a slightly converging course and are inserted by aponeurotic tendons respectively ont and back of the V-shaped area of insertion of the muscle. The acromial portion, ther hand, is multipenniform in composition. Four or five tendinous expansions nto the muscle from the acromion, and three up into the muscle from the tendon of in- From the acromion and from the descending tendinous processes fiber-bundles run to ed on the sides of the ascending processes and into the tendons of insertion of the clavi- l spinous portions of the muscle.

-supply.—The axillary (circumflex) nerve passes across the costal surface of the ear the tendon of insertion and gives off rami which enter lateral to the middle of the The nerve fibers are derived from the (fourth), fifth, and sixth cervical nerves.

n. When the whole muscle contracts, the arm is abducted (raised laterally), to a al position. When the clavicular and acromial parts act, the arm is raised and flexed forward toward the chest). When the acromial and spinous parts act, the arm is id extended (carried toward the back), but in this instance the arm is not brought to a h the shoulder-joint, but only about 45° from the hanging position. The inferior part ɜrratus anterior and the trapezius act in conjunction with the deltoid in abduction. ɔn is greatest when the arm is rotated lateralward. The ventral portion rotates the dially, the dorsal portion laterally. When the arm is fixed, the deltoid carries ior angle of the scapula toward the spinal column and away from the thorax.

ions.—On its ventral border the deltoid is in contact with the pectoralis major muscle. e clavicle the cephalic vein and a small artery pass between the two muscles. Its dorsal s continued into a dense fascial sheet which overlies the infraspinatus muscle. Its ɔf insertion passes between the biceps and triceps muscles. The deltoid overlies the process and upper extremity of the humerus, the coracoclavicular and coraco acromial s, and the insertions of the supraspinatus, infraspinatus, and teres minor muscles, the f the biceps and coracobrachialis, and a part of the long and lateral heads of the triceps. it run the posterior circumflex artery and axillary (circumflex) nerve.

ıtions.—The clavicular portion is frequently separate from the rest of the muscle. The rtions may be distinctly separate—a condition normal in some of the lower mammals. icular and acromial portions have been found missing. The deep portion of the muscle separated as a distinct layer and inserted either into the capsule of the joint or into . Accessory fasciculi may pass into the muscle from the fascia over the infraspinatus ı the vertebral and axillary borders of the scapula. Not infrequently fasciculi are con- ıto the muscle from the trapezius—a condition normal in animals with ill-developed . An accessory tendon of insertion may extend to the radial side of the forearm. of fibers from the axillary border of the scapula have been seen to cross the deep surface leltoid and be inserted into the deltoid fascia. The deltoid may be fused with neigh- ıuscles, the pectoralis major, trapezius, infraspinatus, brachialis, brachioradialis.

teres minor (fig. 394).—*Origin.*—From the upper two-thirds of the axillary border of ıspinous fossa, and from the septa lying between it and the infraspinatus on the one the teres major and subscapularis on the other. The origin is in part fleshy, in part aponeurotic band on its ventral surface toward the subscapularis muscle.

ture and insertion.—The fiber-bundles from this origin take a slightly converging course a tendon of insertion which extends for some distance on the dorsal surface of the The muscle is adherent to the capsule of the joint, and terminates on the inferior of e facets of the great tubercle of the humerus and the posterolateral aspect of that two or three centimeters below the facet.

-supply.—From a branch of the axillary (circumflex) nerve which enters the muscle on al margin about midway between its extremities. A 'ganglion' is usually found upon

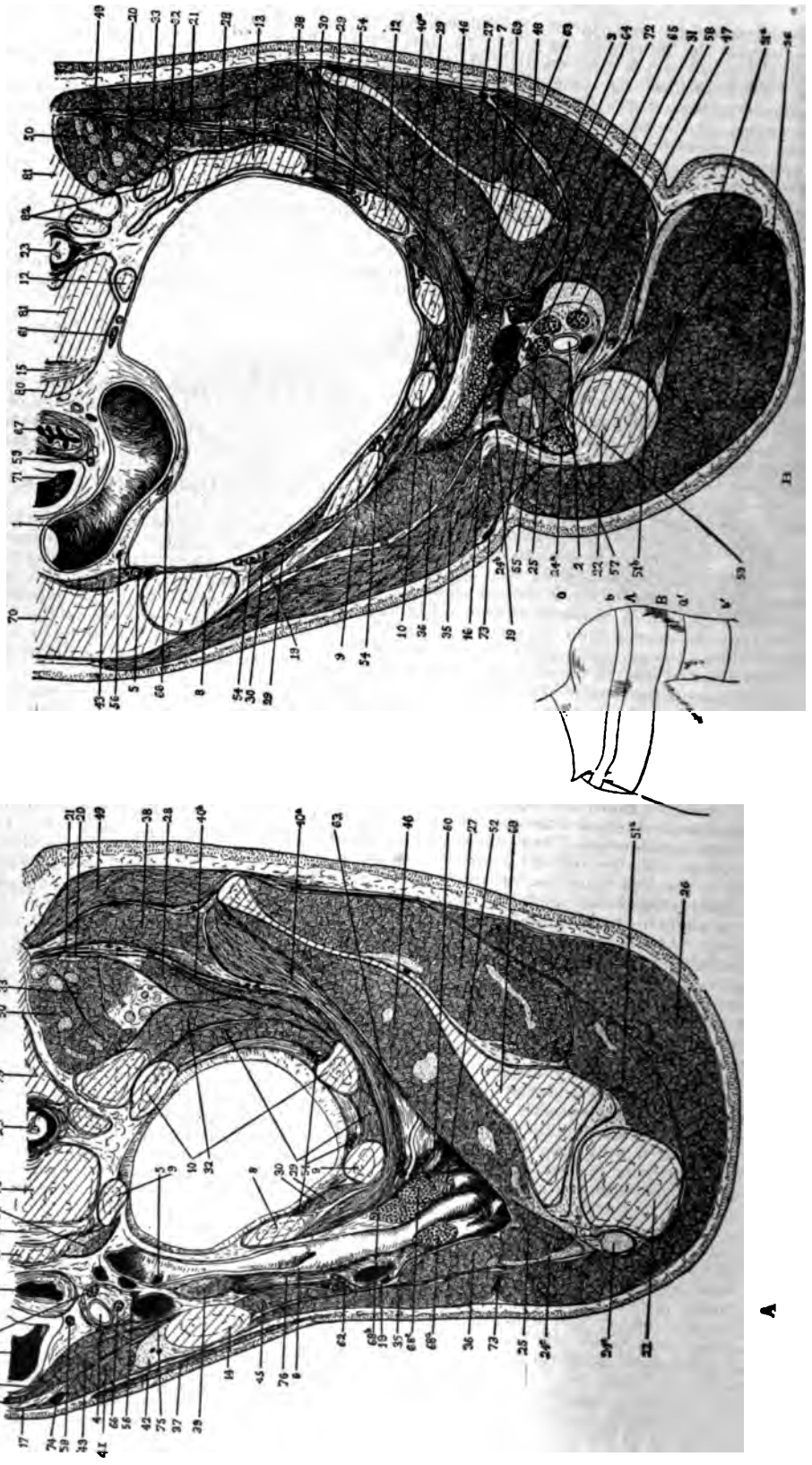


Fig. 388.

nerve. A branch from the nerve to the teres major has also been reported. The nerve rs are derived from the fifth cervical nerve.

Action.—It acts conjointly with the infraspinatus to rotate the arm laterally. It is a or when the arm is down and an extensor when the arm is abducted. It is also an adductor.

Relations.—The muscle is in part covered by the deltoid. Ventrally it enters into relations h the long head of the triceps, the teres major, and the subscapularis. Superiorly, the circnflex (dorsal) scapular vessels run between it and the axillary border of the scapula.

Variations.—Aside from its frequent fusion with the infraspinatus, there has also been ported an isolation of a special fasciculus to the subtubercular attachment.

The infraspinatus (fig. 394).—*Origin.*—From the vertebral three-fourths of the infrainous fossa, from the under surface of the spine, from the enveloping fascia and from interuscular septa between it and the two teres muscles.

Structure and insertion.—The fiber-bundles converge toward the lateral angle of the scapula be attached to a deep-seated tendon which is adherent to the capsule of the joint and is ttached to the middle facet of the great tubercle. The fiber-bundles arising from the inferior urface of the spine and the fascia near this form a distinct fasciculus which descends on and overs the tendon of insertion.

Nerve-supply.—From the suprascapular nerve, which passes beneath the supraspinatus nuscle and enters the deep surface of the infraspinatus in the lateral part of the middle third f its upper margin. From here rami spread out toward the vertebral border of the muscle nd toward the humeral insertion. The nerve fibers are derived from the fifth and sixth ervical nerves.

Action.—This muscle is the chief lateral rotator of the arm, a movement that can be carried hrough 90°. The upper part of the muscle is an abductor, the lower part an adductor of he arm. The muscle is also a flexor.

Relations.—The deltoid and trapezius, and sometimes the latissimus dorsi muscles, cover portion of the dorsal surface. Over most of it extends the complex fascia described above. aterally it adjoins the teres minor and major muscles. Under the muscle lie the transverse suprascapular) and circumflex (dorsal) scapular vessels.

Variations.—These are rare, aside from a greater or less independence of the bundles arising rom the spine and a greater or less complete fusion with the teres minor. A fasciculus has een seen extending to the muscle from the deltoid.

The supraspinatus (fig. 394).—*Origin.*—Fleshy from the medial two-thirds of the supraspinous fossa and from the deep surface of the enveloping fascia near the vertebral end.

Structure and insertion.—The fiber-bundles converge upon a deep-seated tendon nearly to its ttachment into the highest of the three facets on the great tubercle of the humerus.

Nerve-supply.—Two branches from the suprascapular nerve enter the middle third of the eep surface of the muscle. The nerve fibers are derived from the fifth cervical nerve.

Action.—It aids the deltoid in abducting the arm. It is also a weak lateral rotator and exor. It keeps the head of the humerus in place during abduction of the arm.

Relations.—The muscle is covered by the trapezius, the acromion, and the coracoacromial gament. Beyond the base of the spine of the scapula it comes into contact with the infraspinatus muscle. Beneath the muscle pass the suprascapular nerve and transverse scapular suprascapular) vessels.

IG. 388.—A AND B.—TRANSVERSE SECTIONS THROUGH THE LEFT SHOULDER IN THE REGIONS INDICATED IN THE DIAGRAM.

the neighborhood of the brachial plexus in each section some of the adipose and lymphatic tissue has been removed. In section B the fascia covering the apex of the axillary fossa is thus revealed from above. *a* and *b* in the diagram indicate the regions through which pass sections A and B, fig. 382; *a'* and *b'*, the regions through which pass sections A and B, fig. 393.

Aorta. 2. Arteria brachialis. 3. A. circumflexa scapulæ (dorsalis scapulæ). 4. A. carotis communis. 5. A. mammaria interna. 6. A. subclavia. 7. A. thoracalis lateralis (long thoracic). 8. Costa I. 9. Costa II. 10. Costa III. 11. Costa IV. 12. Costa V. 13. Costa VI. 14. Clavicle. 15. Fibrocartilago intervertebralis. 16. Fascia axillaris. 17. Fascia cervicalis (superficial layer). 18. Fascia cervicalis (middle layer). 19. F. coracoclavicularis. 20. F. lumbodorsalis. 21. Fascia of posterior serrati. 22. Humerus. 23. Medulla spinalis (spinal cord). 24. Musculus biceps—*a*, long head; *b*, short head; *c*, tendon of short head. 25. M. coracobrachialis. 26. M. deltoideus. 27. M. infraspinatus. 28. M. iliocostalis dorsi (accessorius). 29. M. intercostales externi. 30. M. intercostales interni. 31. M. latissimus dorsi, tendon. 32. M. levator costæ. 33. M. longissimus dorsi. 34. M. longus colli. 35. M. pectoralis major. 36. M. pectoralis minor. 37. M. platysma. 38. M. rhomboideus major. 39. M. scalenus anterior. 40*a*. M. serratus anterior. 40*b*. M. serratus posterior superior. 41. M. sternomastoideus. 42. M. cleidomastoideus, insertion. 43. M. sternohyoideus. 44. M. sternothyreoideus. 45. M. subclavius. 46. M. subscapularis. 47. M. teres major. 48. M. teres minor. 49. M. trapezius. 50. M. transversospinales. 51. M. triceps—*a*, long head; *b*, lateral head. 52. Nervus axillaris 53. N. cutaneus antibrachii medialis (internal cutaneous). 54.. *a*–*e*, Nn. intercostales I–V. 55. N. medianus. 56. N. phrenicus. 57. N. musculocutaneus. 58. N. radialis. 59. N. recurrens. 60. N. subscapularis. 61. Sympathetic trunk. 62. N. thoracalis anterior. 63. N. thoracalis longus. 64. N. thoracodorsalis (long subcapular). 65. N. ulnaris. 66. N. vagus. 67. Esophagus. 68. Plexus brachialis —*a*, lateral fasciculus; *b*, medial; *c*, posterior. 69. Scapula. 70. Sternum. 71. Trachea. 72. Venæ brachiales. 73. V. cephalica. 74. V. jugularis anterior. 75. V. jugularis inferior. 76. V. subclavia. 77. Vertebra I. 78. Vertebra II. 79. Vertebra III. 80. Vertebra IV. 81. Vertebra V. 82. Vertebra VI.

Variations.—The muscle shows slight variations. Its tendon may be fused with that of the infraspinatus. Its belly may be reinforced by fiber-bundles from the coracoacromial ligament.

The **latissimus dorsi** (figs. 386, 387, 418, 419).—*Origin.*—(1) From an aponeurosis attached to the spines and interspinous ligaments of the five or six last thoracic and the upper lumbar vertebræ, to the lumbodorsal fascia, and to the posterior third of the external lip of the crest of the ilium; (2) from the external surface and upper margin of the last three or four ribs by muscular slips which interdigitate with those of the external oblique. In the lumbar region the aponeuroses of the right and left muscles are connected by fibrous fasciculi which cross the mid-dorsal line above the supraspinous ligament.

Structure and insertion.—From this extensive area of the origin fiber-bundles converge toward the tendon of insertion. In the region of the dorsal wall of the axillary fossa the muscle is concentrated into a thick, ribbon-like band which winds about the teres major and passes to the ventral surface of that muscle. As this takes place the fiber-bundles become applied to each surface of a flat tendon, which, after emerging from the muscle, is six to eight cm. long and three to five cm. broad, and is inserted into the ventral side of the crest of the lesser tubercle of the humerus and into the depth of the intertubercular (bicipital) groove immediately ventral to the tendon of the teres major. With this it is more or less closely bound, although between the tendons there lies a serous bursa. Some of the fasciculi of the tendon extend to the crest of the greater tubercle. Frequently a tendon slip passes from the inferior margin of the tendon to the tendon on the posterior surface of the long head of the triceps or into the brachial fascia (see *latissimo-condyloideus*, p. 412).

Like the teres major, with which it is closely associated, the latissimus dorsi muscle undergoes a torsion between its origin and its insertion, so that the dorsal surface of the muscle is continued into the ventral surface of the tendon and the most cranially situated of the fiber-bundles are most distally attached to the humerus, and *vice versa*. The muscle either directly or through its fascial extension is often adherent to the inferior angle of the scapula.

Nerve-supply.—From the thoracodorsal (long subscapular) nerve (from the sixth, seventh and eighth cervical nerves). This nerve, which may arise in conjunction with the axillary nerve, passes to the deep surface of the muscle in the lower part of the axilla, and here gives rise to rami which diverge as the muscle expands toward its tendons of origin. Though soon embedded in the muscle substance, two main branches may be followed for a considerable distance near the deep surface of the muscle. One usually extends near the lateral, the other near the superior, border of the muscle, and from these large rami pass into the intervening region. Branches of the dorsal thoracic artery and vein accompany the nerve.

Action.—With the trunk fixed, the latissimus dorsi draws the raised arm down and backward and rotates it medialward (swimming movement). When the arm is hanging by the side, the action of the muscle is on the scapula. The upper third of the muscle draws the scapula toward the spine, the inferior two-thirds depress the shoulder. When the humerus is fixed, the latissimus serves to lift the trunk and pelvis forward, as in climbing. It also aids in forced inspiration through its costal attachments.

Relations.—The trapezius covers a small portion of the muscle in the midthoracic region of the back. Over a large area it is subcutaneous, and its fascial investment is adherent to the skin. As it winds about the teres major its tendon comes to lie behind the coracobrachialis muscle. The main nerves and vessels of the arm here pass across its ventral surface. The muscle covers in part the rhomboideus major, the infraspinatus, teres major, serratus posterior inferior, the lower ribs, the external intercostal muscles, the dorsal border of the external and internal oblique muscles, and the lower dorsal part of the serratus anterior (magnus).

Variations.—It may show considerable variation in the extent of its fleshy portion and in the attachment of its aponeurosis to the vertebral column, crest of the ilium, the ribs, and the scapula. Its origin may be merely from the ribs. It may be divided into separate fasciculi. Frequently a fasciculus arises from the inferior angle of the scapula. The muscle is often intimately united to the teres major. For an account of the muscular slip which extends from the latissimus dorsi across the axillary fossa to the tendon of the pectoralis major near the intertubercular (bicipital) groove see the latter muscle (p. 407); and for the slip continued from the tendon of the latissimus dorsi to the olecranon see the TRICEPS MUSCLE (p. 412).

The **teres major** (figs. 387, 419).—*Origin.*—Directly from the dorsal surface of the inferior angle of the scapula and from the septa which lie between this muscle and the subscapularis, teres minor, and infraspinatus muscles.

Insertion.—For about five or six cm. from the lower border of the small tubercle of the humerus, along the medial lip of the intertubercular (bicipital) groove. Proximally the fiber bundles are attached directly to the tubercle; more distally the attachment is by means of a flat tendon which extends for some distance on the dorsal surface of the muscle.

Structure.—The nearly parallel fiber-bundles pass upward in a spiral direction so that the muscle undergoes a torsion on its axis. The fiber-bundles which have the highest attachment to the scapula have the lowest humeral attachment, and *vice versa*.

Nerve-supply.—By a branch of the lower subscapular nerve which enters the muscle near the middle of its scapular border. The nerve fibers are derived from the fifth, sixth (and seventh) cervical nerves.

Action.—It aids the latissimus dorsi in adducting the arm, and in some positions of the arm acts as a medial rotator and as an extensor.

Relations.—Dorsally the muscle is covered by the latissimus dorsi and by the fascia which extends from this muscle to the deltoid and rhomboid muscles. It is also crossed by the long head of the triceps. Its lower border and ventral surface are largely covered by the latissimus dorsi and its tendon. Its upper border helps to bound a triangular space the other sides of which are the borders of the scapula and the humerus. In front lies the subscapularis, and behind, the teres minor. Across this space passes the long head of the triceps. Lateral to this

ead lie the humeral circumflex vessels and axillary (circumflex) nerve; and medial, the circumflex (dorsal) scapular artery.

Variations.—The teres major may be connected with the latissimus dorsi by a fasciculus, or it may be fused with that muscle or its tendon. Slips have also been seen extending to the triceps and into the fascia of the arm. The muscle is rarely absent.

The **subscapularis** (figs. 387, 419).—*Origin.*—The fiber-bundles spring—(1) directly and by means of tendinous bands from the costal surface of the scapula, except near the neck and at the upper and lower angles; and (2) from intermuscular septa between it and the teres major and teres minor muscles.

Insertion.—The tendon of insertion as it passes over the capsule of the joint is intimately bound to this. It is inserted into the lesser tubercle of the humerus and into the shaft immediately below this.

Structure.—The fiber-bundles arising from the tendinous bands attached to the bone converge upon several tendinous laminæ which extend into the muscle from the tendon of insertion, thus forming small penniform fasciculi. The fiber-bundles arising directly from the bone converge toward the extremities of the tendinous laminæ, thus forming triangular bundles interdigitating with the penniform fasciculi. The fasciculus which arises highest on the axillary border goes directly to the humerus.

Nerve-supply.—By two or three subscapular branches from the back of the brachial plexus. One or more of these may arise in association with the axillary (circumflex) nerve. From the main nerves rami spread out to enter the ventral surface of the muscle near the junction of the lateral and middle thirds. The nerve fibers come from the fifth and sixth cervical nerves.

Action.—It is the chief medial rotator of the arm. It strengthens the shoulder-joint by drawing the humerus toward the glenoid cavity. It is an extensor when the arm is at the side, a flexor when the arm is abducted. The upper portion of the muscle, however, acts as a flexor in both positions. The upper part acts as an abductor but when the arm is abducted the muscle is an adductor.

Relations.—Ventrally it forms the greater part of the posterior wall of the axillary fossa, and enters into relation with the serratus anterior (magnus) and the combined tendon of the coracobrachialis and biceps. On it lie the axillary vessels, the brachial plexus, and numerous lymph-vessels and glands. At its lateral border lie the teres major, the humeral circumflex vessels, axillary (circumflex) nerve, and circumflex (dorsal) scapular vessels. Behind it lie the long head of the triceps and the teres minor muscle.

Variations.—It may be divided into several distinct segments. A fasciculus may be sent to the tendon of the latissimus dorsi and another to the brachial fascia. The **subscapularis minor** arises from the axillary border of the scapula and is inserted into the articular capsule (capsular ligament) of the shoulder-joint or into the crest of the lesser tubercle of the humerus

BURSÆ

B. subacromialis.—A large bursa, nearly constantly found, between the acromion and coracoacromial ligament and the insertion of the supraspinatus muscle and capsule of the joint. Processes extend over the greater and lesser tubercles.

B. supracoracoidea.—A bursa sometimes found between the coracoid process and the clavicle and the deltoid muscle.

B. m. subscapularis.—Between the glenoid border of the scapula and the subscapularis muscle. Communicates with the joint cavity. A small portion of this bursa may be isolated adjacent to the base of the coracoid process (*b. subcoracoidea*).

B. m. infraspinati.—Between the tendon of the infraspinatus and the capsule of the joint or the great tubercle.

B. m. latissimi dorsi.—Constant between the tendons of the latissimus dorsi and the teres major.

B. m. teretis majoris.—Under the insertion of the tendon of the teres major muscle.

B. PECTORAL MUSCLES AND AXILLARY FASCIA

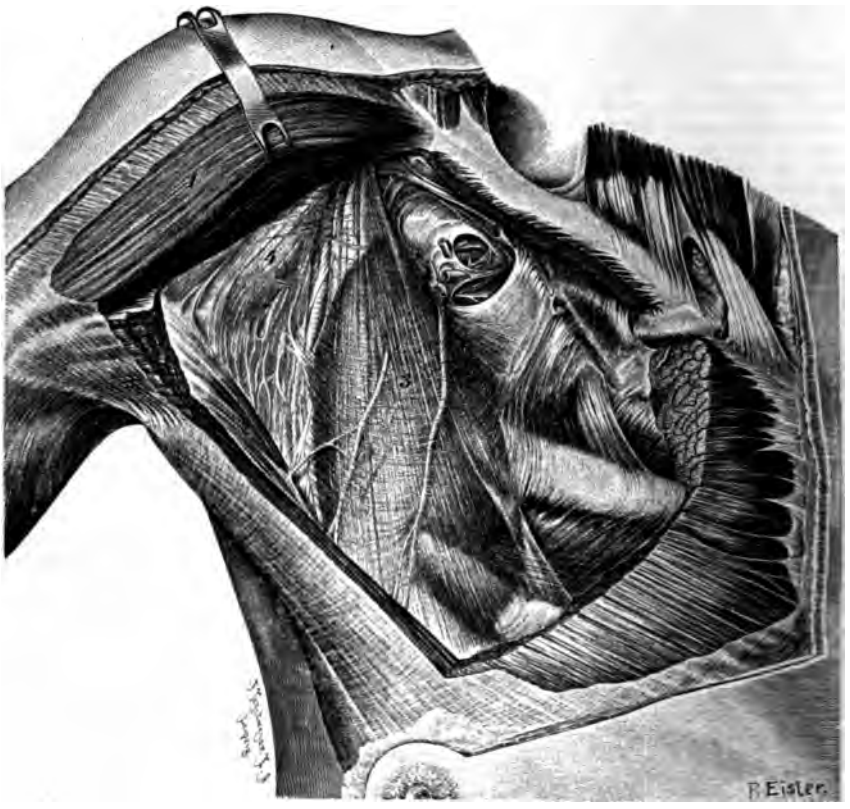
(Figs. 388–392, 419)

The muscles belonging to this group are the pectoralis major, pectoralis minor, and the subclavius. Of these, the largest and most superficial is the triangular **pectoralis major** (fig. 391), which arises from the second to the sixth ribs, the sternum, and the medial half of the clavicle and is inserted into the crest of the greater tubercle of the humerus (pectoral ridge). Its lateral margin adjoins the ventral margin of the deltoid. Beneath this muscle the much smaller triangular **pectoralis minor** (fig. 419) extends from near the ends of the second, third, fourth, and fifth ribs to the tip of the coracoid process, while the small **subclavius** (fig. 392) extends from the first rib upward and lateralward to the clavicle. The pectoralis major adducts and flexes the arm and rotates it medialward. The pectoralis major, pectoralis minor and subclavius muscles draw the shoulder downward and forward.

Of the muscles included in this group, the two pectoral muscles are morphologically the most closely related. They receive a nerve-supply from the same set of nerves, the anterior thoracic. With them the subclavius, which has a separate nerve of its own, is closely associated. Corresponding musculature, although variously modified in different forms, is found throughout the

vertebrate series. In the lower forms it seems to be differentiated directly from the segmental trunk musculature and secondarily attached to the shoulder-girdle, like the superficial and deep musculature of the shoulder-girdle previously described. In man, however, the muscle mass from which these muscles arise is at all times in intimate union with the skeleton of the upper limb, and the nerves which supply it are in much more intimate union with the brachial plexus than are those of the shoulder-girdle muscles. For these reasons the three muscles are classed with the intrinsic muscles of the arm. They have no certain representatives in the lower limb, although the clavicular portion of the pectoralis major is considered by some to represent certain adductor muscles of the thigh. Possibly they correspond in their embryonic origin with the obturator internus group of the lower limb.

FIG. 389.—DEEP FASCIA OF THE BREAST. (AFTER EISLER). THE PECTORALIS MAJOR HAS BEEN IN LARGE PART REMOVED. 1, DELTOID; 2, PECTORALIS MAJOR, ABDOMINAL PART; 3, PECTORALIS MINOR; 4, CORACOBRACHIALIS.



In many of the mammals a subcutaneous muscle arises from the pectoral muscle mass and extends over the axilla and the trunk. In man this musculature is frequently represented by abnormal slips of muscles, of which the 'axillary arch' and possibly the 'sternalis' are representatives. A list of some of the abnormal muscles which are innervated from the anterior thoracic nerves and are evidently derivatives of the pectoral muscle mass is given at the end of this section.

FASCIÆ

In the **tela subcutanea** of the pectoral region the mammary gland is embedded between two layers which ensheath the gland and are connected by dense fiber-bands. To a greater or less extent the platysma extends into the tela of this region from above the clavicle.

Muscle fasciæ.—The pectoralis major is invested with a thin, adherent membrane, **fascia pectoralis,** attached to the clavicle and the sternum and continued into the fascial investment of the external oblique, the serratus anterior (magnus), and the deltoid muscles, and in to the axillary fascia. More important is the **coracoclavicular (costocoracoid) fascia (fig. 389).** This arises from two fascial sheets which invest the subclavius muscle and are attached to the clavicle. From the inferior margin of this muscle the membrane is continued to the superior margin of the pectoralis minor. Between the coracoid process and the first costal cartilage it is strengthened to form the **costocoracoid ligament.** Between this and the pectoralis minor it is thin. At the superior margin of this muscle it again divides to form two adherent fascial sheets, which, at the axillary margin of the muscle, once more unite to form a firm membrane continued into the fascial investment of the coracobrachialis and short head of the biceps and into the axillary fascia. Above, dorsally, the membrane is adherent to the sheath of the axillary vessels and nerves

ıry fascia (figs. 389, 390).—The **axillary fossa** is a pyramidal space above the (external) **and** bounded by the pectoralis major and minor and coracobrachialis muscles in front; **atissimus** dorsi, teres major, and subscapularis muscles behind; by the subscapularis **oward** the joint; and by the serratus anterior (magnus) toward the thoracic wall. In **ve** between the coracobrachialis and the subscapularis and tendons of the latissimus **l** teres major muscles run the main nerves and vessels of the arm. These are surrounded **nsiderable** amount of connective tissue in which numerous blood- and lymph-vessels, **odes**, nerves, and masses of fat are embedded. For topography, see pp. 400, 1412.
this connective tissue the fascia covering the musculature of the neighboring portion **ıoulder** and thorax is continued into the fascia covering the musculature of the medial **he** arm. Thus the fascia covering the pectoralis minor, the coracoclavicular fascia, **ened** by a reflection of the fascial investment of the pectoralis major and deltoid muscles

FIG. 390.—(AFTER EISLER). FASCIA OF THE AXILLARY FOSSA.

ıued across the ventral margin of the axilla into the fascia which covers the coraco- **ıs** and biceps muscles in the arm. Similarly, dorsally, the fascia covering the latissimus **l** teres major is continued over the axilla into that covering the long head of the triceps **rm**. The ventral is connected with the dorsal fascia by a thin membrane which is **:** to the connective tissue filling the axillary space and to the subcutaneous tissue. **.runk** this membrane, the **fascia axillaris**, becomes fused below the axillary fossa with **a** of the serratus anterior (magnus). In the arm it becomes fused with the fascia over **ıs** muscle. Owing to its adherence to the skin and the connective tissue of the axillary **vestigators** have dissected out and figured the axillary fascia in different ways.

MUSCLES

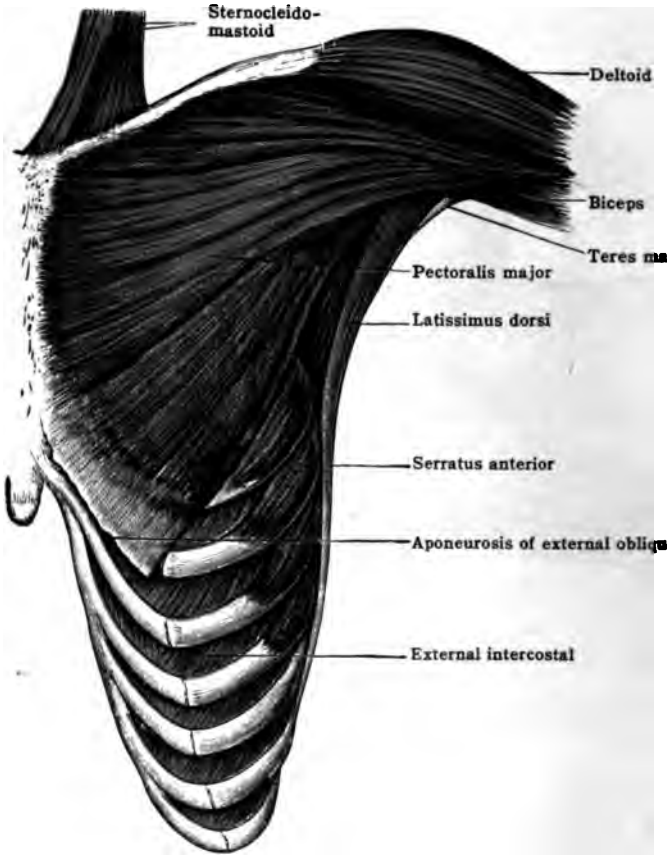
pectoralis major (fig. 391).—*Origin.*—(1) From the medial half of the clavicle; (2) **:** side and front of the sternum as far as the sixth costal cartilage; (3) from the front of **lages** of the second to the sixth ribs; and (4) from the upper part of the aponeurosis of **rnal** oblique where this extends over the rectus abdominis muscle. The costal origin **ıart** take place from the osseous extremities of the sixth and seventh ribs.
tion.—Crest of the greater tubercle (outer lip of the bicipital groove) of the humerus **:** tubercle to the insertion of the deltoid (fig. 211). Some of the tendon fibers are also **d** into the tendon of the deltoid and adjacent fibrous septa and into the fibrous lining **ntertubercular** sulcus.

Structure.—The muscle is divisible into a series of overlapping layers spread out like a fan. Of these, the clavicular portion forms the most cranial and superficial layer, and the portion of the muscle springing from the aponeurosis of the external oblique, the most caudal and deepest layer. This last layer has a special tendon, while the other layers are inserted into a combined tendon lying ventral to this. The two tendons are continuous at their distal margins. (W. H. Lewis.)

Nerve-supply.—From the external and internal anterior thoracic nerves, branches of which enter the sternocostal portion of the muscle about midway between the tendons of origin and insertion, and the clavicular portion in the proximal third. The nerve fibers are derived from the (fifth), sixth, seventh, and eighth cervical and first thoracic nerves.

Action.—With the thorax fixed, the muscle adducts and flexes the arm and rotates it medialward. The clavicular portion draws the arm forward, upward, and medialward; the sternocostal portion draws the arm downward, medialward, and forward. When the arm is pendent, the upper portion elevates, the lower depresses, the shoulder. With the arm fixed, the muscle draws the chest upward toward it. It is of value in forced inspiration.

FIG. 391.—THE PECTORALIS MAJOR AND DELTOID.



Relations.—It lies over the coracoid process, the subclavius, pectoralis minor, intercostal and serratus anterior (magnus) muscles, the coracoclavicular (costocoracoid) fascia, and the thoracoacromial vessels. It forms the main part of the ventral wall of the axillary fossa, and laterally it enters into relation with the deltoid, biceps, and coracobrachialis muscles.

Variations.—In considering variations the muscle may be looked upon as composed of four portions—a clavicular, a sternal, a costal, and an abdominal, the last being that portion which arises from the aponeurosis of the external oblique. These portions vary in the extent of their attachments and in the degree of separation which they present. The abdominal portion may extend to the umbilicus. Huntington considers this portion a derivative of the panicular muscle of the lower mammals. On the sternum the muscles of the two sides may decussate across the middle line. The sternocostal portions of the muscle are more frequently deficient or missing than the clavicular, but in rare cases the entire muscle is absent. The clavicular portion of the muscle may be fused with the deltoid. The sternocostal may extend laterally to the latissimus dorsi. There may be an intimate fusion of the abdominal portion with the rectus abdominis or the external oblique. Sometimes a slip may run from the pectoralis major to the biceps, the pectoralis minor, coracoid process, capsule of the joint, or brachial fascia.

The **pectoralis minor** (fig. 419).—*Origin.*—By aponeurotic slips from the second, third, fourth, and fifth ribs near the costal cartilages.

Structure and insertion.—The fiber-bundles converge upward and outward to a flattened tendon which is attached to the medial border and upper surface of the coracoid process of the scapula.

Nerve-supply.—From the internal anterior thoracic nerve which enters the upper part of the middle third of the deep surface by several branches. Some of the branches extend through to the pectoralis major. The nerve fibers arise from the seventh and eighth cervical nerves.

Action.—When the thorax is fixed, the pectoralis minor pulls the scapula forward, the lateral angle of the bone downward, and the inferior angle dorsalward and upward. When the scapula is fixed, the muscle aids in forced inspiration.

Relations.—It is covered by the pectoralis major. Near its insertion the fibrous investment of the chief nerves and vessels of the arm is adherent to its enveloping fascia.

Variations.—The origin may extend to the sixth rib or may be reduced to one or two ribs. In the primates below man the insertion of the muscle takes place normally into the humerus. In man its insertion may be continued (in more than 15 per cent. of bodies—Wood) over the coracoid process to the coracoacromial or coracohumeral ligaments, to the tendon of the subscapularis muscle, or to the great tubercle of the humerus. It may be divided into two superimposed fasciculi. Fasciculi may extend from the muscle to the subclavius or the pectoralis major.

The **subclavius** (fig. 392).—*Origin.*—From a flat tendon attached to the first rib and its cartilage near their junction.

Structure and insertion.—The fiber-bundles arise in a penniform manner from the tendon of origin which extends for some distance along the lower border of the muscle. They are inserted in a groove which lies on the lower surface of the clavicle between the costal tuberosity and the coracoid tuberosity. The medial fiber-bundles are inserted directly, the lateral by a strong tendon.

FIG. 392.—THE SUBCLAVIUS AND THE UPPER PORTION OF THE SERRATUS ANTERIOR.

Nerve-supply.—By a branch which arises usually from the fifth or fifth and sixth cervical nerves and enters the middle of the back part of the muscle.

Action.—When the first rib is fixed, the subclavius depresses the clavicle and the point of the shoulder. When the clavicle is fixed, the muscle aids in forced inspiration. It also serves to keep the clavicle against the sternum.

Relations.—It is concealed by the clavicle and pectoralis major muscle. Behind it lie the subclavian vessels and the brachial plexus.

Variations.—It may be replaced by a ligament or by a pectoralis minimus muscle (see below). It may be doubled or may be inserted into the coracoid process, coracoacromial ligament, the acromion, or the humerus. The *subclavius posticus* arises near the subclavius, passes backward over the subclavian vessels and brachial plexus and is inserted into the cranial margin of the scapula near the base of the coracoid process.

Abnormal Muscles of the Pectoral Group

The following muscles are usually innervated by the anterior thoracic nerves and are probably generally abnormal derivatives of the pectoral mass. Frequently they represent muscles normally found in lower mammals.

The sternalis.—A flat muscle somewhat frequently seen on the surface of the pectoralis major, usually nearly parallel to the sternum. It arises from the sheath of the rectus and from some of the costal cartilages (third to seventh) and terminates on the sternocleidomastoid, on the sternum, or on the fascia covering the pectoralis major. When present on both sides, the two muscles may be fused across the sternum. This muscle is found in 4 per cent. of normal individuals and 48 per cent. of anencephalic monsters. (Eisler.) Rarely, corresponding muscle slips have been found innervated by the intercostal nerves. These probably represent remains of a thoracic 'rectus' muscle.

The pectorodorsalis (axillary arch).—This muscle in its most complete form extends from the tendon of the pectoralis major over the axillary fossa to the tendon of the latissimus dorsi, to the fascia covering the latissimus dorsi, to the teres major or even more distally. It may, however, be more or less fused with either of the last two muscles mentioned, and it presents a great variety of forms. It may extend from the latissimus dorsi to the brachial fascia over the coracobrachialis or biceps, to the long tendon of the biceps, to the axillary fascia, to the axillary margin of the pectoralis minor, or to the coracoid process, etc. It is found in about 7 per cent.

of bodies. (Le Double.) When supplied from the anterior thoracic nerves, it probably represents a portion of the thoracohumeral subcutaneous (pannicular) muscle of the lower primates. It is also sometimes supplied by the medial brachial cutaneous or the intercostobrachial (humeral) nerve and frequently is partly or wholly supplied by the thoracodorsal (long subscapular) nerve. The part of the muscle supplied by the thoracodorsal nerve is probably derived from the latissimus dorsi musclature.

The **costocoracoideus.**—A muscular slip which arises from one or more ribs or from the aponeurosis of the external oblique between the pectoralis major and latissimus dorsi muscles and is inserted in the coracoid process.

The **chondrohumeralis** (epitrochlearis).—This is a slip which springs from one or two rib cartilages or from the thoracoabdominal fascia beneath the pectoralis major, or from its lower border or tendon, and extends on the medial side of the arm to the intertubercular (bicipital) groove, the brachial fascia, the intermuscular septum, or the medial epicondyle. It is found in 12 to 20 per cent. of bodies (Le Double), and occurs normally in many of the lower mammals.

The **pectoralis minimus (sternochondroscapularis).**—From the cartilage of the first rib and sternum to the coracoid process.

The **sternoclavicularis.**—From the manubrium of the sternum to the clavicle between the pectoralis major and the coracoclavicular (costocoracoid) fascia. In 2 per cent. to 3 per cent. of bodies. (Gruber.)

The **scapuloclavicularis.**—From the coracoid process of the scapula to the lateral third of the clavicle.

The **infraclavicularis.**—From above the clavicular part of the pectoralis major to the fascia over the deltoid.

Bursæ

B. m. pectoralis majoris.—Between the tendon of insertion of the pectoralis major and the long head of the biceps. Frequent.

C. MUSCULATURE OF THE ARM

(Figs. 386, 387, 393–396, 398, 401, 403)

The muscles included in this section are the triceps and anconeus, coracobrachialis, biceps, and brachialis. The *triceps* and *anconeus* (fig. 394) constitute a mass of musculature extending along the back of the arm from the scapula and humerus to the olecranon of the ulna. The *coracobrachialis*, *biceps*, and *brachialis* (figs. 395, 396) constitute a similar mass of musculature extending along the front of the arm from the scapula and the humerus to the humerus, and to the radius and ulna near the elbow. In the upper half of the arm the two groups are separated on the lateral side of the arm by the deltoid, pectoralis major, teres minor, supra- and infraspinatus muscles, and by the greater tubercle of the humerus. On the medial side they are separated by the chief nerves and blood-vessels of the arm and by the tendons of the latissimus dorsi, teres major, and subscapularis muscles. In the distal half of the arm they are separated medially by the medial intermuscular septum (described below) and by the medial epicondyle and the ulnovolar group of muscles of the forearm. On the lateral side of the arm they are separated by the lateral intermuscular septum, by the lateral epicondyle, and by the brachioradialis and the extensor muscles of the forearm which take origin from the lateral epicondyle.

FASCIÆ

The **fasciæ** and the general relations of the muscles of the arm are shown in the cross-sections in fig. 393.

The **tela subcutanea** of the arm is fairly well developed and contains a considerable amount of fat, especially near the shoulder. It is but loosely bound to the muscle fascia, except near the insertion of the deltoid, where the union may be more intimate.

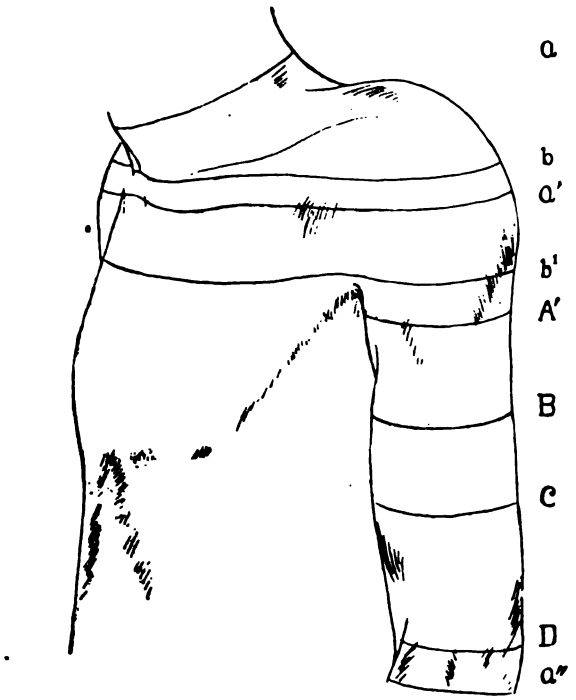
Bursæ.—B. subcutanea epicondyli lateralis.—Between the lateral epicondyle and the skin. Rare. **B. subcutanea epicondyli medialis.**—Between the medial epicondyle and the skin. Inconstant. **B. subcutanea olecrani.**—Between the olecranon process of the ulna and the skin. Nearly constant.

The **brachial fascia** forms a cylindrical sheath about the muscles of the arm. It contains circular and longitudinal fibers, the former being the better developed. The fascia is strong over the dorsal muscles, especially near the two epicondyles of the humerus. Proximally the fascia of the arm is continued into the axillary fascia and into the fascial investment of the pectoralis major, deltoid, and latissimus dorsi muscles; distally it is continued into the fascial investment of the forearm. It is intimately bound to the epicondyles and to the dorsal surface of the olecranon. It is separated by loose areolar tissue from the bellies of the muscles which it covers. From the tendons of the deltoid, pectoralis major, teres major, and latissimus dorsi muscles, however, fibrous bundles are continued into the brachial fascia. There are a number of orifices in the fascia for the passage of nerves and blood-vessels. Of these, the largest is that for the basilic vein and two or three large branches of the medial antibrachial (internal)

, A–D.—Transverse Sections through the Left Arm in the Regions shown in the Diagram.

n the diagram indicate the regions through which pass sections A and B, fig. 382; *a'* *b'*, the regions through which pass sections A and B, fig. 388; and a^{11} the region through h passes section A, fig. 397.

a brachialis. 2. Bursa subcutanea olecrani. 3. Fascia brachialis. 4. Humerus. 5. culus anconeus. 6. M. biceps—*a*, long head; *b*, short head; *c*, tendon of insertion. f. brachialis. 8. M. brachioradialis. 9. M. coracobrachialis. 10. M. deltoideus. M. extensor carpi radialis brevis. 12. M. extensor carpi radialis longus. 13. M. sor digitorum communis. 14. M. flexor carpi radialis. 15. M. flexor carpi ulnaris. M. flexor digitorum sublimis. 17. M. flexor digitorum profundus. 18. M. palmaris s. 19. M. pronator teres. 20. M. triceps—*a*, lateral head; *b*, long head; *c*, medial head N. cutaneus antibrachii medialis (internal cutaneous). 21*b*. N. cutaneus anti- hii dorsalis. 22. N. musculocutaneus. 23. N. medianus. 24. N. radialis—*a*, ular branch. 25. N. ulnaris. 26. Lymphatic gland. 27. Olecranon. 28. Septum musculare laterale. 29. Septum intermusculare mediale. 30. Vena cephalica. 31. asilica. 32. Vv. brachiales.



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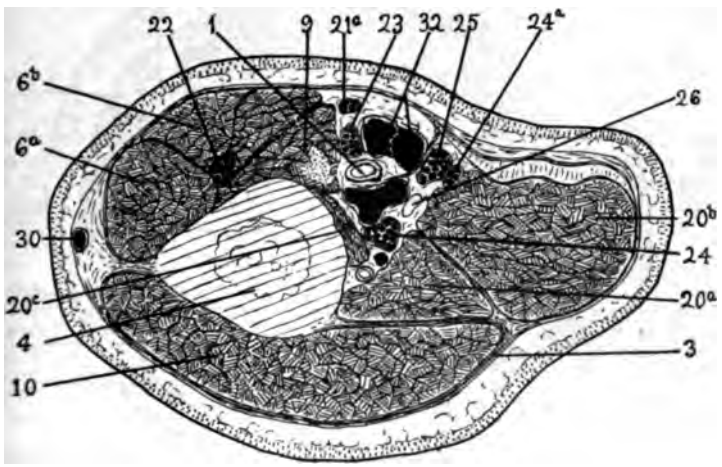

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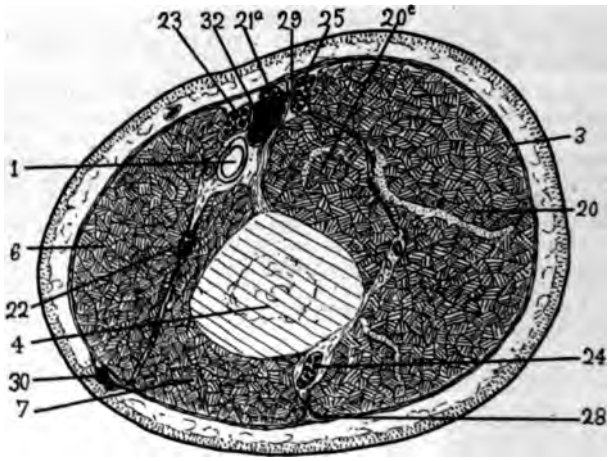
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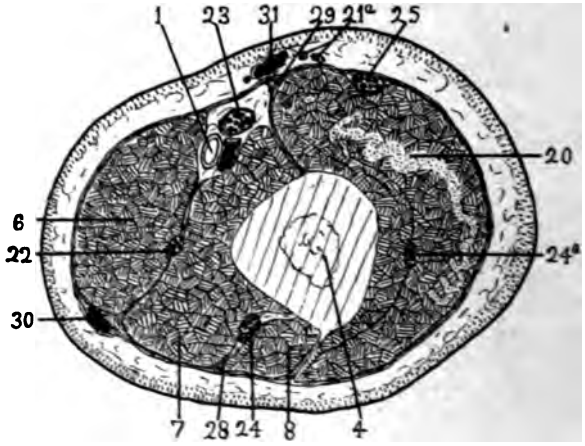
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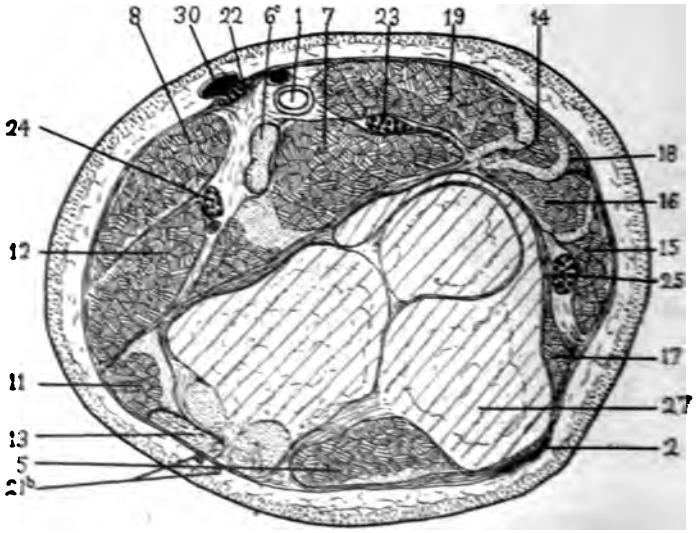
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taneous nerve. This lies on the ulnar margin of the arm in the lower third. On the radial margin lie the cephalic vein in a double fold of the fascia, orifices for branches of the musculocutaneous nerve, and more dorsally orifices for branches of the radial. From the fascia septa descend between the muscles which it invests. Of these septa, the most important are the medial and lateral intermuscular septa, which separate the dorsal group of muscles from the ventral in the distal half of the arm. The **medial intermuscular septum** is the stronger. It is attached to the medial epicondyle and to the medial margin of the humerus proximal to this. It is continued proximally into the tendon of insertion of the coracobrachialis and the investing fascia of this muscle. Into it longitudinal bundles of fibers descend from the tendon. It separates the brachialis and pronator teres muscles from the medial head of the triceps. The **lateral intermuscular septum** is attached to the lateral epicondyle and to the lateral margin of the humerus. It is continued proximally into the dorsal surface of the tendon of insertion of the deltoid muscle, and into the septa between the deltoid and the triceps. It separates the triceps from the brachialis in the third quarter of the arm and from the brachioradialis and extensor carpi radialis longus in the distal quarter. The median nerve and brachial vessels lie in front of the medial septum. The ulnar nerve and the superior ulnar collateral (inferior profunda) artery are bound to its dorsal surface.

ARM-MUSCLES

1. Dorsal or Extensor Group (Fig. 394)

Two muscles are included in this group, the triceps brachii and the anconeus. The triceps is a complex muscle in which proximally three heads, a long or scapular, a lateral humeral, and a medial humeral, may be distinguished. The long head arises from the infraglenoid tuberosity of the scapula, the lateral head from the humerus above and laterally to the groove for the radial nerve (musculospiral groove), the medial head from the lower half and medial margin of the posterior surface of the humerus. Distally these heads fuse and are inserted by a common tendon into the olecranon of the ulna. The **anconeus** lies chiefly in the forearm, but physiolgoically and morphologically it belongs with the triceps, and hence is described in connection with the muscles of the arm. It is a triangular muscle, which arises from the lateral epicondyle and is inserted into the olecranon and adjacent part of the shaft of the ulna. Both muscles are supplied by branches of the radial (musculospiral) nerve. They extend the forearm. The long head is also an adductor of the arm.

The triceps, variously modified, is found in the amphibia and all higher vertebrates. The anconeus is found in the prosimians and all higher forms. The triceps muscle is homologous with the quadriceps of the thigh. The long head is equivalent to the rectus femoris. The anconeus is not represented in the lower limb.

The triceps brachii (figs. 386, 387, 394).—The **long head** *arises* from the infraglenoid tuberosity of the scapula by a strong, broad tendon, some of the fibers of which are connected with the inferior portion of the capsule of the shoulder-joint. The tendon soon divides into two lamellæ, which extend distally, one a short distance on the deep surface, the other much farther on the superficial surface of this head. The parallel fiber-bundles which arise from these lamellæ form a thick muscle-band which twists upon itself so that the ventral surface at the origin becomes dorso-medial at the insertion. At the insertion the long head becomes applied to an aponeurosis which extends upward from the main tendon of insertion of the triceps. The fiber-bundles extend for some distance on the medial side of this tendon and terminate about three-fourths of the way down the arm.

The **lateral head** has a tendinous *origin* from the superior lateral portion of the posterior surface of the humerus along a line extending from the insertion of the teres minor as far as the groove for the radial (musculospiral) nerve, and from the aponeurotic arch formed by the lateral intermuscular septum as it crosses this groove. The constituent fiber-bundles descend, the superior vertically, the inferior obliquely, to be inserted on the dorsal and ventral surfaces of the proximolateral margin of the common tendon of insertion of the triceps.

The **medial head** has a fleshy *origin* from the posterior surface of the humerus below the radial (musculospiral) groove and from the dorsal surfaces of the medial and lateral intermuscular septa. The greater part of the fiber-bundles arising from this extensive area are inserted into the deep surface of the common tendon, but some extend directly to the olecranon and the articular capsule of the elbow. The slip attached to the capsule is sometimes called the **subanconeus** muscle.

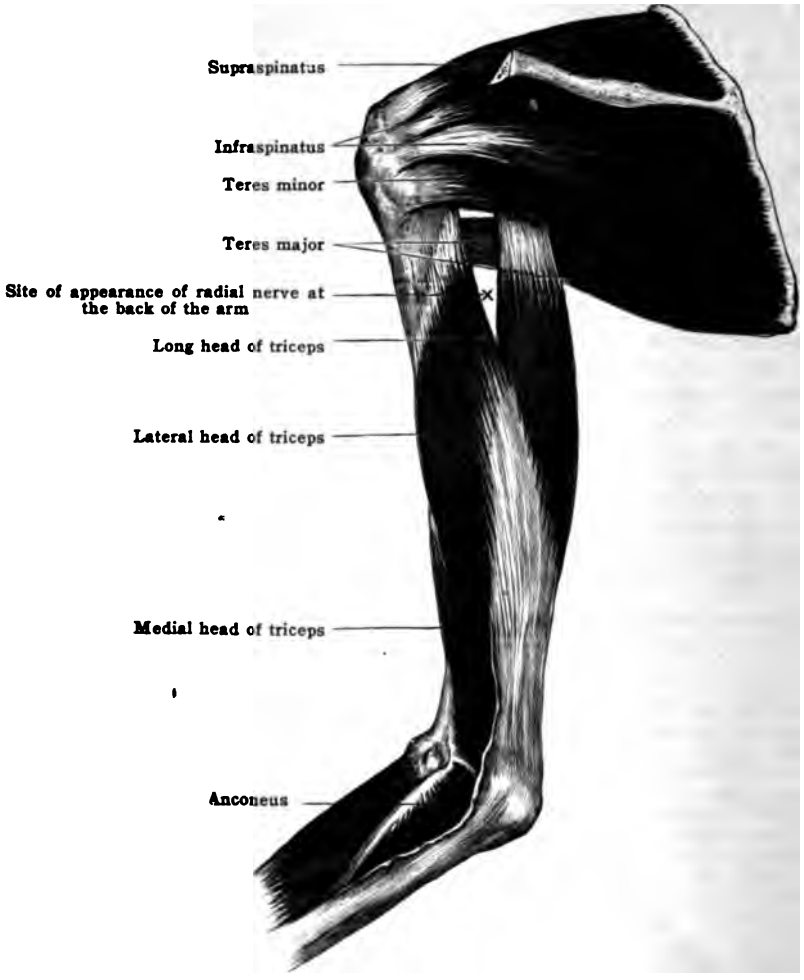
Insertion.—The tendon of insertion of the triceps forms a flat band covering the dorsal surface of the distal two-fifths of the muscle. It also extends proximally between the long and lateral heads and on the deep surface of the former. This tendon is inserted into the olecranon and laterally, by a prolongation over the anconeus, into the dorsal fascia of the forearm.

Nerve-supply.—From the radial (musculospiral) nerve. The branch to the long head arises in the axilla and enters that margin of the muscle which is prolonged down from the lateral edge of the tendon, but which, because of the torsion of the muscle, comes to lie on the medial side. The nerve usually enters through several rami about the middle of the free portion of the long head. Somewhat more distally the radial nerve gives off a branch that enters, by two or three branches, the proximal portion of the medial head. A similar branch is given to the

lateral head and other branches are given to the lateral and medial heads from that portion of the radial (musculospiral) nerve lying in the radial (musculospiral) groove. The nerve fibers arise from the sixth, seventh, and eighth cervical nerves.

Relations.—Near the shoulder the triceps is covered by the deltoid muscle. The long head passes between the teres major and teres minor muscles. The circumflex (dorsal) scapular vessels here pass medial, the circumflex humeral vessels and the axillary (circumflex) nerve lateral, to this head. More distally the muscle lies beneath the brachial fascia. It covers the radial groove of the humerus, in which run the radial (musculospiral) nerve and (superior) profunda brachii artery. Ventrolateral to the muscle lie the deltoid, brachialis, brachioradialis, and extensor carpi radialis muscles; ventromedial, the coracobrachialis, biceps, and brachialis muscles.

FIG. 394.—DORSAL VIEW OF THE SCAPULAR MUSCLES AND TRICEPS.



Action.—It extends the forearm. The leverage is of such a nature that force is sacrificed for speed of movement. The long head of the triceps also serves to extend and to adduct the arm and to hold the head of the humerus in the glenoid cavity.

Variations.—The scapular attachment may extend for a considerable distance down the axillary border of the scapula. Each of the heads may be more or less fused with neighboring muscles. Frequently a fourth head is found. This may arise from the humerus, from the axillary margin of the scapula, from the capsule of the shoulder-joint, from the coracoid process, or from the tendon of the latissimus dorsi.

The *latissimo-condyloideus* (dorsoepitrochlearis).—This muscle is found in about 5 per cent. of bodies. When well developed, it extends from the tendon of the latissimus dorsi to the brachial fascia, the triceps muscle, the shaft of the humerus, the lateral epicondyle, the olecranon, or the fascia of the forearm. It is innervated by a branch of the radial (musculospiral) nerve. It is a muscle normally present in some one of the forms above mentioned or in some similar form, in a large number of the inferior mammals. In the human body it is normally represented by a fascial slip from the tendon of the latissimus to the long head of the triceps or the brachial fascia.

The anconeus.—*Origin.*—By a short narrow tendon from the distal part of the back of the eral epicondyle and the adjacent part of the capsular ligament of the elbow-joint.

Structure and insertion.—The tendon of origin is prolonged on the deep surface and lateral border of the muscle. From this the fiber-bundles spread, the proximal transversely, the more distal obliquely, to be inserted into the radial side of the olecranon and an adjacent impression on the shaft of the ulna. Its superior fiber-bundles are usually continuous with those of the medial head of the triceps.

Nerve-supply.—By a long branch which arises in the radial (musculospiral) groove from the radial (musculospiral) nerve, passes through the medial head of the triceps, to which it gives branches, and enters the proximal border of the anconeus. The nerve fibers arise from the seventh and eighth cervical nerves.

Action.—It aids the triceps in extending the forearm and draws the ulna laterally in pronation of the hand.

Relations.—The muscle lies immediately beneath the antibrachial fascia. It extends over the head of the supinator (brevis) and the elbow-joint and upper radioulnar joint.

Variations.—The extent of fusion of the muscle with the medial head of the triceps varies a good deal. It may also be fused with the extensor carpi ulnaris. It has been reported missing.

BURSÆ

B. intratendinea olecrani.—Within the tendon of the triceps near its insertion. More frequent than the following:—

B. subtendinea olecrani.—Between the tendon of the triceps and the olecranon and dorsal ligament of the elbow-joint. Inconstant.

B. epicondyli medialis dorsalis.—Between the medial epicondyle, the edge of the triceps, and the ulnar nerve. Rare.

B. m. anconei.—Between the tendon of origin of the muscle and the head of the radius. Frequent.

2. VENTRAL OR FLEXOR GROUP

(Figs. 395, 396, 401, 402, 403)

The muscles of this group are the coracobrachialis, the biceps, and the brachialis. The **coracobrachialis** (fig. 396) is a band-like muscle which arises from the coracoid process and is inserted into the middle third of the shaft of the humerus. The **biceps** (fig. 395) arises by two heads: a short head, closely associated with the coracobrachialis, from the coracoid process; a long head, by an extended tendon, from the supraglenoid tuberosity of the scapula. The fusiform belly which arises from the fusion of these two heads is inserted into the radius and into the fascia of the forearm. The **brachialis** (fig. 396) extends under cover of the biceps from the lower three-fifths of the shaft of the humerus to the coronoid process of the ulna. The muscles of this group are supplied by the musculocutaneous nerve. The brachialis also usually receives a branch from the radial nerve. The coracobrachialis and short head of the biceps flex and adduct the arm at the shoulder; the biceps and brachialis flex the forearm at the elbow. The long head of the biceps abducts the arm at the shoulder. The biceps is a powerful supinator of the forearm.

The muscles of this group are found in most of the limbed vertebrates. In many of the lower forms the coracobrachialis, which appears farther down in the vertebrate series than the biceps, has a more extensive insertion than in man. It may extend to the ulna (lizards) and may be subdivided into various muscles which correspond with the adductors of the thigh. The biceps, the place of which is taken in the lower vertebrates by a coracoradial muscle, in most of the mammals presents two heads, the more lateral of which is attached by a tendon to the scapula above the shoulder-joint. This long tendon of the biceps lies primitively outside capsule of the shoulder-joint, but in some of the higher mammals has come to lie within the capsule. In the biceps four elements may be recognized:—a coracoradial, coracoulnar, glenoradial, and glenoulnar. (Krause.) The development of these elements varies in different mammals.

The coracobrachialis (fig. 396).—*Origin.*—(1) By a short tendon from the tip of the coracoid process of the scapula and (2) from the tendon of the short head of the biceps.

Insertion.—(1) By means of a strong tendon into the medial surface of the humerus immediately proximal to the middle of the shaft, and (2) often above this also into an aponeurotic band which extends from the tendon along the medial margin of the humerus, arches over the tendons of the latissimus dorsi and teres major, and is attached to the lesser tubercle of the humerus. When the attachment to the tubercle does not take place, the band becomes closely applied to the deep surface of the muscle.

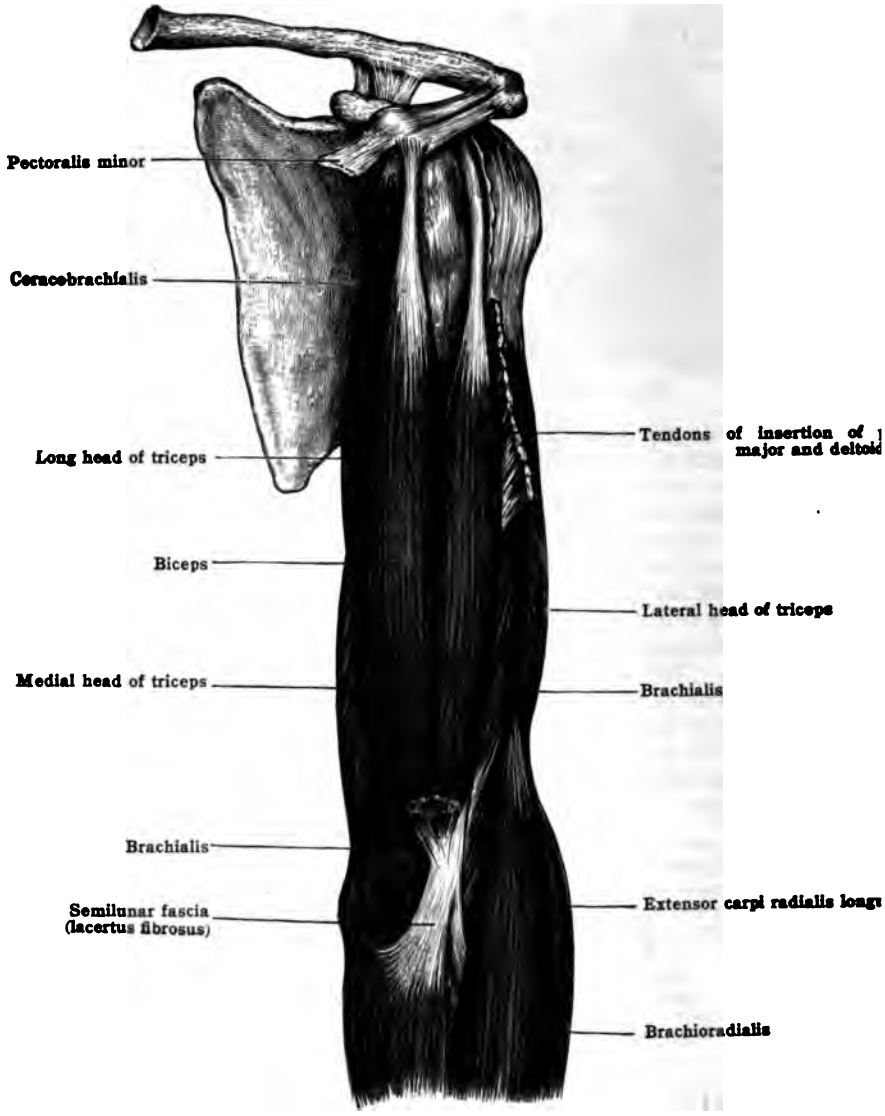
Structure.—From the tendons of origin, which are usually closely associated, the fiber-bundles take an oblique, nearly parallel, course and are attached to the aponeurotic band above mentioned and to both surfaces of the flat tendon of insertion. This extends high into the muscle. The belly of the muscle usually shows some separation into a superficial and a deep portion, between which runs the musculocutaneous nerve. When this separation is well marked, the tendon of origin of the superior fasciculus may be distinct from that of the inferior fasciculus and the short head of the biceps, and the tendon of insertion may give a separate lamina to each fasciculus.

Nerve-supply.—A branch of the musculocutaneous nerve, or of the brachial plex the origin of this nerve, enters the upper third of the medial border of the muscle, and across the constituent fiber-bundles about midway between their attachments. Th fibers arise from the sixth and seventh cervical nerves.

Action.—Adducts and flexes the arm at the shoulder and helps to keep the head humerus in the glenoid fossa. When the arm has been rotated lateralward, it acts as a rotator. It may help to increase extreme abduction.

Relations.—The coracobrachialis is largely covered by the deltoid and pectoralis muscles. Below the inferior border of the latter it becomes superficial. Near its orig

FIG. 395.—SUPERFICIAL MUSCLES OF THE FRONT OF THE ARM.



between the pectoralis minor and the subscapularis muscles. More distally it lies medi humerus and in front of the chief brachial vessels and nerves. The musculocutaneo usually runs through it.

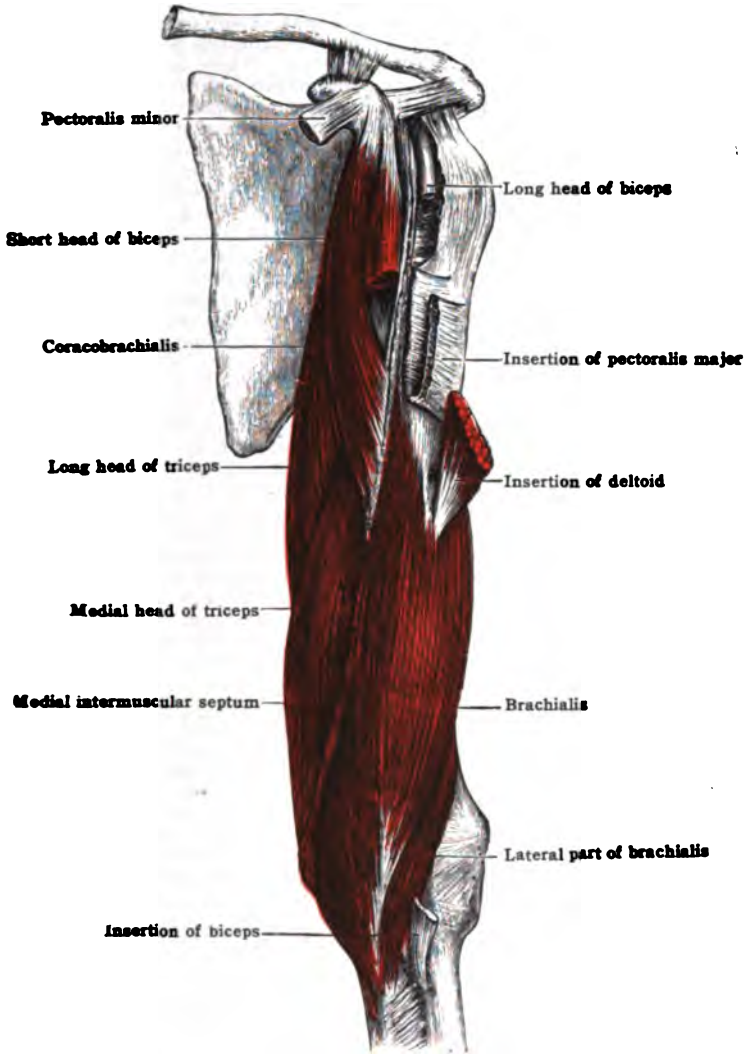
Variations.—The humeral insertion of the muscle varies considerably. According t the coracobrachialis consists primitively of three parts, which arise from the coracoid and are inserted respectively into the upper, the middle, and the distal part of the l along the medial side. The superior division is most deeply, the inferior the most supe placed. In man the muscle is composed of parts of the middle and inferior division inferior division may be completely developed as far as the medial epicondyle. The division of the muscle is occasionally found. Slips from the coracobrachialis to the b have been seen. Complete absence of the muscle has been recorded.

The biceps brachii (figs. 395, 401).—The **short head** *arises* by a flat tendon close [redacted]ed with that of the coracobrachialis from the coracoid process. From the dor

surface of this tendon the fiber-bundles descend nearly vertically, though increasing in number, toward their attachment to the tendon of insertion. The fiber-bundles which arise highest on the tendon of origin are inserted highest on the tendon of insertion, while those which have the lowest origin have the lowest insertion.

The long head *arises* from the supraglenoid tuberosity and from the glenoid ligament by a long tendon (9 cm.) bifuracted at its origin. The tendon at first passes over the head of the humerus within the capsule of the joint, and then passes into the intertubercular(bicipital) groove, which is covered by the capsule of the joint and an expansion from the tendon of the pectoralis major. To this point the tendon is surrounded by the synovial membrane of the joint. After emerging from this the tendon slowly expands and from its dorsal concave surface

FIG. 396.—DEEP MUSCLES OF THE FRONT OF THE ARM.



arise fiber-bundles which, increasing in number, extend, somewhat obliquely, toward the tendon of insertion. As in case of the short head, here also the fiber-bundles which arise highest the tendon of origin have the highest insertion.

Insertion.—The tendon of insertion begins usually in the distal quarter of the arm as a vertical septum between the two heads of the muscle. More distally this broadens out on each side into a flattened aponeurosis. The fiber-bundles are inserted into the sides of the septum and on each surface of the aponeurosis—those of the long head chiefly on the deep surface, those of the short head chiefly on the superficial surface. The aponeurosis is continued into a strong, flattened tendon which descends between the brachioradialis and pronator teres muscles to be inserted on the dorsal half of the bicipital tuberosity of the radius. From the medial border of the tendon an aponeurotic expansion, the **lacertus fibrosus** (semilunar fascia), is continued into the fascia of the ulnar side of the forearm.

Nerve-supply.—By a branch from the musculocutaneous nerve for each head. These branches may be bound in a common trunk for some distance. They enter the deep surface the muscle in the proximal part of the middle third of each belly often by several rami. Usually

there is a distinct intramuscular fissure for the reception of the branches to each head and blood-vessels which accompany them. The nerve fibers come from the fifth and sixth cervical nerves.

Action.—It is a flexor of the arm at the elbow and is the strongest supinator of the forearm. This last action is most marked when the forearm is flexed and pronated. Both heads are flexors and medial rotators of the arm at the shoulder. The long head is an abductor, so also is the short head when the arm is greatly abducted, otherwise the short head is an adductor.

Relations.—The tendons of origin are concealed by the pectoralis major and deltoid muscles. Beyond this the muscle is covered by the fascia brachii. In the lower part of the arm it lies upon the brachialis muscle. Upon the medial margin lie the coracobrachialis muscle, brachial vessels, and the median nerve.

Variations.—Variations are frequent (cf. fig. 213). The whole muscle or either head may be missing, but such cases are rare. The long head may extend only to the bicipital groove. Frequently the muscle is partially divided into the four primitive portions mentioned above. The two heads may be separate from origin to insertion. There may be an accessory head (in 3 subjects—Le Double) which arises from the coracoid process, the capsule of the joint, the tendon of the pectoralis major, or the shaft of the humerus near the insertion of the coracobrachialis. In most instances the origin takes place above the origin of the brachialis from the humerus. Sometimes several accessory heads are seen. Marked variation of insertion is less frequent, but occasionally a supernumerary slip may go to the medial intermuscular septum or the medial epicondyle. The fusion of the biceps with neighboring muscles (pectoralis major and minor, coracobrachialis, brachialis, palmaris longus, pronator teres, brachioradialis) by means of tendinous or muscular slips has been frequently reported.

The **brachialis** (fig. 396).—*Origin.*—(1) From the distal three-fifths of the front of the humerus, (2) from the medial intermuscular septum, and (3) from the lateral intermuscular septum proximal to the heads of the brachioradialis and extensor carpi radialis longus. Proximally it sends up a pointed process on the lateral side of the insertion of the deltoid and another between the insertions of the deltoid and the coracobrachialis. Distally the area of origin stops a little above the capitulum and the trochlea.

Structure and Insertion.—The fiber-bundles arise directly from this area of origin, except near the insertion of the deltoid and on the medial margin, where tendinous bands are developed. The fiber-bundles descend, the middle vertically, the medial obliquely lateralward, the lateral still more obliquely medialward. The tendon of insertion appears on the dorsal side of the lateral edge of the muscle in its lower fourth. Continuous with this stronger lateral portion of the tendon more distally a thinner band appears upon the ventral surface of the muscle above the joint. The tendon becomes thick as it passes distally, is closely united to the capsule of the elbow-joint, and is attached to the ulnar tuberosity. In addition to the main tendon, some of the deeper fiber-bundles of the muscle and some of these coming from the lateral intermuscular septum are attached by short tendinous bands to the coronoid process.

Nerve-supply.—From the musculocutaneous nerve by a branch which enters the ventral surface of the muscle near the junction of the upper and middle thirds of the medial border. In addition the radial (musculospiral) nerve usually sends a small branch into the distal lateral portion of the muscle. A branch from the median nerve frequently supplies the medial side of the muscle near the elbow-joint (Frohse).

Action.—To flex the forearm.

Relations.—It lies behind the biceps, on each side of which it projects. The distal lateral portion of the muscle is grooved by the brachioradialis, which here is closely applied to it. The radial (musculospiral) nerve runs between these two muscles. On the medial side run the brachial vessels and median nerve.

Variations.—It may be divided into two distinct heads continuous with the projections on each side of the deltoid tuberosity. A great number of supernumerary slips have been recorded. These may be attached to the radius, ulna, fascia of the forearm, capsule of the joint, brachioradialis, and extensor carpi radialis muscles. It may be partially fused with neighboring muscles. It has also been reported absent.

Bursæ

B. m. coracobrachialis.—Between the subscapularis muscle, the tendon of the coracobrachialis, and the coracoid process. Frequent.

B. bicipitoradialis.—Between the ventral half of the radial tuberosity and the tendon of the biceps. Constant.

B. cubitalis interossea.—Between the tendon of the biceps and the ulna and the neighboring muscles. Frequent.

D. MUSCULATURE OF THE FOREARM AND HAND

(Figs. 397–410)

The muscles of the forearm arise in part from the **humerus, in part from the** radius and ulna. Their bellies lie chiefly in the **proximal half of the forearm.** They are divisible into two groups:—a radiodorsal, **composed of extensors of the** hand and fingers and supinators of the forearm; and an **ulnovolar, composed of** flexors of the hand and fingers and pronators of the **forearm. The brachio-**radialis, which belongs morphologically with the former **group, is physiologically** a flexor of the forearm.

The two groups are separated on the medial side of the back of the forearm by the dorsal margin of the ulna (figs. 397, 400). Ventrally they are separated by the insertions of the biceps and brachialis and by an intermuscular septum (figs. 397, 401).

In the **hand**, in addition to the tendons of the muscles of the forearm mentioned above (fig. 407), there are several sets of intrinsic muscles. About the metacarpal of the thumb (figs. 406–408) is grouped a set of muscles which arise from the carpus and metacarpus and are inserted into the metacarpal and first phalanx of the thumb. A similar set of muscles is grouped about the metacarpal of the little finger (figs. 406, 407.) These sets of muscles give rise respectively to the thenar and hypothenar eminences. Between the metacarpals lies a series of dorsal and palmar interosseous muscles (figs. 408–410) which are inserted into the first row of phalanges and into the extensor tendons. From the tendons of the deep flexor of the fingers a series of lumbrical muscles passes to the radial side of the extensor tendons (figs. 404, 406). These various muscles abduct, adduct, flex, and extend the digits. In addition to these deeper skeletal muscles of the hand there is a subcutaneous muscle over the hypothenar eminence (fig. 406). Of the muscles of the hand, all are supplied by the ulnar nerve except most of those of the thumb and the two more radial lumbricals, which are supplied by the median nerve.

An arrangement of the muscles of the forearm in which the dorsal extensor-supinator musculature extends proximally on the radial side of the arm to the distal extremity of the humerus and the volar flexor-pronator musculature similarly on the ulnar side, is chararteristic of all limbed vertebrates and is associated with the pronate position of the forelimb characteristic of quadrupeds. In amphibia and reptiles the musculature terminates distally on the carpus and in the aponeuroses of the hand. In the higher forms special tendons are differentiated for those muscles of the forearm which act on the fingers. On the back of the hand in many vertebrates short extensor muscles are found running from the carpus to the phalanges. On the volar surface a complex musculature is found in all forms which have freely movable fingers. In animals which walk on the ends of the fingers, especially in the hoofed animals, the intrinsic musculature of the hand is greatly reduced. The phylogenetic development of the muscles of the forearm and hand is too complex a subject to be briefly summarized. The phylogeny of the forearm flexors and the palmar musculature has been studied by McMurrich. In his papers a summary of the literature on the subject may be found.

FASCIÆ

The **fasciæ** and the general relations of the musculature of the forearm and hand may be followed in the cross-sections, fig. 397.

The **tela subcutanea** contains a moderate amount of fat in the upper part of the forearm. This grows less in amount as the wrist is approached. On the back of the hand it contains little fat. In the palm and on the volar surface of the fingers a moderate amount of fat is embedded between dense vertical bundles of fibers which unite the skin to the fascia. Except on the volar surface of the hand and on the backs of the terminal phalanges, the tela is but loosely united to the underlying fascia.

The **bursa subcutanea olecrani** lies over the dorsal surface of the olecranon. Subcutaneous bursæ are also frequently found over the knuckles (**b. subcutaneæ metacarpophalangeæ dorsales**) and the proximal joints of the fingers (**b. subcutaneæ digitorum dorsales**).

The **antibrachial fascia** encloses the muscles of the forearm in a cylindrical sheath, composed in the main of circular fiber-bundles, but strengthened by longitudinal and oblique bundles extending in from the epicondyles of the humerus, the olecranon, the lacertus fibrosus of the biceps, and the tendon of the triceps. The fascia of the forearm is attached to the dorsal surface of the olecranon and to the subcutaneous margin of the ulna. Above, it is continued into the fascia of the arm; below, into the fascia of the hand. From the antibrachial fascia in the upper half of the forearm a fibrous septum extends between the radiodorsal and the ulnovolar muscle group to the radius. In the radial septum below the elbow a branch of communication extends between the superficial and deep veins of the arm. That part of the fascia overlying the radiodorsal group of muscles is much denser than that covering the volar group, except where the latter is strengthened by the lacertus fibrosus. In addition to the main radial septum other septa descend between the underlying muscles from the antibrachial fascia. These septa are best marked near the attachment of the muscles to the humerus. Here the fascia is firmly fused to the muscles.

Dorsally the antibrachial fascia is strengthened at the wrist by transverse fibers which extend from the radius to the styloid process of the ulna, the triquetrum (cuneiform), and pisiform, and give rise to the **dorsal ligament of the carpus** (posterior annular ligament). From this ligament septa descend to the radius and ulna and convert the grooves in these bones into **osteofibrous canals** which lodge the tendons of the various muscles extending to the wrist and hand.

On the **back of the hand** there is spread a fascia composed of two thin fascial sheets between which the extensor tendons are contained. Between the tendons these sheets are more or less

fused. On the backs of the fingers the fascia blends with the extensor tendons and the associated aponeurotic expansions from the interosseous and lumbrical muscles. Between the fingers it is continued into the transverse fasciculi of the palmar aponeurosis. At the sides of the hand the fascia is continued into the thenar and hypothenar fasciæ. Each dorsal interosseous muscle is covered by a special fascial membrane which is separated by loose tissue from the fascia investing the extensor tendons.

On the **volar side of the forearm** for some distance above the wrist the tendons of the flexor carpi radialis, the palmaris longus, and the flexor carpi ulnaris run between two layers of the fascia. The fascia is much strengthened at the wrist by transverse fibers which give rise to the **volar ligament of the carpus.** Beneath it lies the **transverse ligament of the carpus** (anterior annular ligament). This dense band is broader than the volar ligament but like it extends from the pisiform bone and the hamulus of the hamatum (unciform) to the tuberosity of the navicular and the tuberosity of the greater multangular (trapezium). It serves to complete an osteofibrous canal through which pass the flexor tendons of the fingers. Between the two ligaments which are partially fused with one another run the ulnar artery and nerve.

On the **palm of the hand** the ensheathing fascia presents three distinct areas—a central, a lateral, and a medial.

The central portion, the **palmar aponeurosis,** is composed chiefly of bundles of fibrous tissue which radiate superficially toward the fingers from the tendon of the palmaris longus or from a corresponding region of the forearm fascia when this muscle is absent. Between these bundles are others which arise from the transverse ligament. The deep surface of the fascia is composed of a thin incomplete layer of transverse fibers which continue the transverse fibers of the forearm fascia. Near the capitula of the metacarpals this layer becomes much stronger and constitutes a ligamentous band (**superficial transverse ligament** of Poirier). Near the bases of the digits bundles of transverse fibers (**fasciculi transversi**) lie in the webs of the fingers and constitute an incomplete transverse ligament separated by a distinct interval from the superficial transverse ligament.

From the palmar aponeurosis processes are sent in toward the deeper structures. Of these, the most important are those continued into a fibrous sheath which surrounds the space containing the long flexor tendons and the lumbrical muscle. This dense fibrous sheath is united by fibrous processes to the third, fourth, and fifth metacarpals. As the flexor tendons diverge and the ends of the metacarpals are approached, numerous processes descend from the palmar aponeurosis to the transverse capitular ligament. These hold the tendons in place. On the volar surface of the fingers the fascia serves to complete osteofibrous canals for the long flexor tendons. The ventral surface of the first and second phalanges of each finger is slightly grooved. The fascia is firmly united on each side to the margin of the groove, and over the groove forms a semicylindrical, strong, fibrous sheath, the **vaginal ligament** of the finger. This sheath is strengthened by transverse bands over the bases of the first and second phalanges (**annular ligaments**) and by cruciate bands over the shafts of the phalanges (**cruciate ligaments**). Over the interphalangeal joints the sheath is thin, but is strengthened by crucial bands which permit of freedom of motion.

The **thenar fascia** is a thin membrane covering the short muscles of the thumb. It is continued above into the fascia of the forearm, medially is fused with the tendon of the palmaris

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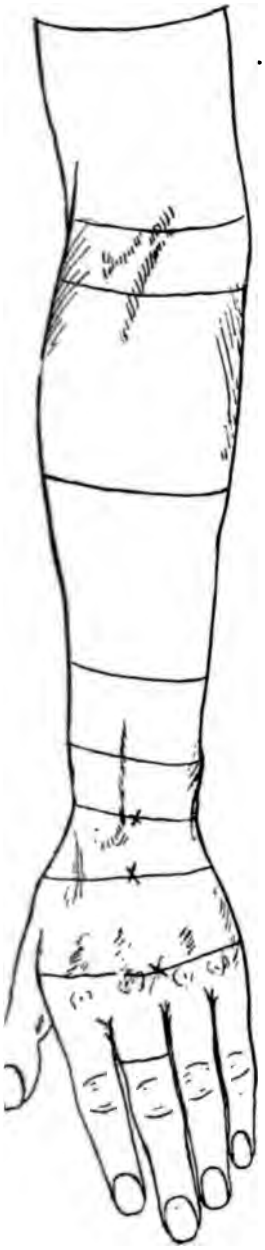
FIG. 397, A–H.—TRANSVERSE SECTIONS THROUGH THE LEFT FOREARM AND HAND.

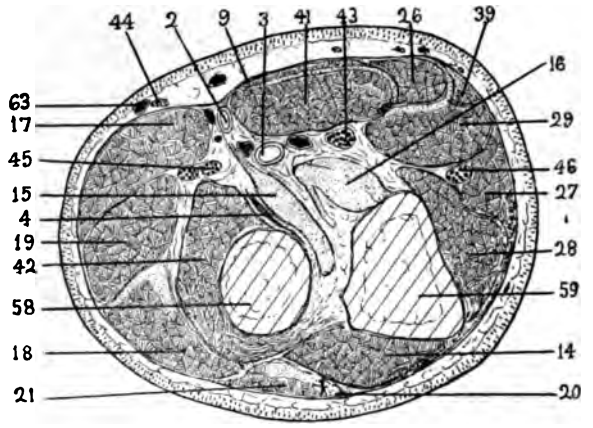
H. Transverse section through the first phalanx of the middle finger, diagrammatic, with the cavity of the synovial sheath of the flexor tendons distended.

The regions through which these sections pass are indicated in the diagram. *c* and *d* in the diagram show the regions through which pass sections C and D, fig. 393.

1. Aponeurosis palmaris. 2. Arteria radialis. 3. A. ulnaris. 4. Bursa bicipitoradialis. 5. Discus articularis. 6. Ligamentum carpale dorsale. 7. L. carpi transversum. 8. L. carpi volare. 9. Fascia antibrachii. 10. Musculus abductor pollicis brevis. 11. M. abductor pollicis longus—a, tendon. 12. M. abductor digiti quinti. 13. M. adductor pollicis. 14. M. anconeus. 15. M. biceps, tendon. 16. M. brachialis, tendon. 17. M. brachioradialis—a, tendon. 18. M. extensor carpi radialis brevis—a, tendon. 19. M. extensor carpi radialis longus—a, tendon. 20. M. extensor carpi ulnaris. 21. M. extensor digitorum communis—a, tendon for second finger; b, tendon for the third finger; c, tendon for fourth finger; d, tendon for fifth finger; e, digital aponeurosis. 22. M. extensor digiti quinti proprius. 23. M. extensor indicis proprius. 24. M. extensor pollicis brevis —a, tendon. 25. M. extensor pollicis longus—a, tendon. 26. M. flexor carpi radialis—a, tendon. 27. M. flexor carpi ulnaris—a, tendon. 28. M. flexor digitorum profundus—a, tendon for second finger; b, tendon for third finger; c, tendon for fourth finger; d, tendon for fifth finger. 29. M. flexor digitorum sublimis—a, tendon for second finger; b, tendon for third finger; c, tendon for fourth finger; d, tendon for fifth finger. 30. M. flexor digiti quinti brevis. 31. M. flexor pollicis brevis. 32. M. flexor pollicis longus a, tendon. 33. M. interossei dorsales. 34. M. interossei volares. 35. M. lumbricales. 36. M. opponens pollicis. 37. M. opponens digiti quinti. 38. M. palmaris brevis. 39. M. palmaris longus—a, tendon. 40. M. pronator quadratus. 41. M. pronator teres. 42. M. supinator. 43. N. cutaneus antibrachii lateralis. 44. N. medianus. 45. N. radialis—a, deep radial nerve; b, superficial radial nerve. 46. N. ulnaris. 47. Os capitatum (magnum). 48. Os hamatum (unciforme). 49. Os lunatum (semilunar). 50. Os metacarpale, I. 51. Os metacarpale, II. 52. Os metacarpale, III. 53. Os metacarpale, IV. 54. Os metacarpale, V. 55. Os multangulum majus (trapezium). 56. Os naviculare. 57. Ossa sesamoidea of fifth digit. 58. Radius. 59. Ulna. 60. Vagina fibrosa (tendon-sheath) of the long digital flexors. 61. Vagina fibrosa (tendon-sheath) of the flexor pollicis longus. 62. Vagina fibrosa (tendon-sheath in digit). 63. Vena cephalica.



A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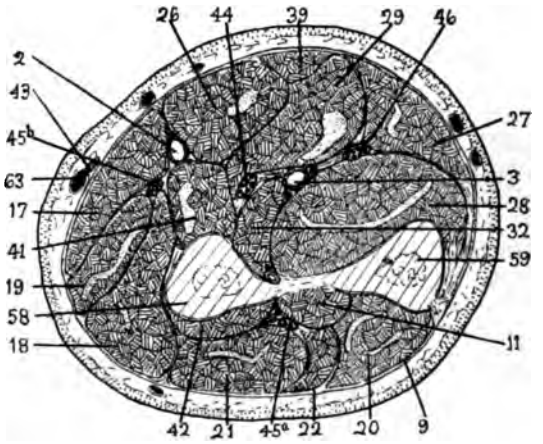
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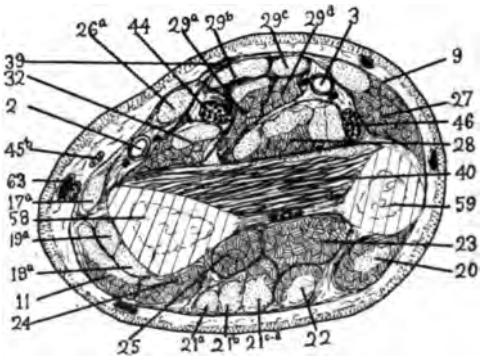
C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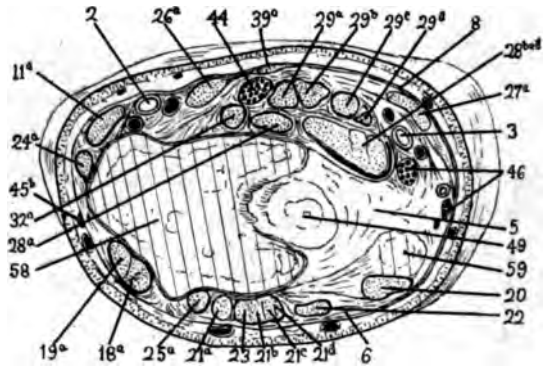
D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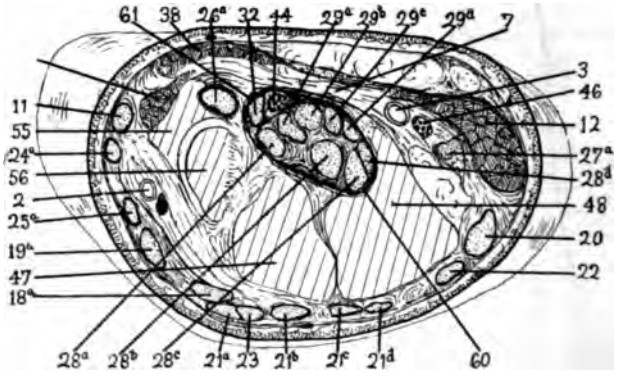
E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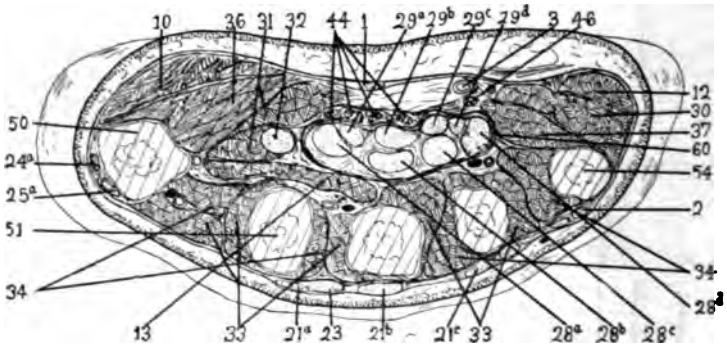
F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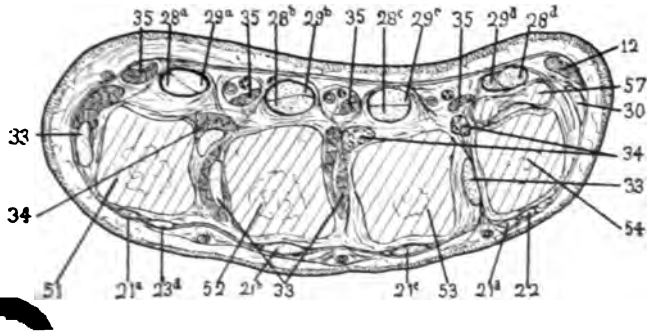
G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21a
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21c
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21d
22

H

the palmar aponeurosis, and extends as a septum to be attached to the third meta-
terally it is attached to the first metacarpal and is continued into the dorsal fascia
. It is fused with an aponeurosis from the tendon of the abductor pollicis longus.
s continued into the vaginal ligament of the long flexor of the thumb. Superficially
adherent to the skin.
othenar fascia invests the palmar muscles of the little fingers. It is continued
ıar margin of the fifth metacarpal over the muscles of the little finger to the palmar
, and, by means of a septum, to the radial side of the fifth metacarpal. Proximally,
d to the hamatum (unciform) and extends into the fascia of the forearm, distally,
ıto the vaginal ligament of the tendon of the fifth digit.
y seated suprametacarpal fascial layer, or **deep palmar fascia,** covers the inter-
ıcles and is attached to the volar surface of the metacarpal bones.
ion to the fasciæ mentioned, intermuscular septa serve to separate more or less
the various intrinsic muscles of the hand.

MUSCLES

1. Radiodorsal Division

uscles of this group lie in two chief layers, a superficial and a deep.

a. Superficial Layer

(Figs. 398, 401, 402)

uscles of this layer, closely associated at their origins, extend from the
of the distal end of the humerus to the distal extremity of the radius,
s and the fingers. They are divisible into a radial, an intermediate,
ıar set.

set.—To this belong three muscles, the brachioradialis, extensor carpi
ngus and brevis. The **brachioradialis** (fig. 401), a forearm flexor, is a
fusiform muscle which arises from the lateral epicondylar ridge of the
ınd is inserted into the base of the styloid process of the radius. The
arpi radialis longus (fig. 402) is a narrow, fusiform muscle which extends
radial margin of the forearm, partly under cover of the brachioradialis.
rom the lateral epicondylar ridge of the humerus, and is inserted into
l metacarpal bone. The **extensor carpi radialis brevis** (fig. 398) is a
muscle more dorsally placed than the last at the radial side of the arm.
rom the lateral epicondyle and is inserted into the bases of the second
metacarpals. These muscles are supplied by branches of the radial
ch arise proximal to the passage of the deep radial (posterior inter-
hrough the supinator muscle. Distally this set of muscles is separated
ntermediate set by the long abductor and the extensors of the thumb,
s from an origin under the latter set over the tendons of the radial
to the thumb.

termediate set.—This consists of the thick, flattened **extensor digitorum**
and the slender **extensor digiti quinti proprius** (fig. 398). They arise
ateral epicondyle, and are inserted into the backs of the fingers.

nar set consists of one muscle, the fusiform **extensor carpi ulnaris** (fig.
:h arises from the lateral epicondyle of the humerus and is inserted into
of the base of the fifth metacarpal.

termediate and ulnar sets of muscles are supplied by branches from the
fundus of the radial nerve after this has passed through the supinator

g the lateral set of the superficial layer is represented by the tibialis anterior. The
e set is represented by the long extensors of the toes. The single muscle which
the medial set is represented by the peroneal muscles.

chioradialis (supinator radii longus) (figs. 398, 401).—*Origin.*—From the upper
of the lateral epicondylar ridge of the humerus and from the front of the lateral
ar septum.

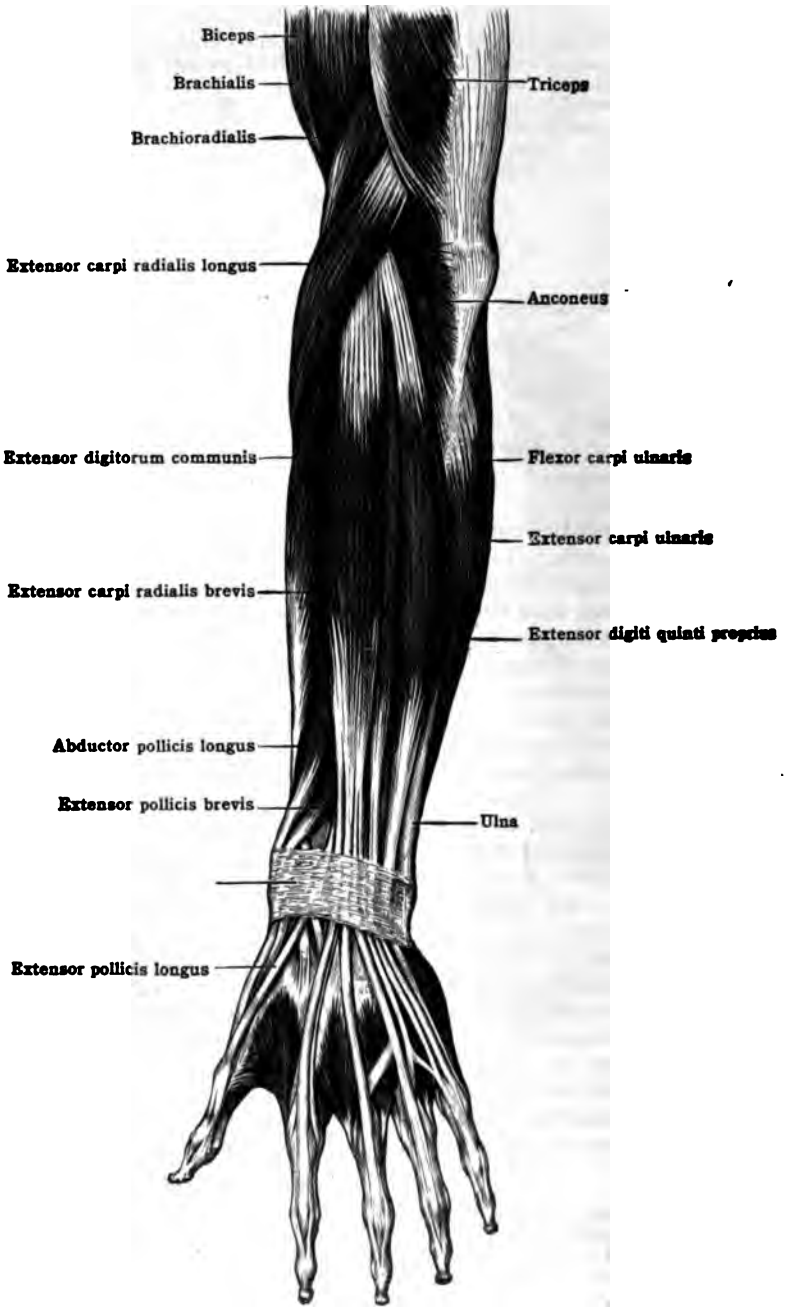
.—Into the lateral side of the base of the styloid process of the radius.

.—The constituent fiber-bundles arise directly from the septum and by short
ands from the epicondylar ridge, extend downward and ventrally, and terminate
rm manner on a tendon which extends high on the deep surface of the muscle.
becomes free about the middle of the forearm as a broad, flat band. This be-
w as the tendon winds about the radius from the volar to the lateral surface. Be-
rtion it expands laterally and is connected with neighboring ligaments. The free
he muscle faces laterally at its origin, but, owing to the torsion, ventrally in the

forearm. The tendon, however, is turned again so that at the insertion it faces laterall more.

Nerve-supply.—From a branch of the radial nerve (musculospiral) which enters the mal third of the muscle on its deep surface. The nerve fibers arise from the fifth and cervical nerves.

FIG. 398.—MUSCLES OF THE RADIAL SIDE AND THE BACK OF THE FOREARM.



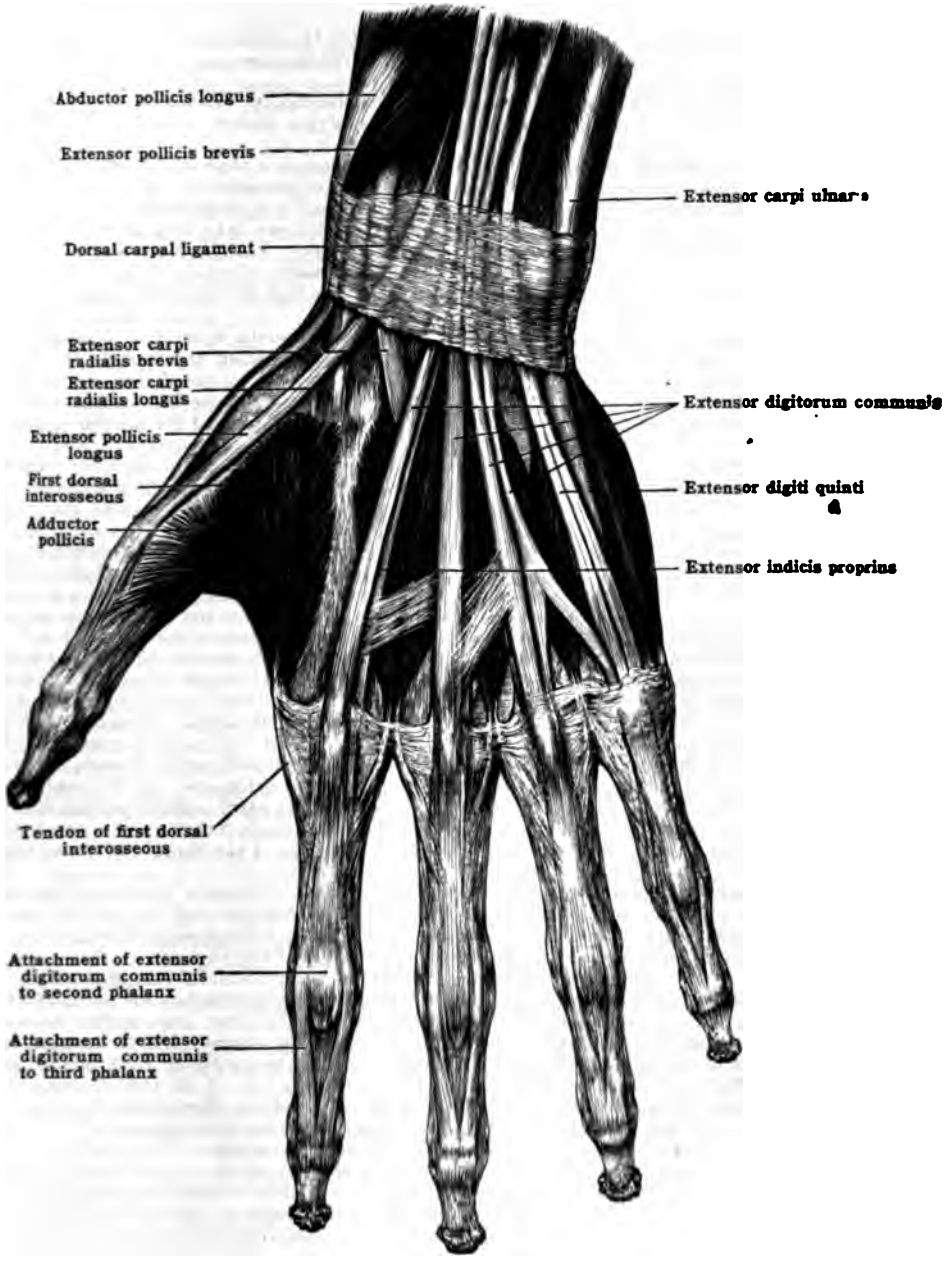
Action.—To flex the forearm. This action is strongest when the forearm is pı It acts as a supinator only when the arm is extended and pronated. It then serves to arm in a state of semipronation. When the forearm is flexed and supinated, it acts a nator.

Relations.—The muscle is superficially placed on the ventrolateral surface of the f Its tendon of insertion, however, is covered by the long abductor and the short extenso thumb. Near its origin (fig. 398) it lies lateral to the brachialis. In the intervening ti the radial nerve and the terminal branch of the profunda brachii artery. Dorsally and l

lies the medial head of the triceps. More distally the muscle overlies the extensor carpi radialis longus. It crosses the supinator, pronator teres, and flexor pollicis longus muscles. Beneath its medial edge lie the radial vessels and nerve.

Variations.—The humeral origin may extend half-way up the shaft. The radial insertion may be as high as the middle of the shaft or descend to the lesser multangular, navicular, or third metacarpal. In about 7 per cent. of bodies (Le Double) the tendon of insertion divides

FIG. 399.—TENDONS UPON THE DORSUM OF THE HAND.



nto two or three slips which are inserted on the styloid process of the radius. Occasionally the radial nerve passes between these slips. An accessory slip may pass to the fascia of the forearm. The muscle may be doubled throughout its length and it may be missing. It may be connected by accessory slips with neighboring muscles, the deltoid, brachialis, long abductor of the thumb, or long radial carpal extensor. The slip most frequently found goes to the brachialis.

The extensor carpi radialis longus (figs. 398, 399, 402).—*Origin.*—From the lower third of the lateral epicondylar ridge, the lateral intermuscular septum, and from the front of the tendons of the extensor carpi radialis brevis and the extensor communis digitorum which arise from the lateral epicondyle.

Structure and insertion.—The fiber-bundles are inserted in a penniform manner on both surfaces of a tendon which first appears on the lateral border of the deep surface of the muscle, becomes free above the middle of the forearm, and descends, closely applied to the tendon of the short radial carpal extensor, to the second compartment beneath the dorsal carpal ligament, through which it passes to its insertion into the base of the second metacarpal near the radial border. The outer surface of the muscle faces at first laterally, then ventrally.

Nerve-supply.—By one or two branches which arise from the radial (musculospiral) nerve as it passes between the brachialis and brachioradialis. The nerve enters the deep surface of the muscle in the proximal third. The nerve fibers arise from the (fifth), sixth and seventh cervical nerves.

Action.—To extend and abduct the hand. It steadies the wrist when the flexors act on the fingers. It is a flexor of the forearm; a supinator when the forearm is extended and pronated, a pronator when it is flexed and supinated.

Relations.—It is covered by the brachioradialis near the elbow. Below it becomes superficial except where crossed by the tendons of the muscles of the thumb. (For the relations to the short radial carpal extensor see below.)

Variations.—The humeral attachment may be more extensive than that indicated above. The tendon of insertion may send a band to the third or to the fourth metacarpal or to the multangulum majus (trapezium). The muscle may be fused, partly or completely, with the short radial extensor. It may send a slip to the abductor pollicis longus or to some of the interossei.

The extensor carpi radialis brevis (figs. 398, 399).—*Origin.*—From a band which descends on its deep surface from the common extensor tendon attached to the lateral epicondyle, from the intermuscular septa surrounding its head, and from the radial collateral ligament of the elbow-joint.

Structure and insertion.—The fiber-bundles converge obliquely toward a tendon which appears high up on the dorsolateral surface of the muscle. Toward the lower third of the forearm this tendon becomes a free, strong band closely applied to the under surface of the tendon of the long radial extensor, and with this passes through the second compartment beneath the dorsal ligament of the carpus, diverging as it does so toward its insertion into the back of the bases of the second and third metacarpal bones.

Nerve-supply.—A branch is supplied to the muscle from the deep radial (posterior interosseous) nerve before this enters the supinator (brevis). The branch enters the middle third of the medial margin of the muscle by several rami. The nerve fibers arise from the (fifth), sixth and seventh cervical nerves.

Action.—To extend the hand radialward and, to a slight extent, to flex the forearm.

Relations.—In its proximal portion the muscle is placed with a medial surface toward the common extensor, a deep toward the supinator (brevis) and pronator teres, and a dorsolateral toward the long radial extensor. More distally the muscle and its tendon become flattened about the radius and partly covered by the long radial extensor and its tendon.

In the distal quarter of the forearm the tendons of these two muscles are crossed by the long abductor and the short extensor of the thumb. Beneath the dorsal carpal ligament the tendon of the short radial extensor is crossed by the tendon of the long extensor of the thumb.

Variations.—The tendon often sends no slip to the second metacarpal. Fusion of the two radial extensors is frequent. The fused muscle may have from one to four tendons. The **extensor carpi radialis intermedius** of Wood is a muscle which arises, rarely directly from the humerus, but not infrequently as a slip from one or both radial extensors. It is inserted into the second or third metacarpal bone or into both. The **extensor carpi radialis accessorius** is a muscle which has an origin like the extensor intermedius, but which terminates on the base of the metacarpal or first phalanx of the thumb, the short abductor of the thumb, or some neighboring structure.

The extensor digitorum communis (figs. 398, 399).—*Origin.*—From a tendon attached to the lateral epicondyle, and from intermuscular septa which lie between the head of the muscle and the short radial extensor, the extensor of the little finger, and the supinator muscle.

Insertion.—By four tendons into the bases of the phalanges of the fingers.

Structure.—The fiber-bundles arise from the interior of the pyramidal case formed by the tendon, the fascia, and intermuscular septa, and pass distally to converge on four tendons which begin in the middle of the forearm, become free a little above the wrist, pass under the dorsal carpal ligament in a groove common to them and the tendon of the extensor indicis proprius, and diverge to the backs of the fingers. Opposite the metacarpophalangeal joint each tendon gives rise on its under surface to a band which becomes attached to the base of the first phalanx of its respective digit. The tendon is also closely bound to the joint by fibrous bands connected with the palmar fascia. On the dorsum of the first phalanx the tendon expands and is bound to an aponeurotic extension from the interosseous and lumbrical muscles. The tendon divides into three bands. The middle band passes to the base of the second phalanx, the lateral bands pass laterally around the joint to be inserted into the back of the base of the third phalanx. The lateral bands are bound to the second joint by a thin layer of transverse and oblique fibers.

An obliquely transverse band usually passes from the tendon of the index to that of the middle finger above the heads of the metacarpals. The tendon to the index finger is united to the tendon of the extensor indicis proprius opposite the metacarpophalangeal articulation. The tendon to the ring finger usually sends a slip to join the tendon of the middle finger. The fourth tendon lies near that of the ring finger and divides into two slips, one of which joins the tendon of the ring finger and one goes to the little finger to join the tendon of the extensor digiti quinti proprius.

Nerve-supply.—From a branch which arises from the deep radial (posterior interosseous) nerve as it emerges from the supinator (brevis) muscle. From this several twigs enter the deep surface of the middle third of the belly. Often the nerve is bound up with the nerve to the extensor of the little finger and the ulnar extensor. On the other hand, there may be several

separate branches to the muscle. The nerve fibers arise from the sixth, seventh, and eighth cervical nerves.

Action.—The muscle extends the two terminal phalanges on the basal, the basal on the metacarpus, and the hand at the wrist. The extensor action is strongest on the first phalanx. The cross-bands between the tendons hinder the independent extension of the middle and ring fingers, while the special extensors of the index and little fingers makes the movements of these fingers freer. When the hand is abducted toward the radial side, the extensor muscles tend to draw the fingers ulnarward. When the hand is abducted toward the ulnar side, the muscles tend to draw the fingers toward the thumb. When the hand is in the mid-position the ring finger and little finger are abducted and the index-finger is adducted. (Frohse.)

Relations.—It is superficially placed. Under it lie the deep muscles of the back of the forearm, the interosseous vessels, and the deep radial (posterior interosseous) nerve. It lies between the short radial carpal extensor and the extensor of the little finger.

Variations.—There is considerable variation in the extent of isolation of the parts going to the various fingers. That to the index-finger is the one most frequently isolated. At times the tendon to the index or little finger may be wanting. More frequently one or more of the tendons subdivides to be attached to two or more fingers or to the thumb. The connections between the tendons on the back of the hand vary greatly.

The **extensor digiti quinti proprius** (extensor minimi digiti) (figs. 398, 399).—*Origin.*—Chiefly from the septum between it and the common extensor, but also in part from the septum between it and the extensor ulnaris and from the overlying fascia.

Structure and insertion.—The fiber-bundles descend in a narrow band which begins near he neck of the radius. They are inserted into the side of a tendon which begins high on the lnar margin of the muscle. The most distal fiber-bundles extend nearly to the wrist-joint. he tendon passes through the fifth compartment beneath the dorsal carpal ligament, and xtends on the back of the fifth metacarpal to the base of the first phalanx of the little finger, here it is joined by a slip from the fourth tendon of the common extensor. The insertion of ie tendons is like that of the tendons of the common extensor.

Nerve-supply.—By a branch or branches from the deep radial (posterior interosseous) nerve. he nerve filaments enter the middle third of the fleshy portion of the muscle on its deep rface. The innervation of this muscle is intimately related to that of the preceding.

Action.—It acts as a portion of the common extensor, but, owing to its separation, in-ependent movement of the little finger is possible.

Relations.—It lies between the common extensor and the ulnar extensor and upon the deep uscles of the back of the forearm.

Variations.—Absence is not very frequent; blending with the common extensor is frequent. s tendon often divides into two or more slips. The belly may also be doubled. It may have supplementary origin from the ulna. A tendon slip to the ring-finger is frequently found.

The **extensor carpi ulnaris** (figs. 398, 399).—*Origin.*—By two heads: one from the inferior rsal portion of the epicondyle by an aponeurotic band attached below the tendon of the mmon extensor, from the enveloping fascia, and from the septa between it and the extensor giti quinti, anconeus, and supinator (brevis); the other from the proximal three-fourths of ie dorsal border of the ulna.

Structure and insertion.—The fiber-bundles descend in an osteofascial compartment bounded r the dorsal surface of the ulna, the fascia of the forearm, the dense fascia overlying the nar origin of the muscles of the thumb, and the origin of the extensor indicis. The tendon mmences high in the muscle and appears on the radial border of the middle third of the back its belly. The fiber-bundles are inserted in a penniform manner on the ulnar border and ep surface of the tendon as far as the wrist. Here the tendon enters the sixth osteo-fibrous nal beneath the dorsal carpal ligament in a special groove on the outer side of the styloid rocess of the ulna. It is inserted into the base of the fifth metacarpal.

Nerve-supply.—By a branch which arises from the deep radial (posterior interosseous) nerve this emerges from the supinator (brevis) muscle. Several filaments enter the deep surface the muscle in the middle third. The nerve fibers arise from the sixth, seventh and eighth rvical nerves.

Action.—To extend and abduct the hand ulnarward. It also abducts and extends the th metacarpal.

Relations.—It occupies a superficial position on the ulnar side of the extensors of the fore-m. Beneath it lie the deep muscles of the back of the forearm and the posterior surface of ie ulna.

Variations.—It may receive a slip from the triceps or be fused with the anconeus or with ie extensor of the little finger. More frequently it is doubled, partially or completely. An cessory tendon may go to the first phalanx of the little finger, to the head of the fifth meta-rpal, to the fourth metacarpal, to the extensor tendon of the little finger, or to the fascia over ie opponens digiti quinti. The muscle may be reduced to a fibrous band. The **ulnaris digiti inti** is a rare muscle arising from the dorsal surface of the ulna and inserted into the base of ie first phalanx of the little finger. It may be represented by a fasciculus or an extra tendon om the ulnar extensor.

b. Deep Layer

(Fig. 400)

The muscles of this group extend from the ulna to the radius, thumb, and dex-finger. They are the supinator, abductor pollicis longus, extensor pollicis ngus brevis, and extensor indicis proprius. The **supinator** is a rhomboid mus-e which arises from the lateral epicondyle of the humerus and the supinator crest

of the ulna, winds laterally around the radius and is inserted into its volar surface. The **abductor pollicis longus** is a fusiform muscle which arises from the middle third of the ulna, the interosseous membrane, and the radius, and is inserted into the base of the first metacarpal. The **extensor pollicis brevis** arises from the radius distal to the preceding muscle, and is inserted into the base of the first phalanx of the thumb. The **extensor pollicis longus** is a narrow muscle which arises from the middle third of the dorsal surface of the ulna and is inserted into the base of the second phalanx of the thumb. The **extensor indicis proprius** is a narrow, fusiform muscle arising from the shaft of the ulna and inserted into the dorsal aponeurosis of the index-finger. These muscles are supplied from branches of the deep radial (posterior interosseous) nerve while this is passing through or after its exit from the supinator.

The extensor pollicis longus is represented by the extensor hallucis longus of the leg. The abductor pollicis longus and extensor pollicis brevis are represented by the abnormal abductor hallucis longus and extensor primi internodii hallucis muscles, the rudiments of which are perhaps normally present in the tibialis anterior. The supinator and the extensor indicis muscles are not represented in the leg. On the other hand, the extensor digitorum brevis, normal in the foot, is only occasionally found on the back of the hand.

The supinator (brevis) figs. 397, 400, 403).—*Origin.*—From (1) the inferior dorsal portion of the lateral epicondyle by a tendinous band which is adherent to the deep surface of the tendons of origin of the radial and common extensors and to the radial collateral ligament of the joint; and (2) the ulna by a superficial aponeurosis and by fiber-bundles attached directly to the depression below the radial notch and to the supinator crest.

Insertion.—The lateral and volar surfaces of the radius from the tuberosity to the attachment of the pronator teres.

Structure.—From their origin the fiber-bundles descend spirally in a musular sheet which enwraps the radius (fig. 397). The attachment extends to the oblique line. The muscle is divided into a superficial and a deep plane by a septum in which the deep radial (posterior interosseous) nerve runs. The radial attachments of these two portions are separated by an osseous area into which no fiber-bundles are inserted. The fiber-bundles of the superficial layer have a much more vertical course and are longer than those of the deep layer.

Nerve-supply.—By branches which arise from the deep radial (posterior interosseous) nerve before it passes between the two layers of the supinator muscle. The nerve fibers arise from the fifth, sixth, and seventh cervical nerves.

Action.—To supinate the forearm.

Relations.—The supinator is covered by the superficial group of extensor muscles above described and by the anconeus.

Variations.—The extent of separation of the muscles into two portions varies. Accessory fasciculi of origin are not uncommon. These may spring from the annular ligament, **tensor ligamenti annularis anterior** (5 per cent. or more of bodies—Le Double), the lateral epicondyle, the tendon of the biceps, the tuberosity of the radius, etc. A sesamoid bone may lie in the tendon of origin. The **tensor ligamenti annularis posterior** is a slip generally present and often independent of the supinator. It runs from the ulna behind the radial notch to the annular ligament of the radioulnar joint.

The abductor pollicis longus (extensor ossis metacarpi pollicis) (fig. 400).—*Origin.*—From (1) the lateral margin of the dorsal surface of the ulna in the proximal portion of the middle third, and the adjacent interosseous membrane, (2) the dorsal surface of the radius distal and medial to the attachment of the supinator, and (3) at times, from the septa lying between it and the supinator, extensor carpi ulnaris, and extensor pollicis longus.

Structure and insertion.—The fiber-bundles from this extensive area of origin converge in a bipenniform manner upon a tendon which appears as an aponeurosis on the deep surface of the muscle about the middle of the forearm. The tendon as it descends becomes rounded. The insertion of fiber-bundles continues nearly to the wrist. Here, together with the tendon of the short extensor, it enters the first osteofibrous canal beneath the dorsal carpal ligament upon the lateral surface of the distal extremity of the radius. Upon leaving this canal the tendon extends to be inserted on the radial side of the base of the first metacarpal bone.

Nerve-supply.—By one or more branches from the deep radial (posterior interosseous) nerve after it has emerged from the supinator. The branches enter the muscle on the superficial surface in the proximal third. The nerve fibers come from the sixth, seventh (and eighth) cervical nerves.

Action.—It abducts the first metacarpal. At the height of its contraction it flexes and abducts the hand at the wrist.

Relations.—Near its origin the muscle is covered by the superficial extensors of the forearm More distally, accompanied by the short extensor, it passes radially, becomes superficial, and crosses the tendons of the two radial carpal extensors.

Variations.—The muscle or its tendon may be doubled. An accessory tendon may be applied to the multangulum majus (trapezium), the transverse ligament of the carpus, the superficial muscles of the thenar eminence, or the first metacarpal. Of these, the attachment to the short abductor and short flexor is the most frequent (7 out of 36 bodies—Wood). There may be three or more tendons. The muscle may be fused with the short extensor.

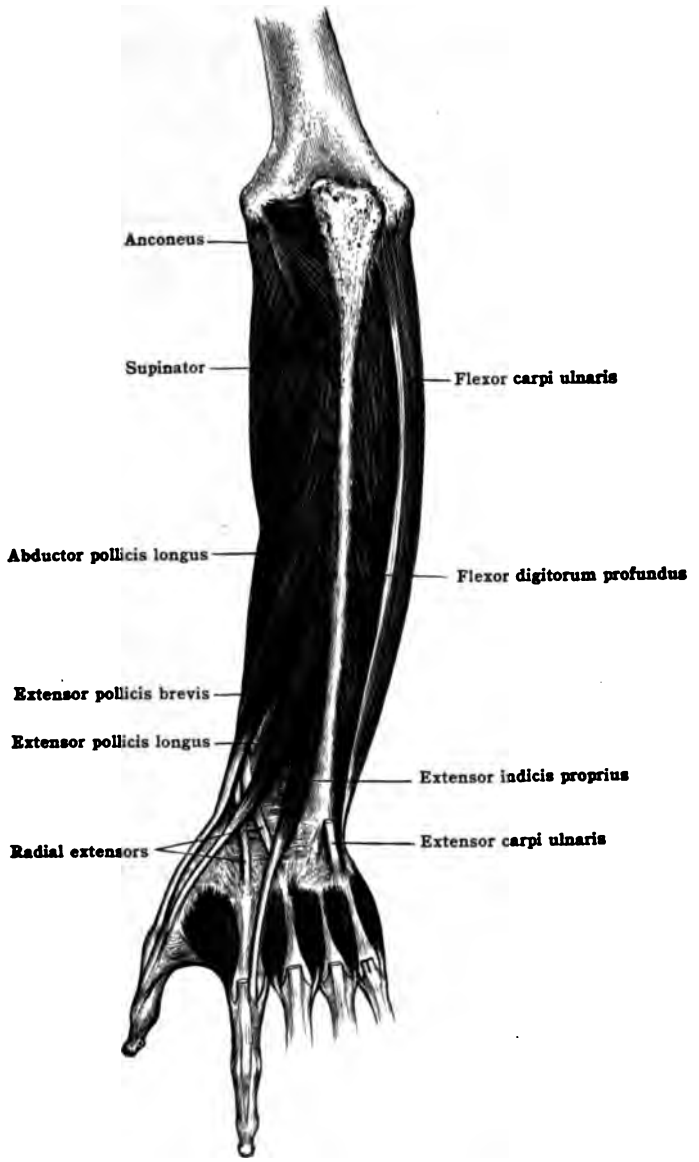
The extensor pollicis brevis (fig. 400).—*Origin.*—From the distal part of the middle third of the medial portion of the dorsal surface of the radius and from the neighboring portion of the interosseous membrane. Rarely its origin extends to the ulna.

Structure and insertion.—The fiber-bundles converge on a tendon which appears on the radial

er. The fibers are inserted as far as the dorsal carpal (posterior annular) ligament. The on lies parallel to the ulnar side of that of the abductor pollicis longus, and, in close con- ion with it, passes through the first compartment beneath the dorsal carpal ligament, and es the metacarpophalangeal joint on the radial side of the long extensor tendon. It erted on the base of the first phalanx of the thumb or into the capsule of the metacarpo- angeal joint.

erve-supply.—From a branch derived from the deep radial (posterior interosseous) nerve, branch is usually given off in common with or near the nerve to the abductor pollicis longus. may traverse that muscle to reach the extensor pollicis brevis, which it enters in the proxi- third of its radial border. The nerve fibers come from the sixth, seventh (and eighth) cal nerves.

FIG. 400.—THE DEEP MUSCLES OF THE BACK OF THE FOREARM.



ction.—To extend the thumb at the metacarpophalangeal joint and to abduct the first acarpal. It is a radial abductor of the hand at the wrist-joint.

Relations.—It lies between the abductor pollicis longus and the extensor pollicis longus, rhich its origin is partly overlapped. In company with the former muscle it passes medially ı beneath the common extensor of the fingers and over the tendons of the radial carpal nsors to reach its osteofibrous canal under the dorsal carpal ligament.

Variations.—The head of the muscle may be fused with the long abductor. Its tendon nsertion may give rise to a slip inserted on the first metacarpal (in 2 out of 85 bodies—Le ble) or into the terminal *phalanx. Its tendon is often* united with that of the long extensor.

It may be fused with the long abductor of the thumb and has been found missing. It may be doubled.

The extensor pollicis longus (fig. 400).—*Origin.*—From the middle third of the lateral part of the dorsal surface of the ulna; from the neighboring part of the interosseous membrane; and from the septa between it and the extensor indicis proprius and the extensor carpi ulnaris.

Structure and insertion.—The fiber-bundles converge in a bipenniform manner on the two sides of a tendon which appears high on the dorsal surface of the muscle. They extend as far as the dorsal carpal (posterior annular) ligament. The fusiform body of the muscle descends somewhat obliquely on the dorsal surface of the forearm. The tendon enters the third osteofibrous canal beneath the dorsal carpal (posterior annular) ligament. On emerging from the canal it passes very obliquely across the dorsal surface of the carpus, over the tendons of the radial extensors, to the ulnar side of the first metacarpal. It passes along this and, on the dorsal surface of the first phalanx, expands to be inserted into the base of the second phalanx. The aponeurosis of insertion receives tendinous slips from the short muscles of the volar surface of the thumb.

Nerve-supply.—By a twig from the deep radial (posterior interosseous) nerve. The branch gives rise to twigs which enter the proximal third of the radial border of the muscle. The fibers arise from the sixth, seventh, and eighth cervical nerves.

Action.—To extend the second phalanx on the first, and this on the metacarpal. It also draws the whole thumb when extended toward the second metacarpal. It is a radial abductor of the hand at the wrist-joint.

Relations.—The head of the muscle is partly overlapped by the long abductor of the thumb. It lies between this and the extensor pollicis brevis on one side, and the extensor indicis proprius on the other. Over it lie the extensors of the fingers and the ulnar carpal extensor.

Variations.—The tendon may give a slip to the base of the first phalanx of the thumb to the dorsal carpal ligament, or to the index finger. It may receive an accessory slip from the common extensor of the fingers or the short extensor of the thumb. It is frequently doubled. An additional extensor is found in about 6 per cent. of bodies between the extensor of the index finger and that of the thumb. It has a double tendon and insertion into both digits (**extensor communis pollicis et indicis**).

The extensor indicis proprius (fig. 400).—*Origin.*—From the proximal part of the distal third of the posterior surface of the ulna, medial and distal to that of the preceding muscle, from the adjacent interosseous membrane, and from the septum between it and the extensor pollicis longus.

Structure and insertion.—The fiber-bundles are inserted on a tendon which first appears on the radial border of the muscle. The insertion of fiber-bundles extends nearly to the dorsal carpal (posterior annular) ligament. Here the tendon passes beneath that of the extensor of the little finger and enters the fourth osteofibrous canal beneath the lateral tendons of the common extensor. It passes across the wrist beneath the tendon from the extensor communis to the index finger, and is inserted on the ulnar side of this into the dorsal aponeurosis of the index finger opposite the base of the first phalanx.

Nerve-supply.—By a twig from the deep radial (posterior interosseous) nerve. This twig enters the proximal third of the radial border of the muscle. It frequently arises from a branch to the extensor pollicis longus. The nerve fibers come from the sixth, seventh, eighth cervical nerves.

Action.—To extend the first phalanx on the metacarpal. Like the common extensor it has a limited action on the two terminal phalanges. It also abducts the index finger.

Relations.—It is covered by the superficial extensor group.

Variations.—These are frequent. It may be absent. There may be two heads, or the muscle may be completely doubled. It may receive an accessory slip from the ulna or the carpus. The tendon may give accessory slips to the middle finger, the ring finger, or the thumb. The accessory tendon to the middle finger is the most frequent. The tendon to the index finger may be inserted on the metacarpus.

Abnormal Muscles of the Back of the Wrist and Hand

The **extensor medii digiti** is a small muscle which arises from the ulna beneath the extensor of the index finger, with which it is more or less fused. It sends a tendon to the extensor aponeurosis of the middle finger or slips both to this finger and the index finger. It is present in about 10 per cent. of bodies (Le Double).

The **extensor digiti annularis** is a muscle similar to the extensor medii digiti, but much rarer.

The **extensor digitorum brevis**, which resembles the muscle of corresponding name on the dorsum of the foot, may have from one to four fasciculi, but most frequently one. The most common fasciculus is one which sends a tendon to the extensor tendon of the index finger. One for the middle finger is nearly as frequent. Others are rare. A fasciculus for the thumb has not been reported. (Le Double.) The fasciculi usually arise from the bones of the ulnar half of the carpus—lunatum (semilunar), triquetrum (cuneiform), hamatum (unciform), and capitatum (magnum), and from the dorsal ligaments uniting these bones. The tendons are inserted either into the corresponding extensor tendons or into the metacarpals. The muscle is found in about 10 per cent. of bodies (Wood).

Bursæ

B. m. extensoris carpi radialis brevis.—Between the tendon and the base of the third metacarpal.

B. m. abductoris pollicis longi.—Between the tendons of the long and short radial extensors and the tendons of the abductor pollicis longus and extensor pollicis brevis. Another bursa lies beneath the tendon of insertion of the abductor.

B. intermetacarpophalangeæ.—Between the lateral surfaces of the heads of the metacarpal bones of neighboring fingers dorsal to the transverse capitular ligament.

B. tendinum m. extensoris digitorum communis.—Small bursæ are sometimes found beneath the tendons to the index and little fingers near where they begin to diverge from the common tendon.

B. m. extensoris carpi ulnaris.—A small bursa may be found under the tendon of origin of this muscle.

B. m. supinatoris.—Between the supinator and the tendon of the extensor muscles.

B. m. extensoris pollicis longi.—Between the tendon and the first metacarpal.

Synovial Tendon-sheaths

Vagina tendinum mm. extensorum carpi radialium.—Synovial sheaths cover the tendons of the two radial carpal extensors as they pass beneath the dorsal carpal (posterior annular) ligament. In the adult these sheaths usually are more or less fused and communicate with the sheath of the extensor pollicis longus where this crosses them.

Vagina tendinum mm. extensoris digotorum communis et extensoris indicis.—A synovial sheath surrounds the tendons of these muscles as they pass beneath the dorsal carpal (posterior annular) ligament. This sheath extends for some distance on the tendons as they diverge.

Vagina tendinis m. extensoris digiti quinti.—A synovial sheath extends on the tendon of this muscle from above the dorsal carpal (posterior annular) ligament to the base of the metacarpal.

Vagina tendinis m. extensoris carpi ulnaris.—This sheath commences above the carpal (posterior annular) ligament and extends to the insertion of the tendon.

Vagina tendinum mm. abductoris pollicis longi et extensoris pollicis brevis.—The sheaths which surround these two tendons beneath the dorsal carpal (posterior annular) ligament usually communicate freely.

Vagina tendinis m. extensoris pollicis longi.—A long synovial sheath surrounds this tendon. Where it crosses the tendons of the radial extensors, a communication is found with the sheath of the latter.

2. Ulnovolar Division

The muscles on the volar side of the forearm lie in four layers.

a. First Layer

(Fig. 401)

Of the four muscles of associated ulnar epicondylar origin which constitute this layer the **pronator teres** is a strong, band-like muscle which is inserted into the lateral surface of the middle third of the shaft of the radius; the fusiform **flexor carpi radialis** sends a tendon to the base of the second metacarpal; the slender **palmaris longus** is inserted into the palmar fascia; and the medially situated, fusiform **flexor carpi ulnaris** into the pisiform bone and the palmar fascia. The pronator teres is the most powerful pronator of the forearm. When the hand is slightly flexed the ulnar carpal flexor abducts ulnarward. When the hand is greatly flexed lateral movement is difficult. The ulnar flexor is supplied by the ulnar nerve, the other muscles by the medial.

The pronator teres probably corresponds with the popliteus of the leg. The flexor carpi radialis and flexor carpi ulnaris probably represent in the main the two heads of the gastrocnemius; and the palmaris longus, the plantaris.

The pronator teres (fig. 401).—*Origin.*—By two heads:—(1) the *humeral* or chief head arises by a tendon from the superior half of the ventral surface of the medial epicondyle and directly from the overlying fascia and from the intermuscular septa between it and the medial head of the triceps and the flexor carpi radialis. (2) The *ulnar*, deep or accessory, head arises by an aponeurotic band attached to the inner border of the coronoid process medial to the tendon of the brachialis. Between the humeral and ulnar heads is a fibrous arch beneath which the median nerve passes.

Structure and insertion.—The fiber-bundles of the humeral head are inserted in a penniform manner on a tendon which begins near the middle of the belly of the muscle on the superficial surface along the radial border. The tendon gradually becomes broader, winds about the volar surface of the radius, and is inserted into the middle third of its lateral surface. The attachment of fiber-bundles continues nearly to this insertion. The fiber-bundles of the ulnar head form a slender fasciculus which is inserted into the radial side of the deep surface of the humeral head.

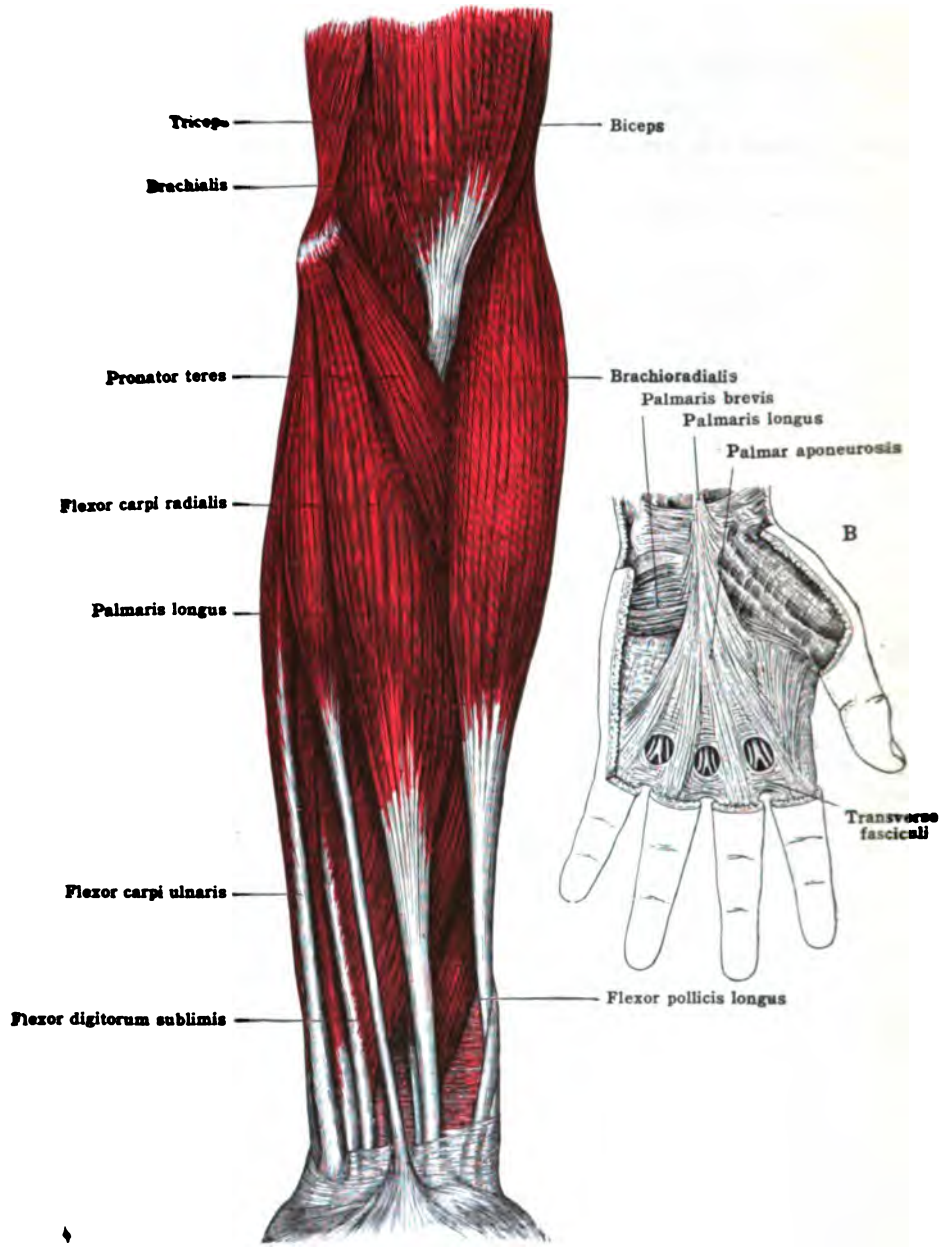
Nerve-supply.—By a branch derived from the median nerve before it passes between the two heads of the muscle. The nerve enters the proximal part of the middle third of the main belly of the muscle on its deep surface near the radial border. The branch to the ulnar head usually enters this portion of the muscle somewhat proximal to its fusion with the humeral head. The nerve fibers arise from the sixth and seventh cervical nerves.

Action.—To pronate and flex the forearm.

Relations.—The muscle is superficially placed. Near its origin it is covered by the lacertus fibrosus of the biceps, and near its insertion by the radial vessels and nerve and the brachio-

uscles. It is the most radial of the group of muscles under con-
r helps to bound an angular space, the cubital fossa, in which lie
nerve, and the tendon of the biceps. The median nerve passes
r heads. The muscle overlies the supinator, the brachialis, and
digitorum sublimis muscles and the ulnar artery.
ry fasciculi may arise from the humerus, the medial intermuscular
carpi radialis, the flexor sublimis, or the brachialis muscles. The

FIG. 401.—FRONT OF THE FOREARM: FIRST LAYER OF MUSCLES.



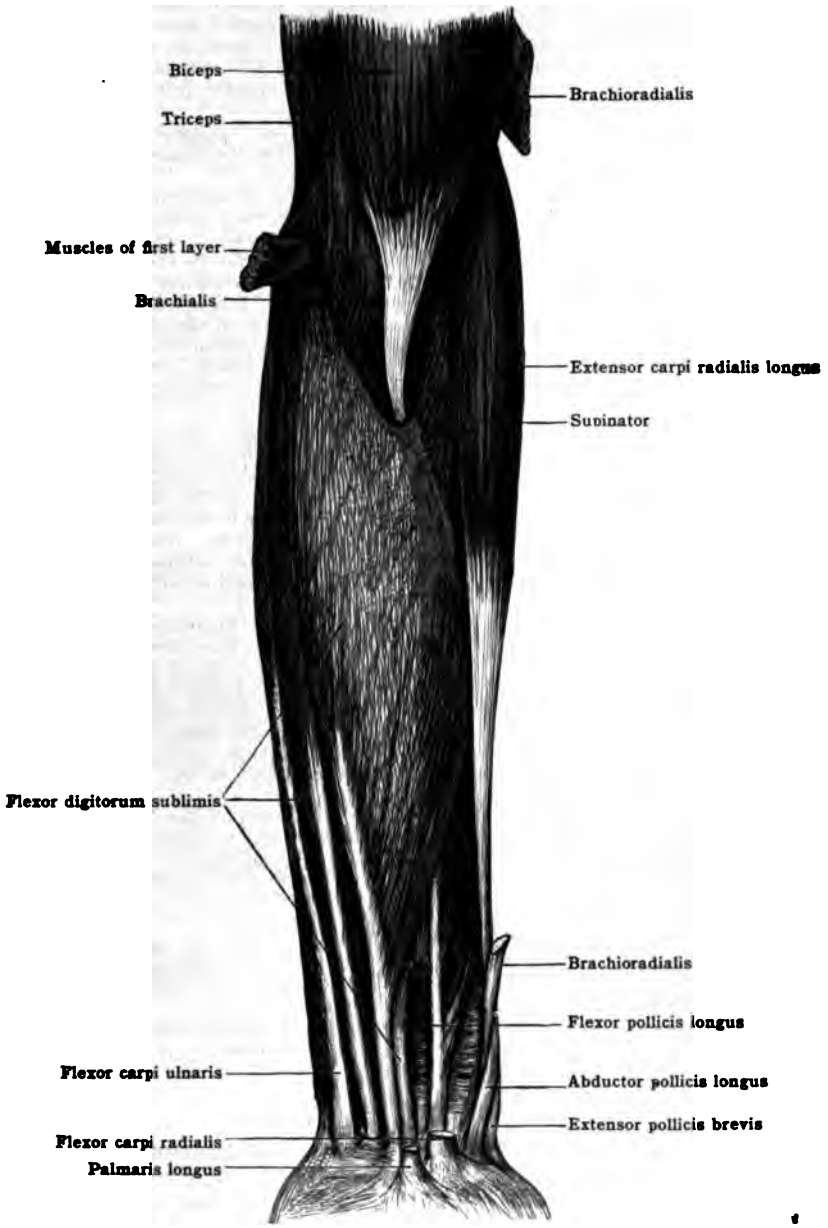
two portions of the muscle may be distinct from origin to insertion. Either part of the muscle may be doubled. The ulnar head may be absent. The radial insertion may be extensive. Fasciculi may extend to the long flexor of the thumb. There may be a sesamoid bone in the tendon of origin from the humerus.

The flexor carpi radialis (fig. 401).—*Origin.*—From (1) the common tendon attached to the medial epicondyle; and (2) the septa between its head and the pronator teres, the flexor sublimis, and the palmaris longus.

Structure and insertion.—The fiber-bundles descend to converge upon a tendon at first intramuscular, but which in the middle of the arm appears on the volar surface of the muscle and

becomes free from the attachment of fiber-bundles. The fiber-bundles from the epicon- descend nearly vertically to the front and sides of the tendon, while those from the inter- cular septa take an oblique course to the deep surface of the tendon. The tendon is at first , but soon becomes cylindrical, bound to the superficial muscle fascia, and enters the hand ough a special osteofibrous canal formed mainly by the groove in the os multangulum jus (trapezium) and the transverse carpal (anterior annular) ligament. It is inserted into base of the second metacarpal. It usually also sends a tendon slip to the third.

FIG. 402.—FRONT OF THE FOREARM: SECOND LAYER OF MUSCLES.



Nerve-supply.—By a branch from the median nerve which divides into several twigs that the muscle near the junction of its proximal and middle thirds on the deep surface. The usually arises near the elbow. The nerve fibers arise from the sixth, seventh (and eighth) cal nerves.

ction.—To flex the hand at the wrist. To a slight extent it may also act as a pronator e forearm and a flexor of the forearm on the arm.

Relations.—It is superficial except near its insertion. The belly of the muscle lies between pronator teres and the palmaris longus and upon the flexor digitorum sublimis. The tendon e muscle passes over the flexor pollicis longus, and near the wrist is a guide to the radial

artery, which here lies lateral to it. In the hand the tendon lies beneath the thenar muscles and is crossed by the tendon of the long flexor of the thumb.

Variations.—It may receive a fasciculus from the brachialis or biceps muscles or from the radius or ulna. It may send tendon slips to the multangulum majus (trapezium), navicular, the transverse carpal (anterior annular) ligament, or the fourth metacarpal. The insertion may take place variously into these structures.

The palmaris longus (fig. 401).—*Origin.*—From the common tendon attached to the medial epicondyle and from the surrounding intermuscular septa.

Structure and insertion.—The fiber-bundles take a nearly parallel course to a tendon which appears high in the middle third of the forearm on the volar surface of the muscle. In the middle of the forearm the attachment of fiber-bundles usually ceases, the tendon becomes bound to the overlying fascia, and descends parallel with that of the radial flexor. Near the proximal border of the transverse carpal (anterior annular) ligament the tendon expands into radiating bundles of fibers of which the medial and lateral are attached to the fascia over the intrinsic muscles of the thumb and little finger, while the middle, much more developed, constitute the chief portion of the palmar aponeurosis.

Nerve-supply.—From a branch which usually arises in company with the nerve to the proximal part of the flexor sublimis. It frequently traverses the superficial fibers of the flexor sublimis. The nerve enters the middle third of the muscle.

Action.—To flex the hand. It is also a weak flexor and pronator of the forearm.

Relations.—It is placed between the radial and ulnar flexors over the flexor sublimis. In the distal part of the forearm the tendon lies over the median nerve.

Variations.—It is absent in 11.2 per cent. of all cases (Le Double). It may be highly developed or reduced to a tendinous band. The belly of the muscle may lie in the distal instead of in the proximal part of the forearm. It may be digastric. It may be fused with neighboring muscles. It may arise from the medial intermuscular septum of the arm or from the lacertus fibrosus, from the radius, from the coronoid process, from the radial or ulnar flexor, or from the flexor sublimis muscles. The tendon may terminate in the fascia of the forearm, the thenar eminence, the carpus, or the abductor of the thumb. The muscle may be partly or wholly doubled.

The flexor carpi ulnaris (fig. 401).—*Origin.*—By two heads:—(1) the **humeral head** arises from the common flexor tendon attached to the lower ventral part of the medial epicondyle. Fiber-bundles of this head are also attached to the surrounding intermuscular septa and the deep fascia of the forearm. (2) The **ulnar head** arises by short tendinous fibers from the medial side of the olecranon and by an aponeurotic band common to it and the flexor digitorum profundus from the upper two-thirds of the dorsal border of the ulna. Proximally the two heads of the muscle are united by a fibrous arch extending from the olecranon to the medial epicondyle. Beneath this band pass the ulnar nerve and the dorsal recurrent ulnar artery. (See EPITROCHLEO-OLECRANONIS, p. 436.)

Structure and insertion.—The fiber-bundles of the humeral head descend nearly vertically, those of the ulnar head obliquely distally in a radial direction. They are inserted in a penniform manner on a tendon which appears in the proximal part of the middle third of the belly of the muscle on the radial margin of the deep surface, and in the distal third of the forearm forms the radial border of the muscle. On the ulnar side the insertion of fiber-bundles continues nearly to the pisiform bone. The insertion of the tendon takes place chiefly into the pisiform bone, but from it tendinous bundles extend to the palmar aponeurosis, volar ligament of the carpus, to the pisohamate (pisounciform), ligament, and to the bases of the fifth, fourth, and third metacarpals.

Nerve-supply.—From two or three branches of the ulnar nerve, the most proximal of which arises near the elbow-joint. These branches, which may arise by a single trunk, enter the deep surface of the proximal third of the muscle and send long twigs distally across the middle third of the constituent fiber-bundles. The nerve fibers arises from the seventh and eighth cervical and first thoracic nerves.

Action.—To flex the hand and to abduct the hand ulnarward.

Relations.—It is superficially placed. Its aponeurotic origin is adherent to the fascia of the forearm. It lies medial to the palmaris longus and flexor sublimis and upon the flexor profundus. Beneath the muscle lies the ulnar nerve. The ulnar artery extends along the radial border of the tendon near the wrist.

Variations.—These are rare. Slips from the tendon may pass to the metacarpophalangeal articulation of the little finger. (See, however, ABNORMAL MUSCLES, p. 436.)

b. SECOND LAYER

This is composed of one muscle, the **flexor digitorum sublimis,** which, although in part covered by the muscles of the preceding layer, is in part superficial. It arises from the medial epicondyle of the humerus, and from the radius and the ulna, and sends tendons to the second row of phalanges of the fingers. It corresponds probably to the soleus and the tendons of the flexor digitorum brevis in the leg and foot.

The flexor digitorum sublimis (figs. 402, 404, 406).—*Origin.*—By two heads: the **ulnar or chief head** arises (1) by the tendon common to it and the superficial group of muscles from the medial epicondyle, and by short tendinous bands from the ventral surface of the epicondyle; (2) from the ulnar collateral ligament of the elbow, the ulnar tuberosity, the medial border of the coronoid process, and the inferior extremity of the tendon of the brachialis; and (3) from the intermuscular septum between the flexor sublimis and the overlying muscles. The **radial**

head arises from an oblique line on the volar surface of the radius, and from the middle third of the anterior border.

Insertion.—Into the sides of the volar surface of the shafts of the second row of phalanges of the fingers.

Structure.—The fiber-bundles of the ulnar head and the upper part of the radial head converge, the ulnar fiber-bundles nearly vertically, the radial obliquely, to form a common belly the deep surface of which on the ulnar side is backed by a dense tendinous band. On the radial side of this a less dense membrane covers over an oval canal which passes distally along the line of junction of the two heads and lodges the ulnar artery and the median nerve.

The fiber-bundles of the ulnar head form a superficial and a deep group. The superficial portion near the middle of the forearm divides into a lateral and a medial division, the former being inserted on a tendon that goes to the middle and the latter on one that goes to the ring finger. The fiber-bundles of the radial head join with the lateral division of the superficial layer of the ulnar head and are inserted on the tendon of the middle finger nearly as far as the wrist. A small muscle fasciculus of the superficial portion of the ulnar head is usually united by a tendon to the long flexor of the thumb.

The deep portion of the ulnar head about the middle of the forearm terminates in large part on the volar surface of the dense tendinous band above mentioned. From this in turn two muscle bellies arise. One of these is inserted in a bipenniform manner on a tendon going to the index finger, the other on a tendon going to the little finger. A muscle fasciculus also usually passes from the region of the tendon band to that portion of the superficial fasciculus which terminates on the tendon of the ring finger.

The four tendons pass together through the carpal canal under the transverse carpal (anterior annular) ligament, those to the middle and ring fingers lying at first superficial to the other two. The tendons then diverge, and each tendon, together with and above a tendon of the flexor profundus, passes over the metacarpophalangeal joint into an osteofibrous canal on the palmar surface of the first phalanx of the finger for which it is destined. Here the tendon becomes flattened about the round tendon of the flexor profundus. Opposite the middle of the phalanx the tendon divides into two slips, between which the tendon of the flexor profundus passes. The divided halves of the sublimis tendon fold about the profundus tendon so that their lateral edges come to meet in the mid-line beneath this tendon opposite the phalangeal joint (figs. 406, 407). They then again separate, extend distally, and are attached one on each side into a ridge at the middle of the lateral border of the second phalanx. The tendons are also attached by **vincula tendinum**, a **ligamentum breve**, between the tendon and the head of the first phalanx and the joint, and a **ligamentum longum**, between the tendon and the volar surface of the first phalanx.

Nerve-supply.—Before the median nerve passes between the two heads of the pronator teres a branch arises which accompanies the nerve through the pronator and sends several branches into the proximal third of the ulnar head of the muscle. As the median nerve passes beneath the muscle, one or more branches are given to the radial head, and a long branch is given to the fasciculus of the second and from this one to that of the fifth digit. Occasionally, the median nerve in the distal third of the forearm gives rise to branches for these fasciculi. The nerve fibers arise from the seventh and eighth cervical and first thoracic nerves.

Action.—Chiefly to flex the second phalanx of each finger on the first; secondarily, to flex the fingers on the hand and the hand on the forearm.

Relations.—The belly of the muscle is covered by the pronator teres, flexor carpi radialis, and palmaris longus, but is superficial along a narrow strip between the flexor carpi ulnaris and the palmaris longus, and on each side of the tendon of the flexor carpi radialis. The muscle rests on the flexor pollicis longus and flexor digitorum profundus, the median nerve (see description given above) and ulnar vessels. The median nerve emerges from beneath the radial border of the muscle in the lower third of the forearm. In the palm the tendons lie beneath the palmar aponeurosis, the superficial palmar arch, and the branches of the median nerve, while they lie in front of the tendons of the flexor profundus, with which they are closely associated into a common bundle by loose fibrous tissue. The digital relations of the tendons are described above.

Variations.—The whole muscle may be rendered digastric by a transverse tendon. A fasciculus of the flexor sublimis may replace the palmaris longus or the two may coexist. A fasciculus may terminate in the fascia of the forearm or in the transverse carpal ligament, the palmar aponeurosis, etc. Various parts of the muscle may be absent or more independent than usual. The extent of the radial attachment varies greatly and may be missing. A special fasciculus may be received from the coronoid process of the ulna. A fasciculus may be sent to the flexor profundus or to other muscles. There may be some fusion with neighboring muscles.

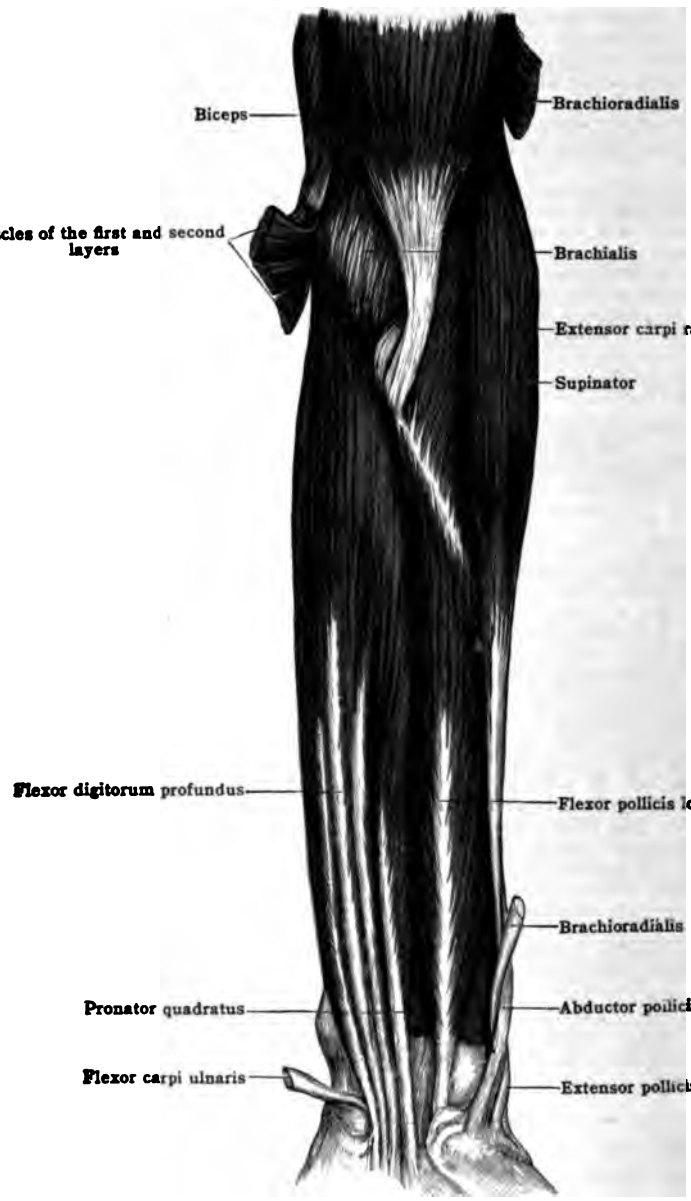
c. Third Layer
(Figs. 403–407)

The two muscles which constitute this layer may be looked upon as differentiated from a single deep flexor muscle. The **flexor digitorum profundus** is a strong, broad muscle which arises from the upper three-fourths of the volar surface of the ulna and gives rise to tendons which are inserted into the bases of the third row of phalanges of the fingers. The **flexor pollicis longus**, likewise broad and flat, arises from the volar surface of the radius and is inserted into the base of the second phalanx of the thumb. Both muscles are supplied by the median nerve and the flexor profundus is also supplied by the ulnar nerve.

These muscles correspond to the flexor digitorum longus and the flexor l cis longus of the leg.

The flexor digitorum profundus (figs. 403–407).—*Origin.*—(1) Through an apone septum between it and the flexor carpi ulnaris from the dorsal border of the ulna; (2) di from the proximal two-thirds of the medial surface and the proximal three-fourths of the surface of the ulna and from the adjacent interosseous membrane; and (3) inconstantly, f small area on the radius below the bicipital tuberosity.

FIG. 403.—FRONT OF THE FOREARM: THIRD LAYER OF MUSCLES.



Structure and insertion.—The fiber-bundles descend nearly vertically and give ris common belly which soon divides into four portions, each of which is attached about n down the forearm in a semipenniform manner to the dorsal surface of a tendon. The ment of fiber-bundles continues nearly to the wrist. The digital divisions of the muscle v the height to which they extend. That belonging to the index finger is usually the one m tensively isolated, and that to the little finger is the next most so. The tendons pass side under the transverse carpal (anterior annular) ligament, and then diverge to the bases fingers. At the metacarpophalangeal joints, they enter the osteofibrous canals des above (p. 433). On the volar surface of the first phalanx each tendon passes through in the sublimis tendon. The tendon then is continued over the second phalanx to the base

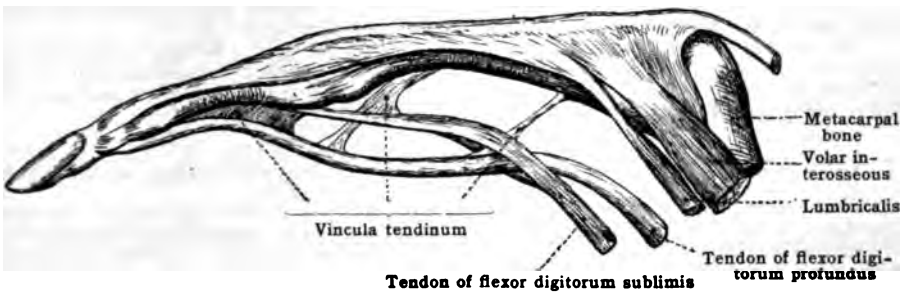
ird. **Vincula tendinum** are described passing to the capsule of the second interphalangeal int(**ligamentum breve**) and to the tendon of the flexor sublimis (**ligamentum longum**). The mbrical muscles arise from the tendons while they are in the palm.

Nerve-supply.—The interosseous branch of the median nerve arises usually before the rve passes through the pronator teres and accompanies the main trunk. This branch as it ses beneath the flexor sublimis gives off a branch (or two) from which several twigs spring. hese twigs enter the muscle near the radial border and pass in across the middle third of the onstituent fiber-bundles of the fasciculi to the index and middle fingers. The ulnar nerve near he elbow gives rise to a branch which enters the volar surface of the muscle near the junction f the proximal and middle thirds of that portion of the belly, giving tendons to the ring and ittle fingers. There is some variation in the extent of the innervations by the branches of the lnar and those of the median nerve. To a greater or less extent through anastomosis their erritories overlap. The nerve fibers arise from the seventh and eighth cervical and first horacic nerves.

Action.—To flex the terminal phalanx of each finger on the second and the second on the irst, while that of the superficial flexor is to flex the second phalanx on the first. The ction of the two flexors on the first phalanx is somewhat more limited. The interosseous nuscles, aided by the lumbricals, are the chief flexors of the first row of phalanges. The flexor rofundus acts, though not powerfully, as a flexor of the wrist.

Relations.—The flexor profundus muscle lies beneath the flexor sublimis and the flexor carpi lnaris muscles, the median nerve, and the ulnar vessels and nerve. Under the muscle lie the lna the interosseous membrane, and the pronator quadratus muscle. Under the transverse

FIG. 404.—INSERTIONS OF THE TENDONS OF THE MUSCLES WHICH ACT ON THE FINGER. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



pal (anterior annular) ligament the tendons lie beneath those of the flexor sublimis in the ie synovial sac. In the palm the tendons with the associated lumbrical muscles lie upon the erosseous muscles, the adductor of the thumb, and the deep palmar arch, and beneath flexor sublimis tendons. For the relations to the synovial bursæ see p. 436.

Variations.—There is considerable variation in the extent of the radial origin and in the ent of the independence and fusion of the different fasciculi. In the prosimians a common don extends as far as the hand. The division in the higher forms is associated with refine- nt of movements of the fingers. One or more special fasciculi not infrequently join the scle from the flexor sublimis, the flexor pollicis longus, the medial epicondyle, or the ulna. e **accessorius ad flexorem digitorum profundum** is a fasciculus which arises from the coro- d process of the ulna and sends a tendon to join the tendon of one of the fingers, most fre- ntly the middle or index. It is found in 20 per cent. of bodies.

The flexor pollicis longus (fig. 403).—*Origin.*—The attachment extends along the oblique e and the ventral border of the radius from slightly below the bicipital tuberosity to within m. of the wrist. Medially it is continued into the interosseous membrane. Proximally the don frequently extends to the distal radial margin of the coronoid process of the ulna and es rise to fiber-bundles connected with the muscle, as well as to a fasciculus of the flexor fundus.

Structure and insertion.—The fiber-bundles descend obliquely to be inserted in a penni- m manner on a tendon which begins high up on the volar surface near the ulnar border the muscle, and descends as a broad band which near the wrist becomes cylindroid. The ertion of fibers continues nearly to the point where the tendon passes under the transverse pal ligament. Here the tendon enters the carpal canal radial to the tendons of the flexor fundus, and passes beneath the superficial head of the short flexor of the thumb, then between thumb sesamoids into the osteofibrous canal of the thumb, in which it is continued to the e of the terminal phalanx.

Nerve-supply.—Usually from two branches of the volar interosseous ramus of the median ve. These enter the proximal half of the ulnar margin of the muscle. The nerve fibers e from the sixth, seventh (and eighth) cervical nerves.

Action.—It is a strong flexor of the second phalanx on the first and has less powerful action the metacarpophalangeal joint and on the wrist. It adducts and flexes at the carpometa- pal joint.

Relations.—It lies beneath the flexor sublimis, the flexor carpi radialis and brachioradialis scles, and the radial artery. Near the wrist it crosses over the insertion of the pronator adratus. In the hand the tendon runs beneath the opponens pollicis and the superficial head the flexor brevis, and across the deep head of the latter.

Variations.—It may be fused or united by fasciculi with the flexor profundus, the flexor sublimis, or the pronator teres. It may be partially doubled, giving rise to an accessory tendon which extends to the index finger. The origin may extend to the medial epicondyle of the humerus (epitrochlear bundle).

d. Fourth Layer

This layer consists of a single quadrilateral muscle which passes transversely across the lower part of the forearm from the ulna to the radius. In the leg there is no corresponding muscle.

The pronator quadratus (fig. 408).—*Origin.*—Medial side of the volar surface of the lower fourth of the ulna.

Structure and insertion.—From the ulna a strong aponeurosis extends a third of the way across the volar surface of the muscle. From this membrane and from the bone fiber-bundles extend transversely to be inserted on the distal quarter of the volar surface of the radius and on the triangular area above the ulnar notch. The deeper fiber-bundles which arise directly from the ulna are inserted into the radius by means of an aponeurosis. The superficial and deep portions of the muscle are often separated. The muscle is thicker distally than proximally.

Nerve-supply.—The volar interosseous nerve descends along the interosseous membrane, passes behind the middle of the proximal margin of the muscle, and sends branches into its deep surface. The nerve fibers arise from the (sixth), seventh and eighth cervical and first thoracic nerves.

Action.—To pronate the forearm.

Relations.—The muscle lies immediately beneath the muscles of the third layer and upon the radius and ulna, the interosseous membrane, and radioulnar joint. The radial artery and ulnar nerve pass in front of it, the volar interosseous artery behind it.

Variations.—It may be missing or may extend further up the forearm than usual or down upon the carpus. It may be triangular or divided into parts the fiber-bundles of which take different directions. It may send fasciculi to the carpus or metacarpus or be fused with the flexor carpi radialis brevis (see below).

Abnormal Muscles of the Volar Side of the Forearm and Wrist

The epitrochleo-olecranonis (anconeus internus).—A muscle fasciculus, distinct from the distal margin of the triceps, which runs from the medial epicondyle to the olecranon over the groove for the ulnar nerve, by a branch of which it is supplied. It takes the place of the fibrous arch normally extending between the epicondylar and ulnar heads of the flexor carpi ulnaris. It occurs in about 25 per cent. of bodies (Testut), and represents an adductor of the olecranon of the lower mammals. Occasionally the medial head of the triceps may descend over the ulnar groove, but this forms another type of muscle variation.

The flexor carpi ulnaris brevis (ulnocarpeus).—An abnormal muscle which arises from the distal quarter of the volar surface of the ulna and is inserted in the hamatum (unciform) the pisiform, the abductor of the little finger, or the superior extremity of the fifth metacarpal.

The uncipisiformis.—A short, thick band of muscle which runs from the pisiform to the tip of the hamulus of the os hamatum (unciform) parallel with the pisohamate (pisounciform) ligament. It is innervated by the ulnar nerve.

The flexor carpi radialis brevis (radiocarpeus). An abnormal muscle found in about 5 per cent. of bodies (Le Double). It arises from the lateral or the volar surface of the distal half of the radius Some of the fiber-bundles may spring from the pronator quadratus, the fasciæ of the forearm, or the ulna. It is inserted into the carpus or metacarpus, and occasionally even into the first phalanx of the index finger, etc. It is supplied by a branch of the volar interosseous nerve. It serves to flex the wrist. It is said to represent the tibialis posterior of the leg.

Bursæ

B. m. flexoris carpi ulnaris.—Between the tendon of this muscle and the pisiform bone.

B. m. flexoris carpi radialis.—Between the tendon of this muscle and the tubercle of the navicular bone.

A bursa is often found between the tendon of the deep flexor of the index finger and the carpus. This bursa is frequently in communication with the radial and ulnar tendon-sheaths.

A bursa is also often found between the deep and superficial tendons of the index finger.

Synovial Tendon Sheaths
(Figs. 397 and 405)

Vagina tendinis m. flexoris carpi radialis.—About the tendon as it passes beneath the transverse carpal ligament.

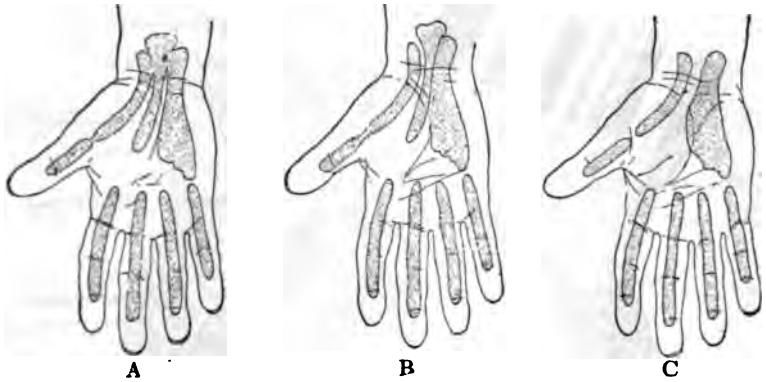
Vaginæ tendinum mm. flexorum digitorum.—The osteofibrous canals of the digits are lined by a synovial membrane which is reflected by means of a fold (cul-de-sac) to the tendons at each end and over the vincula tendinum, in which blood-vessels and nerves for the tendons are contained. The synovial cavity of the first and usually that of the fifth digit communicate with those of the palm.

In the wrist and palm two large synovial sacs may usually be recognized, although the number may be raised to five or reduced to one.

The radial sac, vagina tendinis m. flexoris pollicis longi, surrounds the long flexor tendon of the thumb in the wrist and palm and usually communicates with that of the thumb. In the palm a well-marked mesotendon usually extends to the deep ulnar side of the tendon from the parietal layer of the sheath.

The ulnar sac, **vagina tendinum mm. flexorum communium,** surrounds the tendons of the long flexors of the fingers. It begins proximal to the transverse carpal ligaments and extends nearly or quite to the synovial sheath of the little finger on the ulnar side and on the radial side to the center of the palm.

FIG. 405.—SYNOVIAL SHEATHS OF THE TENDONS OF THE LONG FLEXORS OF THE FINGERS. A. Frequent type; B. normal type; C. fetal type. (After Poirier and Charpy.)



3. MUSCULATURE OF THE HAND
(Figs. 397, 399, 406–410)

The intrinsic muscles of the hand are taken up in the following groups:—

a The subcutaneous muscle of the palm.
b The muscles of the little finger.
c The muscles of the thumb.
d The lumbrical muscles.
e The interosseous muscles.

The ulnar nerve supplies the muscles of the little finger, the interossei, the medial lumbrical muscles, and two of the muscles of the thumb; the median nerve supplies most of the muscles of the thenar region and the lateral lumbrical muscles.

(*a*) *Subcutaneous Muscle*
(Fig. 406)

The **palmaris brevis** is a small, trapezoid sheet situated between the hypothenar fascia and the skin. It arises at the lateral edge of the palmar aponeurosis from tendinous slips which may be traced through the aponeurosis to the navicular and greater multangular. It is composed of nearly parallel fiber-bundles, and extends into the deep surface of the skin along the ulnar border of the palm. It is generally taken to be a subcutaneous muscle like the superficial muscles of the head and neck. It has, however, been suggested that it represents the remnants of a short flexor of the digits corresponding with the flexor digitorum brevis of the foot.

Nerve supply.—The superficial branch of the palmar division of the ulnar nerve gives rise to a twig which enters the deep surface of the muscle. The fibers come from the (seventh and) eighth cervical and first thoracic nerves.

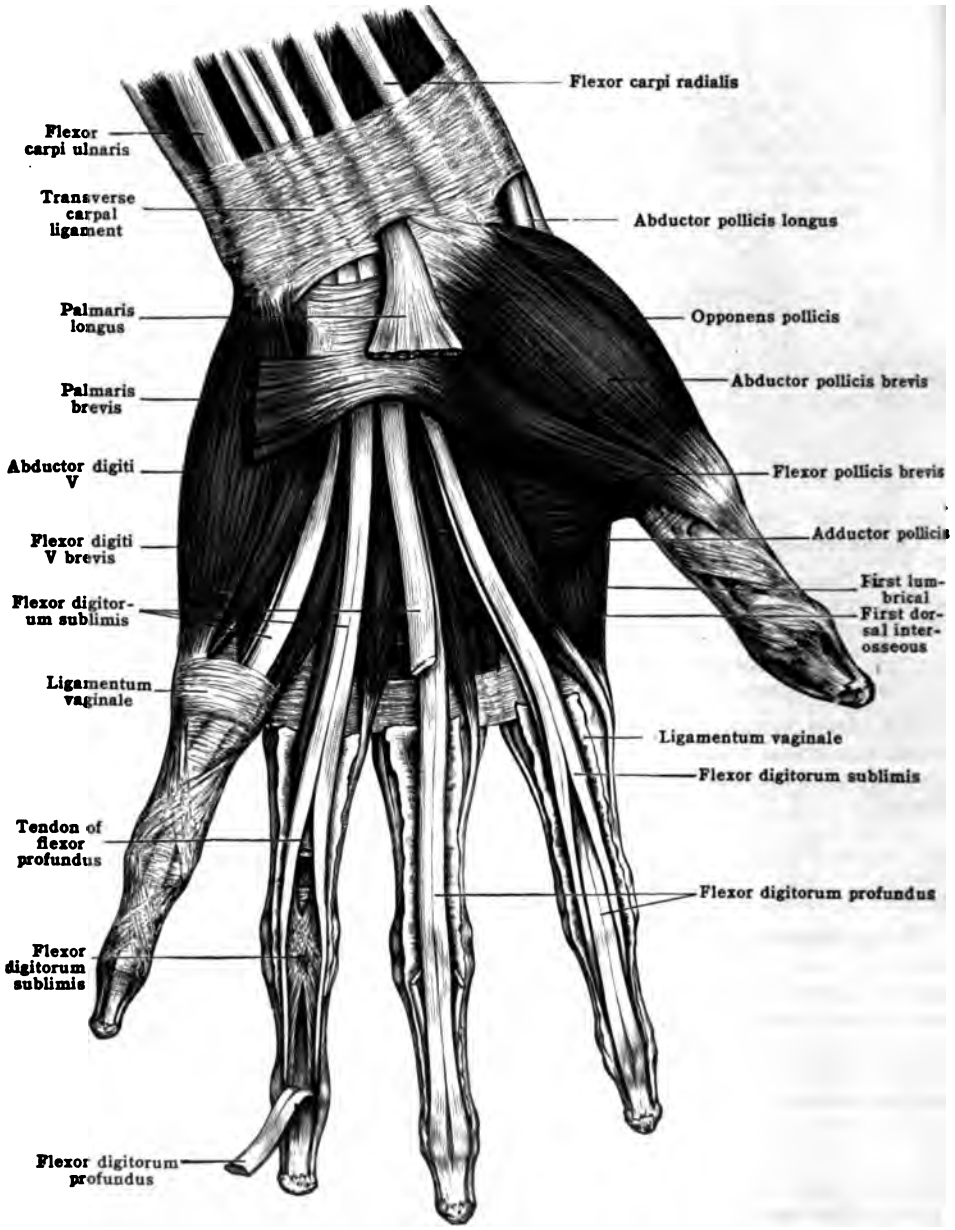
Action.—The action of the muscle is to draw the skin of the ulnar side of the hand toward the center of the palm. It is said that it thus helps to from a cup-shaped hollow when the hand conveys fluid to the mouth The contraction of the muscle by raising a ridge over the ulnar nerve and artery when an object is grasped hard serves, according to Henle, to protect these structures.

Variations.—It varies in size. In about 2 per cent. of bodies it is absent (Le Double). It may send tendinous slips to the pisiform bone. (For a thenar subcutaneous muscle, see variations of the abductor pollicis brevis.)

(*b*) *Muscles of the Little Finger*
(Figs. 406–408)

In the hypothenar eminence are three muscles, the abductor, the flexor brevis, and the opponens digiti quinti. The **abductor digiti quinti** is a flat, fusiform muscle which arises from the pisiform and is inserted into the ulnar border of the first phalanx and into the dorsal aponeurosis through which it helps to flex the

FIG. 406.—THE SUPERFICIAL MUSCLES OF THE PALM OF THE HAND.



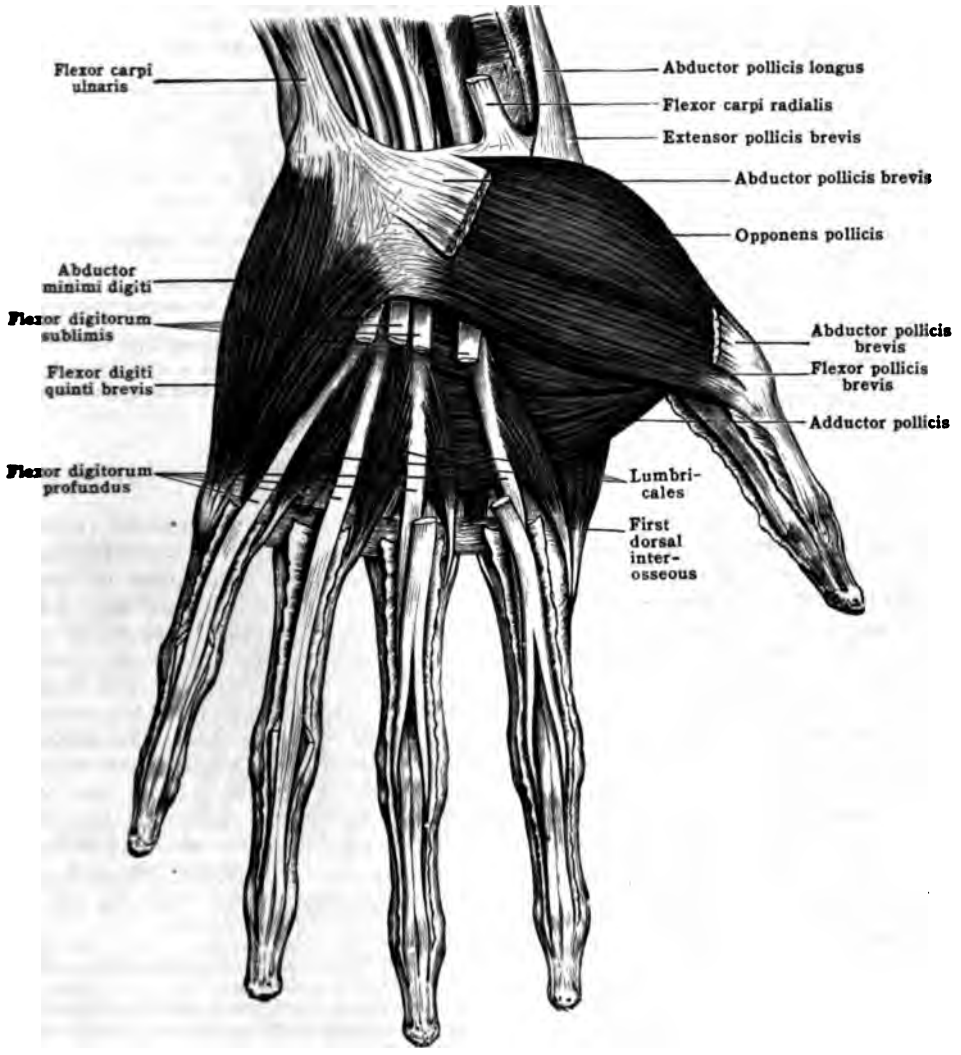
first and extend the second and third phalanges of the little finger. **The fusiform flexor brevis** arises from the hamatum (unciform) and adjacent part of the transverse carpal (anterior annular) ligament and is inserted into the ulnar side of the base of the first phalanx. The triangular **opponens** likewise arises from the hamatum (unciform) and the transverse (anterior annular) ligament. It is inserted into the ulnar border and the head of the fifth metacarpal.

The abductor of the little finger corresponds with that of the little toe. A part of the opponens beneath the ulnar nerve corresponds with that of the little toe, while the more superficial portion is unrepresented in the foot. The flexor brevis of the little toe corresponds with a part of the deep portion of the opponens of the little finger. The flexor brevis of the little finger is unrepresented in the foot. (Cunningham.)

The abductor digiti quinti (figs. 406, 407).—*Origin.*—From the distal half of the pisiform, the ligaments between this and the hamatum, the tendon of the flexor carpi ulnaris, and often from the transverse carpal (anterior annular) ligament.

Structure and insertion.—The fiber-bundles descend vertically, at first increasing in number and then concentrated, toward two short tendons one of which is inserted into the ulnar border of the first phalanx of the little finger and the other into the aponeurosis of the extensor tendon of the little finger.

FIG. 407.—THE DEEPER MUSCLES OF THE PALM OF THE HAND.



Nerve-supply.—From the deep palmar division of the ulnar nerve before it passes through the opponens, or from the superficial palmar branch, arise one or more twigs which enter the radial side of the muscle on its deep surface in the proximal third. The nerve fibers arise from the (seventh and) eighth cervical and first thoracic nerves.

Action.—To abduct the little finger, flex the first phalanx, and extend the last two.

Relations.—It overlies the opponens and flexor brevis. Superficially it is covered by fascia and the palmaris brevis muscle. Along the proximal part of its radial margin run the deep palmar branches of the ulnar artery and nerve.

Variations.—It may be missing or doubled. It may be fused with the short flexor or receive fasciculi from the palmaris longus, the ulnar flexor, the fascia of the forearm, etc.

The flexor digiti quinti brevis (figs. 407, 408).—*Origin.*—By a short tendon from the hook of the hamatum (unciform) and from the adjacent parts of the transverse carpal (anterior annular) ligament.

Structure and insertion.—The fiber-bundles take a nearly parallel course and are inserted by a short tendon which is fused with that of the abductor and is inserted into the ulnar side of the base of the first phalanx of the little finger. A sesamoid bone may lie in the tendon.

Nerve-supply.—A branch from the superficial or deep palmar division of the ulnar nerve enters the deep surface of the muscle in its proximal half. The nerves to the abductor and flexor may arise in common from the ulnar. The nerve fibers arise from the (seventh and) eighth cervical and first thoracic nerves.

Action.—To flex the first phalanx of the little finger. When it sends a tendon slip to the aponeurosis of the extensor of the finger it helps to extend the two terminal phalanges.

Relations.—The muscle closely adjoins and is partly covered by the abductor. The palmaris brevis and the lateral volar digital artery to the fifth finger lie superficial to it. Under it lies the opponens.

Variations.—The muscle may be wanting or may be closely fused with the abductor or the opponens. It may receive an accessory slip from the forearm fascia. It may give a tendon slip to the extensor aponeurosis or to the head of the fifth metacarpal.

The opponens digiti quinti (fig. 408).—*Origin.*—Partly tendinous, from the distal ulnar border of the hook of the hamatum (unciform) and from the adjacent transverse carpal (anterior annular) ligament.

Structure and insertion.—The fiber-bundles diverge, the proximal short and horizontal, the distal long and oblique, and are inserted on the whole of the ulnar border and on a part of the head of the fifth metacarpal. Often the muscle is divisible into two portions between which the ulnar nerve runs.

Nerve-supply.—Before the deep palmar branch passes through the muscle it gives rise to a twig which enters its volar surface in the middle third near the ulnar margin. The nerve fibers arise from the (seventh and) eighth cervical and first thoracic nerves.

Action.—To flex, adduct, and slightly rotate the fifth metacarpal; as, for example, in 'cupping' the hand to drink from it.

Relations.—The opponens lies beneath the abductor and flexor brevis muscles. The deep branches of the ulnar nerve and artery pass through the opponens near its carpal origin and then under it extend into the palm.

Variations.—It may be fused with neighboring muscles or receive accessory slips.

The **tensor capsularis articulationis metacarpophalangei digiti quinti** is a slender muscle which arises from the ligaments which unite the pisiform to the hamatum, and is inserted into the volar surface of the metacarpophalangeal joint of the little finger.

(c) *Muscles of the Thumb*
(Figs. 406–408)

In the thenar region there are four muscles. Of these, the **abductor pollicis brevis** is the most superficial. Then come the **opponens pollicis** and the **short flexor**, and beneath the last the **adductor pollicis**. All are **triangular in form.** The **abductor pollicis brevis** arises from the radial side of the **volar surface** of the carpus and is inserted into the radial side of the base of the **first phalanx** of the thumb. The **opponens** is a thick muscle extending from the **transverse carpal** (anterior annular) ligament to the radial side of the first **metacarpal.** The **flexor pollicis brevis** arises by two heads, a deep and a superficial, from the carpus and is inserted into the radial side of the base of the first phalanx. The **adductor pollicis** arises from the carpus and the second and third metacarpals and is inserted into the ulnar side of the first phalanx of the thumb. From the tendons of insertion of the abductor and flexor brevis slips are continued into the dorsal aponeurosis of the thumb so that they aid in extending the second phalanx.

In the foot an opponens hallucis occurs as an abnormal muscle. The abductor, flexor brevis and adductor of the thumb are represented by the corresponding muscles of the big toe, although the last two muscles are not perfectly homologous in the hand and foot.

The abductor pollicis brevis (fig. 406).—*Origin.*—From the volar surface of the transverse carpal (anterior annular) ligament, and from the greater multangular bone (trapezium). Also often from the navicular bone and from a tendon slip of the long abductor.

Structure and insertion.—The fiber-bundles converge upon a flat tendon with two lamellæ, the deeper of which is inserted into the radial side of the base of the first phalanx of the thumb and the superficial into the aponeurosis of the extensor pollicis longus.

Nerve-supply.—By a branch of the first volar digital ramus of the median nerve. This branch passes over or through the flexor brevis and enters the muscle on the volar surface in the middle third near its ulnar border.

Action.—To abduct the thumb, flex the first phalanx, and extend the terminal phalanx.

Relations.—It lies beneath the thenar fascia lateral to the superficial head of the flexor brevis and over the opponens. The superficial volar artery usually perforates the muscle.

Variations.—It may be wanting or may be divided into two divisions. The origin may extend to the fascia of the forearm or styloid process of the radius. It may receive an accessory slip from the long radial extensor, the opponens, or the short extensor of the thumb. A *thenar subcutaneous muscle* is occasionally present. It is narrow, is closely associated with the short abductor of the thumb, and extends from the radial side of the base of the first metacarpal into the skin of the thenar eminence.

The opponens pollicis (fig. 408).—*Origin.*—From the volar surface of the transverse carpal (anterior annular) ligament and from the tubercle of the greater multangular bone (trapezium).

Structure and insertion.—The fiber-bundles extend obliquely in a nearly parallel direction to their insertion along the whole lateral border of the volar surface of the shaft and the head of the first metacarpal.

Nerve-supply.—By a branch of the first volar digital ramus of the median nerve. This branch passes over or through the superficial division of the flexor brevis near the origin of the muscle. One or two twigs enter the deep surface of the proximal third of the oppponens near its ulnar border. The nerve fibers arise from the sixth and seventh cervical nerves.

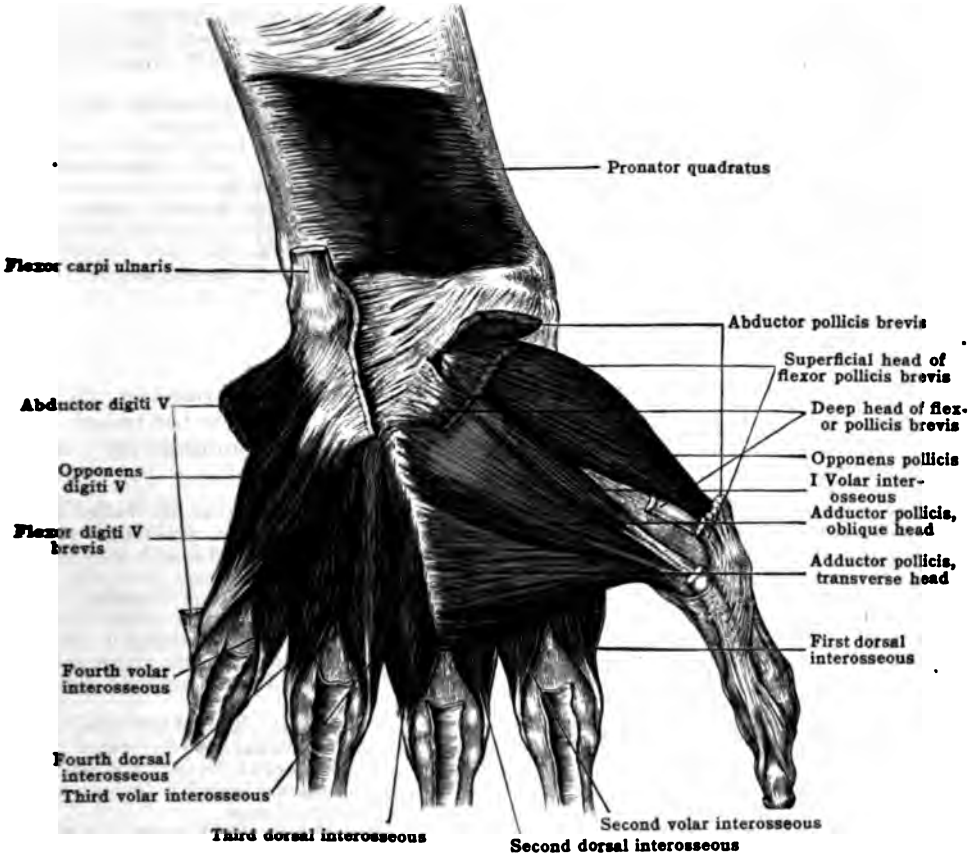
Action.—To flex, adduct, and rotate medialward the first metacarpal bone. The volar surface of the thumb is thus brought to face the volar surface of the other digits.

Relations.—It lies beneath the thenar fascia and the abductor brevis. The flexor brevis overlies its ulnar border.

Variations.—It may be absent or it may be divided into two heads. It is usually more or less fused with the short flexor.

The flexor pollicis brevis (figs. 407, 408).—The muscle is divided by the tendon of the long flexor into a superficial and a deep portion. The **superficial head** arises from the greater

FIG. 408.—THE PRONATOR QUADRATUS AND DEEP MUSCLES OF THE PALM.



multangular bone (trapezium), the adjacent part of the transverse carpal (anterior annular) ligament, and the tendon sheath of the flexor carpi radialis. The fiber-bundles descend closely applied to the opponens, and terminate by a tendon which is attached to the lateral side of the front of the base of the first phalanx. Over the joint a sesamoid bone lies in the tendon. The **deep head** has a tendinous origin from the os multangulum minus (trapezoid) and the os capitatum (magnum). The fiber-bundles take an oblique course, to be inserted into the tendon of the superficial part. A muscle fasciculus which arises from the ulnar side of the base of the first metacarpal and the neighboring carpal ligaments and is inserted on the ulnar side of the base of the first phalanx, is sometimes considered to be the deep head of the flexor brevis. It is closely bound up with the carpal head of the adductor pollicis and they have a common tendon. Some fibers of the medial division of the tendon may be traced into the aponeurosis of the extensor tendon. It is probable that this portion of the muscle represents a first volar interosseous, and it is so described later with the interosseous muscles. There is much dispute as to what fasciculi should be included in the flexor brevis.

Nerve-supply.—The muscle is usually supplied by twigs derived from a branch from the first volar digital ramus of the median nerve as this branch passes through its substance, and by twigs from the deep branch of the ulnar. Brookes found this supply in 19 out of 29 instances, in 5 by the median alone, and in 5 by the ulnar alone. The nerve fibers come from the sixth and seventh cervical nerves.

Action.—To flex, adduct, and rotate medialward the metacarpal of the thumb; flex the first phalanx; and extend the second phalanx.

Relations.—Proximally the short flexor is grooved for the tendon of the long flexor, beneath which more distally the deep head of the muscle passes laterally. The superficial portion of the muscle lies beneath the skin. The ulnar border of the deep head is fused proximally with the adductor.

Variations.—The deep head may be absent. Either or both heads may be double. The superficial head may be fused with the abductor brevis, and is usually more or less fused with the opponens.

The adductor pollicis (fig. 408).—*Origin.*—By two heads. The **carpal or oblique head** arises from the deep carpal ligaments, the capitatum and the bases of the second and third metacarpals; the **metacarpal or transverse head,** from the crest of the third metacarpal, from the suprametacarpal fascia of the third interspace, and sometimes also from that of the fourth interspace and from the capsules of the second, third, and fourth metacarpo-phalangeal articulations.

Structure and insertion.—The fiber-bundles converge toward a tendon which is inserted into the ulnar side of the front of the base of the first phalanx of the thumb. A sesamoid bone lies in the tendon over the joint.

Nerve-supply.—One or more twigs from the deep palmar branch of the ulnar enter the middle third of the muscle on its deep surface. There may also be an anastomosing branch from the median nerve. The nerve fibers come from the sixth, seventh and eighth cervical and first thoracic nerves.

Action.—To adduct and flex the first metacarpal and flex the first phalanx of the thumb. When the thumb is in an extreme position of apposition, it acts as an abductor.

Relations.—Superficial to the muscle lie some of the tendons of the deep flexor of the fingers and the first two lumbrical muscles. It extends over the two more lateral intermetacarpal spaces, and is in part subcutaneous on the dorsal surface. The deep volar arch extends between the two heads and beneath the oblique head. The oblique head of the muscle is closely united to the first volar interosseous, so that the latter by some is considered a part of the adductor.

Variations.—The extent of the attachments of origin of the muscle vary considerably. The two heads of the muscle may be more or less completely separated from one another. Each may be divided into separate fasciculi.

(*d*) *Lumbrical Muscles*

From the deep flexor tendons in the palm of the hand arise the lumbrical muscles, four in number, which are attached by small tendons to the radial side of the extensor tendons (figs. 404, 407, 408). These lumbrical muscles have homologues in the sole of the foot.

The lumbricales (figs 406, 407).—*Origin.*—The two lateral arise from the radial side of the volar aspect of the first and second tendons of the flexor digitorum profundus; the two medial arise from the adjacent sides of the second and third andthird and fourth tendons.

Structure and insertion.—The fiber-bundles of each muscle arise directly from the flexor tendons near the distal border of the transverse carpal (anterior annular) ligament. They converge as far as the metacarpophalangeal joint, upon a small tendon which begins about the middle of the muscle. The tendon passes out between the palmar aponeurosis and the transverse capitular ligament, winds about the metacarpophalangeal joint, expands, and is attached along the side of the first phalanx to the radial border of the tendon of the extensor digitorum communis.

Nerve-supply.—Branches from the median nerve enter the middle third of the radial border of the first two or three lumbrical muscles. The last one or two are supplied by branches from the deep volar branch of the ulnar nerve, which enter the middle third of the deep surface. The third lumbrical and sometimes one or more of the others may receive a branch from both nerves. The nerve fibers come from the eighth cervical and first thoracic nerves.

Action.—Together with the interosseous muscles they flex the basal phalanges on the metacarpal bones and extend the terminal and middle phalanges. They also adduct the fingers toward the thumb.

Relations.—The muscles run between the tendons of the flexor profundus and beneath the palmar aponeurosis. They lie upon the fascia covering the interosseous muscles, the capitular ligaments, and the septum over the adductor and deep head of the flexor pollicis brevis.

Variations.—These are very frequent, especially in case of the third and fourth. Each may be doubled or missing. They may arise from the tendons of the flexor sublimis or from the belly of the deep flexor. The first lumbrical may come from the tendon of the long flexor, from the opponens, or the metacarpal of the thumb. The tendon of insertion may go to the ulnar side of the base of the digit opposite that to which the tendon is usually attached, or the tendon may divide and go to the adjacent sides of two fingers. Kopsch has found that in 110 bodies all four lumbricals were inserted on the radial side of their respective digits in 39 per cent. In 35 per cent. the first, second, and fourth were so inserted, while the third sent slips to the adjacent sides of the middle and ring fingers. An accessory fasciculus has been found to arise from the tendon of the flexor pollicis longus and go to the base of the index finger.

(*e*) *Interosseous Muscles* (figs. 408–410)

These muscles lie between the metacarpal bones and are covered dorsally and ventrally by fasciæ attached to the metacarpals. In each interspace are two mus-

a dorsal and a volar (palmar). The volar interossei are inserted into all the rs except the middle finger, and are adductors toward an axis passing through middle finger; the dorsal interossei are inserted into both sides of the middle r and into the radial side of the second and the ulnar side of the fourth finger, are abductors. All also serve as flexors of the first row of phalanges and sors of the second and third. In the foot the axis to and from which the osseous muscles adduct and abduct the toes passes through the second toe.

FIG. 409.—THE VOLAR INTEROSSEI.

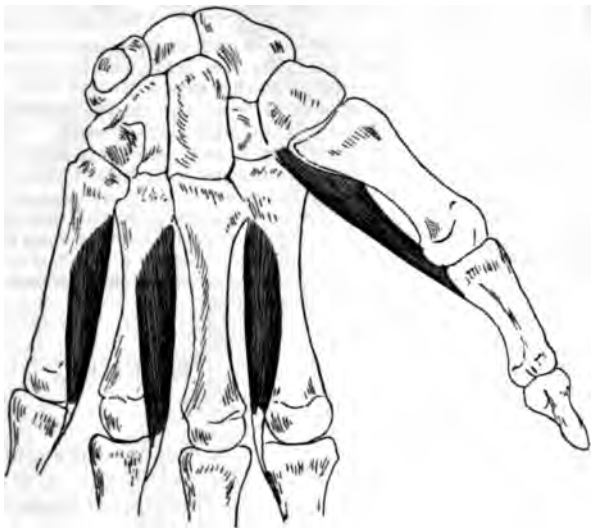


FIG. 410.—THE DORSAL INTEROSSEI.

e **interossei volares** arise from the sides toward the middle finger and the front of the of the first, second, fourth, and fifth metacarpals. The first arises from near the base, the from three-fourths of the shaft. The fiber-bundles of each muscle converge in a penni- manner upon a tendon which is inserted into the aponeurosis of the digital extensor tendon e base of the first phalanx on the middle finger side of the corresponding digit (see fig. 404) rst volar interosseous is often described as a division of the flexor pollicis brevis or of the tor pollicis.

The interossei dorsales arise from the adjacent sides of the metacarpal bones in each interspace. On the sides nearest the middle finger they cover three-fourths of the bone, on the opposite sides much less. The fiber-bundles converge in a bipenniform manner upon a tendon which begins high in the muscle and is inserted into the aponeurosis of the extensor muscle and the base of the first phalanx on each side of the middle finger, on the thumb side of the index finger, and the ulnar side of the ring finger. The interosseous muscle in the first interspace is thick and strong and forms with the adductor pollicis the fleshy web between the base of the thumb and the palm.

Nerve-supply.—By branches of the deep volar division of the ulnar nerve. As a rule, a branch to each volar interosseous enters the proximal third of the muscle. To each dorsal interosseous a branch is given which enters between the two heads. These branches may be variously combined before entering the interosseous muscles. The nerve fibers arise from the eighth cervical and first thoracic nerves.

Action.—To move the fingers toward the radial and ulnar sides, to flex the first phalanx and extend the second and third. The volar interossei move the fingers toward the median axis of the middle finger in repose, the dorsal from this axis.

Relations.—The volar interossei lie volarward from the dorsal interossei. The two sets of muscles are bound in place by the dorsal and volar metacarpal fasciæ. The tendons pass out on the dorsal side of the transverse capitular ligament and are closely applied to the metacarpophalangeal joints. The muscles of the first two interspaces lie immediately dorsal to the adductor of the thumb; the others dorsal to the flexor tendons.

Variations.—The tendon-slip from an interosseous muscle to the base of the first phalanx of a digit may be missing. This is more frequent in case of the volar than in that of the dorsal interossei, and in the medial than the lateral muscles. Either a volar or a dorsal interosseous muscle may be double or missing. Rarely the insertions of the interosseous muscles characteristic of the foot (see p. 531) may be found in the hand.

III. SPINAL MUSCULATURE

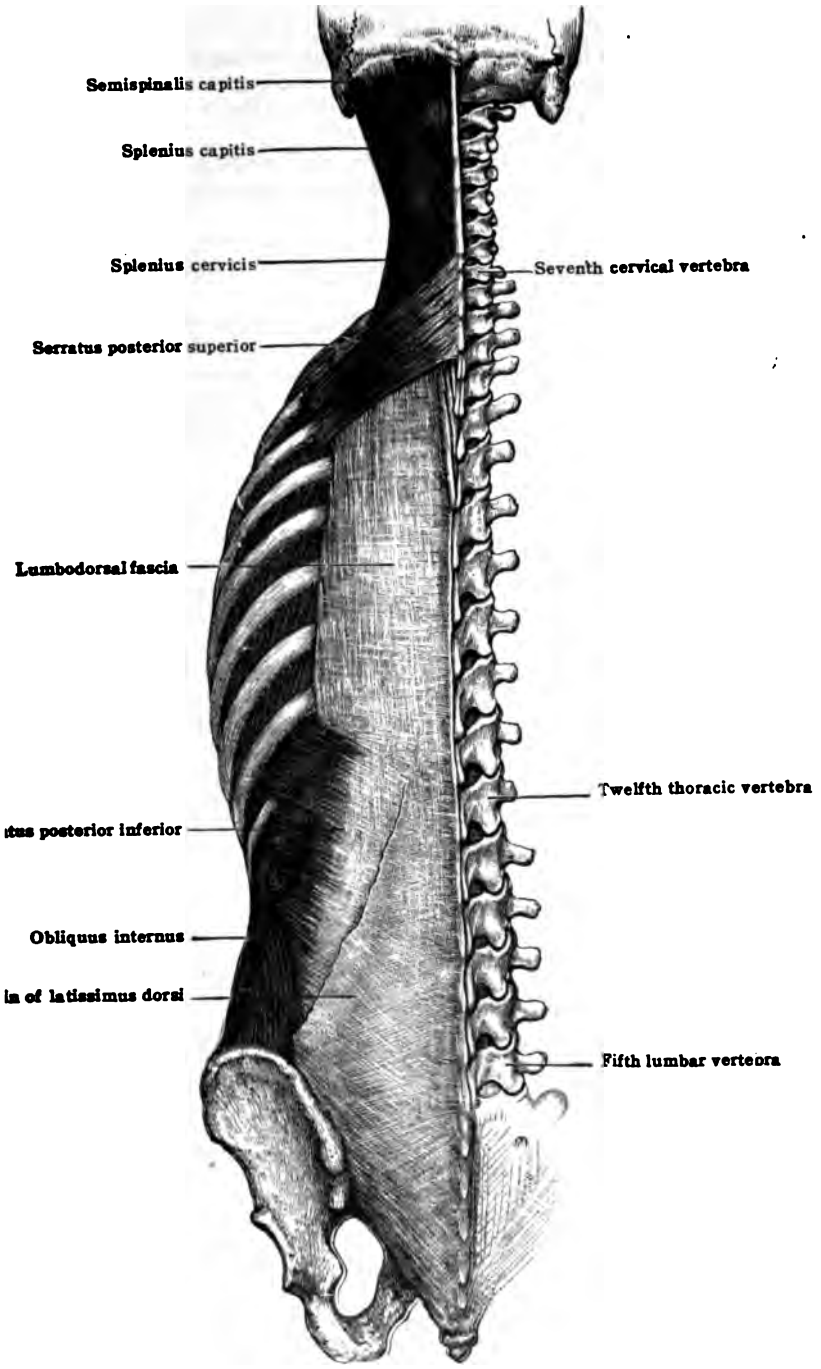
(Figs. 411–414)

The spinal (vertebral) column is of special interest as the segmented longitudinal axial support of the body which has given rise to the term 'vertebrates' as applied to the group of animals of which man is the highest form. The segmentation in fishes permits the lateral movements of the body which are their chief means of propulsion. In the land-vertebrates, with the exception of snakes, the limbs are developed as the chief organs of propulsion but flexibility of the column is retained for the sake of freedom of movement. In man the spinal column, with the exception of the sacral region, may be readily extended (bent backward) and flexed (bent forward), abducted (bent to the side) and rotated. Freedom of movement is greatest in the cervical and lumbar region and is restricted by the thorax in the thoracic region. The cervical region allows considerable flexion, extension and rotation, but a more limited abduction. In the thoracic region rotation and abduction are freer than flexion and extension. The lumbar region is that in which the chief flexion and extension of the trunk takes place, but abduction and rotation are limited, especially the latter. In the isolated articulated spinal column freedom of movement of the various parts depends chiefly upon the thickness and elasticity of the intervertebral disks, upon the conformation of the articular processes, and upon the elasticity or arrangement of the various ligaments uniting the vertebræ. In the living body freedom of movement is further restricted by the musculature and skeletal apparatus attached to the column. There is much individual variation in the flexibility of the vertebral column.

The various movements of the column are produced partly by muscles which act directly on it and partly by muscles which act on it through the head, thorax or pelvis. Most of the muscles which act on it directly belong to the intrinsic dorsal musculature; that is, to musculature which is derived from the dorsal divisions of the myotomes and is innervated by the dorsal divisions of the spinal nerves. This musculature extends from the sacrum to the skull and is closely applied on each side of the middorsal line of the body to the backs of the vertebræ and the back of the thorax (fig. 412). Its chief function is to extend the spinal column and head, hence the old term applied to the superficial portion of this musculature 'erector spinæ.' During the development of the body, muscles belonging to the ventrolateral thoracic musculature and to the upper extremity come to overlie in part the intrinsic dorsal musculature. The trapezius and rhomboid muscles which cover it in the cervical and thoracic regions, and the latissimus dorsi which covers it in the thoracic and lumbar regions belong to the shoulder girdle and arm and have already been described, p. 382. The serratus posterior superior, which overlaps it in the upper thoracic region, and the serra-

erior inferior, which overlaps it at the junction of the thoracic and lumbar are derived from the intercostal musculature which is described later, p. 411). All of these muscles are innervated by the ventrolateral divisions pinal nerves. The levatores costarum (fig. 414), which extend from the

FIG. 411.—THE THIRD AND FOURTH LAYERS OF THE MUSCLES OF THE BACK. (INTRINSIC DORSAL MUSCULATURE)



se process of the thoracic vertebræ to the ribs, and which, in spite of their ct chiefly on the spinal column, are derived from the external intercostal ture and are innervated by the intercostal nerves.

Ventral to the spinal column and closely applied to it there are a few muscles the chief function of which is to flex the column. All are supplied by branches from the ventrolateral divisions of the spinal nerves. Of these the *longissimus colli* and *longissimus capitis* and *scalene* muscles have been described in connection with the muscles of the neck, p. 388. In the thoracic region there are no muscles of this type. In the lumbar region there are four muscles on each side, the pillars of the *diaphragm*, the *psoas minor*, the *psoas major* and the *quadratus lumborum* (figs. 422, 437). All of these muscles are flexors of the spine, except the quadratus, which is an extensor. The psoas major muscle is also a flexor of the thigh. Even more powerful flexors of the column than those above mentioned are some of those which work indirectly upon it through the leverage o ered by the skull (sterno-cleidomastoid described above, p. 382), and the thorax (the ventrolateral abdominal musculature).

Abduction and rotation of the spine are produced by contraction of muscles on one side while the corresponding muscles on the other side are relaxed. See Table, p. 536.

In the present section we shall confine our attention to the intrinsic dorsal musculature, leaving for consideration elsewhere the other musculature which acts on the vertebral column.

The **intrinsic dorsal musculature** is attached to the sacrum, to the ilium, to the spines, transverse, and articular processes and laminæ of the lumbar, thoracic, and cervical vertebræ, to the backs of the ribs and to the base of the skull. Two great longitudinal subdivisions may be recognized, a **lateral,** supplied by lateral branches of the posterior divisions of the spinal nerves, and a **medial,** supplied by medial branches. The lateral portion is further divisible into a **superficial division,** including the splenius and sacrospinalis, consisting chiefly of systems of muscles extending laterally from the spines of the vertebræ upward toward the transverse processes of the vertebræ, the ribs, and the mastoid process of the skull; and a **deep division,** the dorsal intertransverse muscles, extending between successive transverse processes. The medial portion likewise consists of two parts: a **superficial medial** (spinalis dorsi and cervicis) composed of fasciculi extending from inferior to superior spines, best developed in the dorsal region; and a **deep portion** (semispinalis capitis, transversospinal and interspinal), consisting mainly of muscle fasciculi which pass from the transverse processes upward toward the spines of vertebræ situated more cranially. In the neck the more superficial extend to the base of the skull.

Between the base of the skull and the first two vertebræ there are several specialized muscles. There is also frequently present the rudimentary *sacrococcygeus posterior* described on p. 481, which represents an extension into the caudal region of the intrinsic dorsal musculature.

The primitive condition of the dorsal musculature is one of metameric segmentation. This is characteristic of fishes, many amphibia, and of the embryos of all higher vertebrates. In the tailless amphibia, however, a partial differentiation of the dorsal musculature takes place during embryonic development, and in all higher forms a differentiation takes place which corresponds in many ways to that described above for man. According to Favaro, the splenius is differentiated from the medial dorsal system, but its innervation should place it with the lateral system. In the human embryo the dorsal segmental musculature extends into the tail region, but afterward here undergoes retrograde metamorphosis.

The **fasciæ** and the general relations of the muscles of the back may be followed in the cross-sections shown in figs. 378, 382, 388, 415, and 438.

The **tela subcutanea** of the upper dorsal region has been described in connection with the muscles of the shoulder girdle (p. 382). It is thick, fibrous, and adherent. In the lower dorsal region it is somewhat less compact, but is thicker and contains more fat. It is usually divisible into two layers, of which the deeper is adherent to the lumbodorsal fascia.

The splenius (fig. 411) is enveloped in a thin, adherent fascial covering. The sacrospinalis is covered by a fascia, the **fascia lumbodorsalis** (fig. 411), which inferiorly is attached to the iliac crest, the distal and lateral margins of the sacrum, and the sacral spines. In the lumbar and thoracic regions it is attached medially to the vertebral spines. Laterally, in the lumbar region, it is reflected around the muscle to its ventral surface, where a 'ventral' or 'deep' layer forms an intermuscular septum (fig. 415) between the quadratus lumborum and the sacrospinalis. This ventral layer (fig. 414) extends from the twelfth rib to the iliac crest and the iliolumbar ligament, and is attached medially to the transverse processes of the lumbar vertebræ, from which fiber-bands extend laterally into it. It is strengthened above by fiber-bundles which pass from the first and second lumbar vertebræ to the twelfth rib (lumbocostal ligament). (For the relation of the abdominal muscles to this fascia see p. 459.)

In the thoracic region (fig. 415) the lumbodorsal fascia is attached to the ribs lateral to

the iliocostal muscle. In the cervical region (fig. 382) the fascia is continued into the intermuscular septa which surround the muscles of this group in the neck.

The *transversospinal muscles* are covered throughout their extent by a fascial membrane which serves to separate them from the longissimus in the sacral, lumbar, and thoracic regions.

In the dorsal region of the neck (figs. 378, 382, 388) the muscles are covered on each surface by adherent fascial sheets, **fascia nuchæ**, and are arranged in several concentric layers, each of which is separated from its neighbors by dense fatty areolar tissue. The deepest of the layers is formed by the muscles of the transversospinal group. This is covered by a dense membrane, and is separated from the semispinalis capitis (complexus) by a thick layer of areolar tissue containing the chief blood-vessels and nerves of the neck. The semispinalis capitis (complexus) is covered on each surface by a more delicate adherent membrane, and is separated from the splenius by loose tissue. The splenius has a somewhat denser adherent fascial covering into which the fascia of the levator scapulæ is continued. Separated from this by areolar tissue lies the trapezius. The cervical and thoracic portions of the semispinalis are separated by delicate membranous septa from the semispinalis capitis (complexus), the levator scapulæ, and the splenius. The muscles of each side are separated in the dorsal median plane by the dense ligamentum **nuchæ**, into which the various cervical septa and fasciæ extend. The suboccipital muscles are covered by fascial sheaths which are so fused as to constitute a special fascia for these muscles. Distally this is continued into the fascia of the transversospinal muscles.

MUSCLES

A. Superficial Lateral Dorsal System

The splenius (fig. 411).—The two parts of which this muscle is composed may be separately considered.

The splenius cervicis.—*Origin.*—By a narrow aponeurotic band from the spinous processes and the supraspinous ligament of the third to the sixth thoracic vertebræ.

Structure and insertion.—The fiber-bundles extend upward and laterally and give rise to a flat muscle sheet from which fasciculi arise that are inserted by short tendinous processes on the posterior tubercles of the transverse processes of the first two or three cervical vertebræ. The processes are often united with those of the levator scapulæ and the longissimus cervicis.

The splenius capitis.—*Origin.*—From the ligamentum nuchæ in the region of the third to the seventh cervical vertebræ and from the spinous processes and the supraspinous ligament of the first two to five thoracic vertebræ.

Structure and insertion.—The fiber-bundles form a sheet which continues cranialward that of the splenius cervicis. The fiber-bundles converge somewhat and are inserted by a short, broad, thick tendon into—(1) the back, the side, and the tip of the mastoid process below the sternocleidomastoid muscle, and (2) into the neighboring part of the occipital bone.

Relations.—The splenius lies dorsal to the semispinalis capitis (complexus) and to the cervical (transversalis cervicis) and the cranial (trachelomastoid) portions of the longissimus and the cervical portion (cervicalis ascendens) of the iliocostalis and to the levator scapulæ, and is partly covered by the trapezius, sternocleidomastoid, serratus posterior superior, and the rhomboids. In the triangle bounded by the trapezius, sternocleidomastoid, and the levator scapulæ it is subcutaneous.

Nerve-supply.—The lateral branches of the posterior divisions of the second, third and fourth (sometimes also of the first, the fifth and the sixth) cervical nerves give off rami which enter the deep surface of the muscle.

Action.—To incline and rotate the head and neck toward the side on which the muscle is placed. When both muscles act, the head and neck are extended.

Variations.—The extent of separation and of fusion of the two muscles varies. Absence of either muscle is rare. The splenius capitis may be divided into mastoid and occipital portions. The attachment of the muscle also varies somewhat. Occasionally the spinal origin of the splenius may extend to the cranial end of the ligamentum nuchæ. The origin may extend laterally over the fascia covering the deeper dorsal muscles. An accessory slip, the **splenius cervicis accessorius**, separated from the main muscle by the tendon of the serratus posterior superior, is frequently (8 per cent. of instances, Le Double) found to run from the lower cervical or upper thoracic vertebræ to the transverse process of the atlas.

The sacrospinalis (erector spinæ), (figs. 412, 413).—*Origin.*—(1) From a strong aponeurosis attached to the spines of the lumbar, and the sacral vertebræ, to the ligament passing from the sacrum to the coccyx, to the lateral sacral crest, the sacrotuberous ligament, the long posterior sacroiliac ligament, and to the dorsal fifth of the iliac crest; (2) directly from the iliac crest in front of and lateral to the attachment of the aponeurosis; and (3) from the short posterior sacroiliac ligaments. The aponeurosis covers the muscles of the sacral region and is there united to the overlying fascia by more or less dense areolar tissue. Opposite the iliac crest fiber-bundles begin to take origin from the lateral margin of the dorsal surface as well as from the deep or ventral surface of the aponeurosis of origin, and gradually the line of dorsal attachment extends medially until, in the lower thoracic region, the tendon becomes completely embedded in the muscle-fasciculi which take their origin from it. The aponeurosis, which is the strongest in the lower lumbar region, is composed chiefly of fibers which take a direction upward and somewhat lateralward.

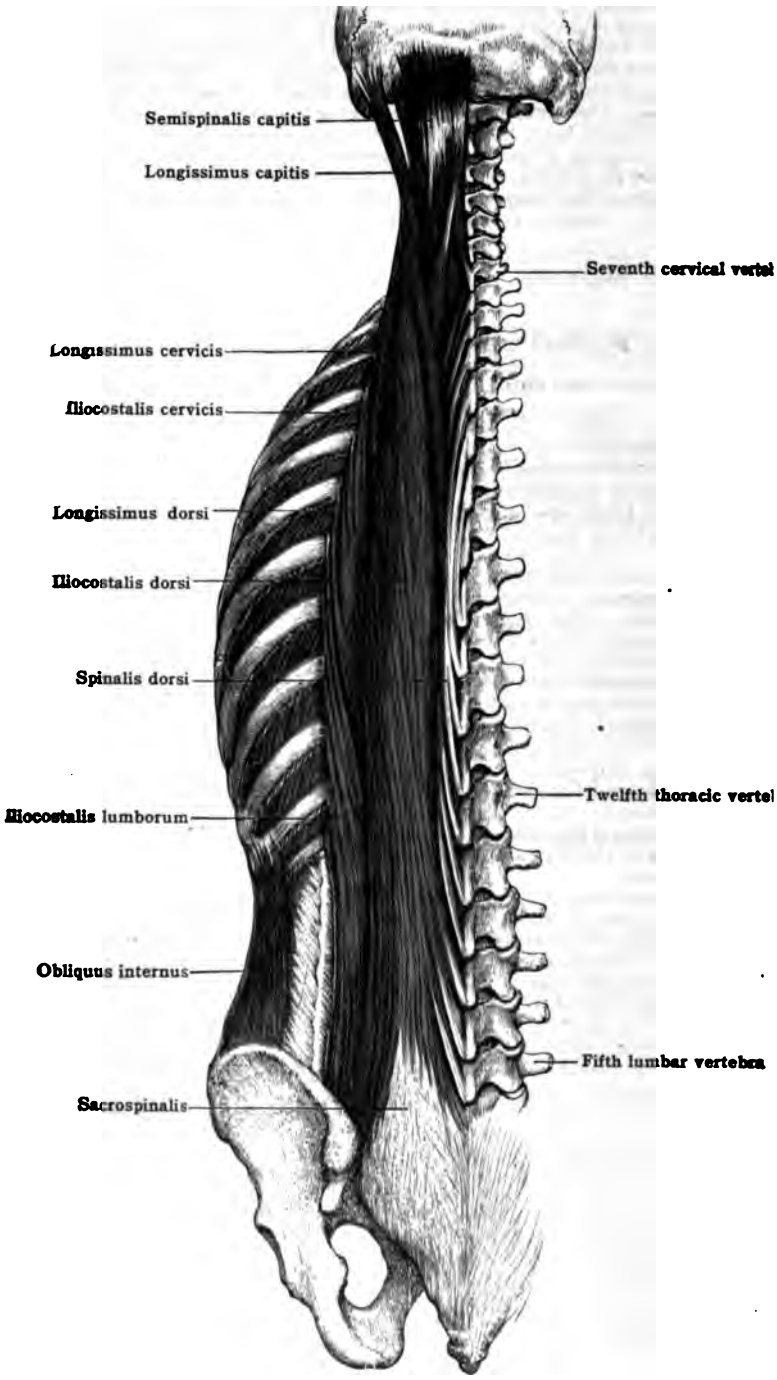
In the lower lumbar region the sacrospinalis (erector spinæ) muscle begins to show a distinct division into its two chief component parts, the iliocostalis and the longissimus. The parts of which the iliocostalis and longissimus are composed will be taken up separately.

The iliocostalis lumborum (figs. 412, 413).—*Origin.*—(1) Chiefly from the back of the sacrospinal aponeurosis, medial to and cranialward from the iliac crest, and (2) from the iliac

crest directly. The deep medial surface of the muscle is closely united in the lumb to the longissimus.

Structure and insertion.—From the mass of fiber-bundles which compose the m ciculi are given off which are attached chiefly by tendinous slips to—(1) the tips of the processes of the lumbar vertebræ; (2) the fibrous processes which extend lateralward

FIG. 412.—THE FIFTH LAYER OF THE MUSCLES OF THE BACK.



tips of the transverse processes of the upper lumbar vertebræ into the anterior l lumbodorsal fascia; (3) the inferior margin of the last six or seven ribs near the angle sertions into the lumbodorsal fascia and the twelfth rib are usually fleshy. The tached to the lumbar vertebræ are by some considered to belong to the longissim

Relations.—The muscle lies on the lateral margin of the longissimus and upon t

the external intercostal and levatores costarum muscles, and under the axioappendicular muscles described above.

The iliocostalis dorsi (accessorius).—*Origin.*—By fleshy fasciculi from the superior borders of the lower seven ribs medial to the angles.

Structure and insertion.—The slips of origin lie beneath the preceding portion of the muscle, pass medial to and partly fuse with it, and give rise to a belly from which tendinous slips extend to be inserted into the upper seven ribs near their angles and to the transverse process of the seventh cervical vertebra.

Relations.—The muscle lies upon the ribs and the external intercostal muscles lateral to the longissimus.

The iliocostalis cervicis (cervicalis ascendens).—*Origin.*—By fleshy slips from the upper borders near the angles of the seventh to the third (sometimes to the second or first) ribs.

Structure and insertion.—The slips of origin are covered by the slips of insertion of the dorsal portion (accessorius). They emerge medial to them and give rise to a fleshy belly from which tendons pass to the backs of the transverse processes of the sixth to the fourth cervical vertebræ.

Relations.—The scalenus posterior lies in front, the levator scapulæ at the side, and the splenius and longissimus (transversalis) cervicis medial to this muscle.

A *bursa* is frequently found between the muscle and the tubercle of the first rib.

The longissimus dorsi (figs. 412, 413).—*Origin.*—(1) From the deep surface of the sacrospinal aponeurosis; (2) from the short posterior sacroiliac ligaments; and (3) through accessory slips which arise from the transverse processes of the first two lumbar and the last five or six thoracic vertebræ. In the lumbar region it is fused dorso-laterally with the iliocostalis.

Structure and insertion.—From the muscle mass arise fasciculi which are inserted partly directly, partly by means of tendons, into—(1) the lower border of the back of the transverse processes of the lumbar vertebræ and the inferior margins of the ribs lateral to the tubercles; and (2) the accessory tubercles of the lumbar and the tips and inferior margins of the transverse processes of the thoracic vertebræ. The attachment to the first rib is usually wanting. The attachment to the first five ribs may fail. The medial attachments seldom extend to the first vertebra.

Relations.—The lateral margin of the muscle is covered by the iliocostalis. Medially it overlies the transversospinal muscles. The lateral branches of the dorsal veins, arteries, and nerves pass mainly in the fibrous tissue which separates the longissimus from the iliocostalis, the medial branches chiefly between the longissimus and the transversospinal muscles. The relations to the axioappendicular muscles and to the dorsal fascia have been pointed out above. Ventrally it lies upon the intertransverse muscles, the external intercostals, and the levatores costarum.

The longissimus cervicis (transversalis cervicis).—*Origin.*—By tendinous slips from the transverse processes of the first four to six thoracic vertebræ.

Structure and insertion.—The fasciculi which arise from these slips give rise to a muscle belly from which tendons of insertion extend to the posterior tubercles of the transverse processes of the mid-cervical (second to sixth) vertebræ.

Relations.—This muscle lies between the longissimus dorsi and capitis with which it is to some extent fused and the iliocostalis dorsi (accessorius) and cervicis (cervicalis ascendens) muscles.

The longissimus capitis (trachelomastoid).—*Origin.*—By tendinous slips from the transverse processes of the first three or four thoracic vertebræ and the articular processes of the last four cervical.

Structure and insertion.—The muscle fasciculi arising from these tendons form a belly which is united to the mastoid process by a short tendon. A tendinous inscription often crosses the muscle.

Relations.—It lies ventral to the splenius capitis, lateral to the semispinalis capitis (complexus) and medial to the longissimus cervicis (cervicalis ascendens).

Nerve-supply of the sacrospinalis.—From the lateral branches of the posterior divisions of the spinal nerves. The exact distribution of these branches is too complex to be treated here. The nerves for the iliocostalis arise from the eighth cervical to the first lumbar, those for the longissimus from the first cervical to the fifth lumbar.

Action of the sacrospinalis.—The sacrospinalis serves, when acting on one side, to bend the spinal column toward that side, and when acting on both sides, to extend the spinal column. The cranial portions of this musculature incline the head and neck and rotate them toward the side on which they lie, and when both muscles act they extend the head and neck. The iliocostalis muscle has the greatest power for producing lateral inclination. The iliocostalis lumborum depresses the ribs, while the iliocostalis cervicis (cervicalis ascendens) may aid in elevating them. The spinalis muscle serves merely as an extensor.

Variations of the sacrospinalis.—The slips of origin and insertion of the various parts of this muscle and the extent of fusion of the various parts vary greatly. Statistical data from which the most frequent conditions might be determined are wanting. Tendinous inscriptions may extend across the longissimus cervicis and other parts of the sacrospinalis.

B. Deep Lateral Dorsal System

The intertransversarii (figs. 383, 414).—These are vertical bands composed of short bundles which pass between the transverse processes of the cervical, lumbar, and the lower thoracic vertebræ.

(a) *Cervical* (fig. 383).—Ventral, lateral and dorsal muscles are found in the cervical region. The ventral and lateral muscles run between the ventral tubercles and tips of the transverse processes of the vertebræ, are homologous with the intercostal muscles, are supplied by branches from the anterior divisions of the corresponding spinal nerves, and have been described above (p. 390). The dorsal muscles run between the dorsal tubercles and belong to the intrinsic

dorsal musculature. They are supplied by the lateral branches of the posterior divisions of the cervical nerves. (According to Lickley, both sets of cervical intertransverse muscles are supplied by the anterior divisions of the spinal nerves.) The three sets of muscles are, however, more or less fused. The first pair of muscles extends between the atlas and axis, the lowest passes to the transverse process of the first thoracic vertebra, or to the first rib close to this. The *obliquus capitis superior* (described later) belongs, however, to the posterior set of muscles, the *rectus capitis lateralis* (p. 391) to the lateral set. The vertebral artery runs vertically between each pair of muscles above the sixth, and the anterior division of each cervical nerve passes laterally between the artery and the dorsal muscle in each space, and then out between the ventral and lateral muscles. The posterior division of each cervical nerve passes medial to each dorsal muscle.

(b) *Thoracic.*—Small muscle fasciculi may extend between the transverse processes of the thoracic vertebræ and between the last thoracic and first lumbar. They are most frequent in the upper and lower thoracic regions. Often they are replaced by tendinous bands. In the second interspace the insertion may extend to the rib near the transverse process. The innervation is from the lateral branches of the posterior divisions of the spinal nerves.

(c) *Lumbar* (fig. 414).—In the lumbar region there is a lateral set of muscles connecting the adjacent margins of the transverse processes and a medial connecting the mammary tubercle of one vertebra to the mammary or the accessory tubercle of the vertebra next above. They extend between each two of the five lumbar vertebræ and sometimes also to the first sacral. They lie between the sacrospinalis and psoas muscles. The medial muscles are supplied by the lateral branches of the posterior divisions of the spinal nerves. The lateral muscles are supplied by branches from the junction between the two divisions of the corresponding spinal nerves. These branches probably belong to the anterior divisions.

Action.—The intertransverse muscles bend the vertebral column laterally, and when acting on both sides, make it rigid.

Variations.—The number of intertransverse spaces occupied by the muscles varies, especially in the thoracic region. They may be doubled or extend over more than one interspace.

C. Superficial Medial Dorsal System

The spinalis dorsi (fig. 412).—*Origin.*—By tendinous bands from the tips of the two upper lumbar and the last two thoracic spines.

Structure and insertion.—From the deep surface of the tendinous bands there arises a long slender muscle belly which is fused laterally with the longissimus dorsi. It is inserted by tendinous processes to the spines of the upper thoracic vertebræ, usually the second or third to the ninth.

Nerve-supply.—From the medial divisions of the sixth to ninth thoracic nerves.

The spinalis cervicis.—A muscle of inconstant development which arises from the spines of the two upper thoracic and two lower cervical vertebræ and extends to the spines of the second to the fourth cervical vertebræ. The nerve supply is from the dorsal divisions of the lower cervical nerves.

Action.—To extend the vertebral column.

Variation.—There is great variation in the development of the spinalis muscles. Similar fasciculi are sometimes found in the lumbar region and in the cervical region sometimes extend to the skull.

D. Deep Medial Dorsal System

1. *Vertebro-occipital Muscle*

The semispinalis capitis (complexus) (fig. 412).—This muscle is usually separated from the semispinalis muscles of the back and neck by a well-marked septum and has a distinctive structure.

Origin.—(1) By long tendinous fasciculi from the tips of the transverse processes of the upper five or six thoracic vertebræ and of the seventh cervical vertebra; (2) by short fleshy processes from the articular processes and bases of the transverse processes of the third to the sixth cervical vertebræ; and (3) by delicate fleshy fasciculi from the spinous processes of the upper thoracic vertebræ.

Structure and insertion.—The slightly diverging fiber-bundles form a long, flat belly which is inserted, partly by means of an aponeurosis which covers the muscle laterally, into the lower surface of the squamous portion of the occipital, between the superior and inferior nuchal lines. There is often a transverse tendinous inscription across the muscle opposite the sixth cervical vertebra, and less frequently one between the upper and middle thirds of the muscle. These are best marked in the medial portion of the muscle, which comes from the thoracic vertebræ and is sometimes separately designated as the *spinalis capitis* (*biventer cervicis*).

Nerve-supply.—It is supplied chiefly by the medial branches of the posterior divisions of the first four or five cervical nerves. The muscle also gets some twigs from the lateral branches.

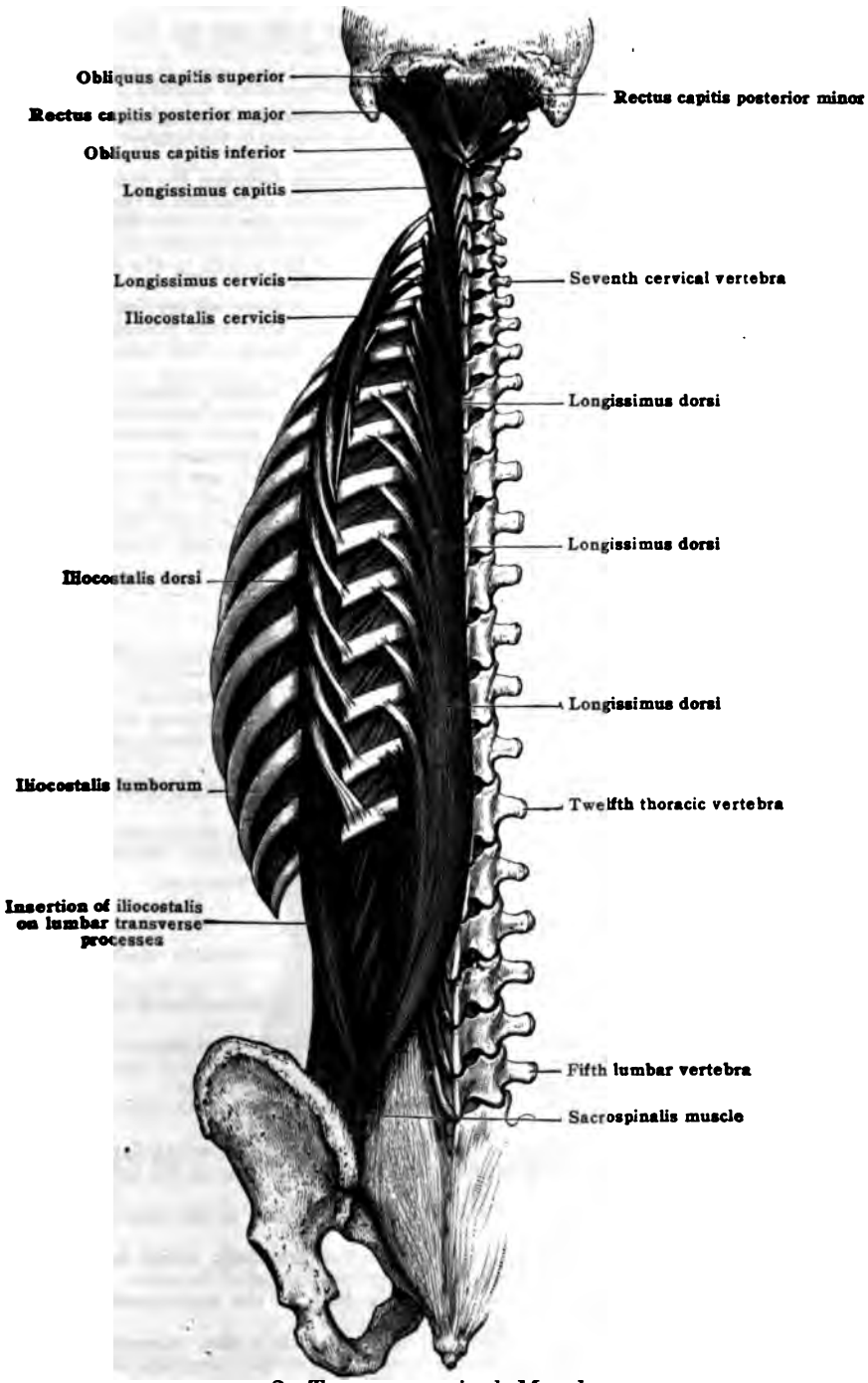
Relations.—It lies dorsolateral to the suboccipital muscles and to the semispinalis cervicis. From this latter it is separated by a septum containing the descending branch of the occipital artery, the deep cervical artery, and the medial dorsal branches of the cervical nerves. It is covered laterally by the longissimus capitis (trachelomastoid), and dorsally by the splenius, and above the upper margin of the splenius by the trapezius.

Action.—To extend the head and to incline it slightly toward the same side.

Variations.—The origin of the muscle may extend to the eighth thoracic vertebra or merely to the first thoracic. It may be fused with the longissimus (transversalis) cervicis. A special

fasciculus may run beneath the muscle from the upper thoracic vertebræ to the head. The origin from the spinous processes of the thoracic vertebræ is not constant. The part of the muscle arising from this origin may be looked upon as a spinalis capitis.

FIG. 413.—THE FIFTH LAYER OF THE MUSCLES OF THE BACK, AFTER SEPARATING THE LONGISSIMUS AND ILIOCOSTALIS DIVISIONS.



2. *Transversospinal Muscles*

The semispinalis dorsi et cervicis (fig. 414).—This superficial transversospinal muscle sheet extends from the twelfth thoracic to the second cervical vertebra. The fasciculi which compose it arise by short tendons from the backs of the transverse processes, and are inserted by short tendons into the spines.

The semispinalis dorsi.—*Origin.*—From the sixth to the tenth or twelfth thoracic vertebræ.

Insertion.—The upper four to six thoracic and the last two cervical vertebræ. The fasciculi extend over four to six vertebræ.

Nerve-supply.—Third to sixth thoracic.

The semispinalis cervicis.—*Origin.*—From the upper five or six thoracic vertebræ.

Insertion.—Into the fifth to the second cervical vertebræ. The fasciculi extend over four to five vertebræ.

Nerve-supply.—Third to sixth cervical.

Relations.—This muscle lies beneath the longissimus dorsi and the semispinalis capitis (complexus) and over the following musculature.

Variations.—A semispinalis lumborum is a muscle rarely found extending from the lumbar to the lower thoracic vertebræ.

The multifidus (fig. 414).—This second layer of transversospinal musculature extends from the sacrum to the second cervical vertebra. It is best developed in the lumbar region and least so in the thoracic.

Origin.—(1) From the groove on the back of the sacrum between the spines and the articular elevations, from the dorsal sacroiliac ligaments, from the dorsal end of the iliac crest, and from the deep surface of the aponeurosis of the sacrospinal muscle; (2) from the mammary and accessory processes of the lumbar vertebræ; (3) from the backs of the transverse processes of the thoracic vertebræ; and (4) from the articular processes of the fourth to the seventh cervical vertebræ and the back of the transverse process of the seventh.

Insertion.—Spinous processes of the lumbar, thoracic, and lower six cervical vertebræ.

Structure.—The more superficial fasciculi arise by short tendinous processes, the deeper ones directly. The more superficial fasciculi extend to the fourth or fifth vertebra above, the middle to the third, and the deepest to the second above.

The rotatores.—These, the third layer of transversospinal muscles, extend from the sacrum to the second cervical vertebræ. They are composed of short fleshy fasciculi which extend to the second vertebra above (*rotatores longi*) and to the first above (*rotatores breves*). The fasciculi arise from the back and upper borders of the transverse processes or their homologues, and are inserted into the laminæ of the preceding vertebræ. They are best developed in the thoracic region. Some authors consider the rotatores breves confined to the thoracic region. In the cervical region the fasciculi usually run from articular processes to the bases of the spines, in the lumbar region from the mammary processes to the caudal margin of the laminæ of the arches.

3. *The Interspinal Muscles*

The **interspinales** consist of short fasciculi which extend from the upper surface of the spine of each vertebra near its tip to the lower surface of the spine of the vertebra above. In the neck the muscles lie in pairs between the bifid extremities of the vertebræ. In the lumbar region they form broad bands attached to the whole length of the spinous processes and are separated by the interspinous ligaments. In the thoracic region they usually are undeveloped.

NERVE SUPPLY AND ACTION OF MEDIAL DORSAL MUSCLES

These muscles are all supplied by the medial branches of the posterior divisions of the spinal nerves. They extend the vertebral column when acting on both sides. When acting on one side, they produce a movement of rotation toward the opposite side.

E. Suboccipital Muscles
(Figs. 413, 414)

The rectus capitis posterior major.—*Origin.*—From the upper surface of the spine of the epistropheus.

Structure and insertion.—The muscle-fibers diverge to form a broad triangular band which is inserted into the lateral half of the inferior nuchal line of the occipital bone and the area below it. Its insertion is immediately below that of the obliquus superior.

The rectus capitis posterior minor.—*Origin.*—From the upper part of the side of the posterior tubercle of the atlas.

Structure and insertion.—The fiber-bundles diverge to form a flat, triangular sheet inserted below the medial third of the inferior nuchal line of the occipital bone on the inferior surface of the squama occipitalis.

The obliquus capitis inferior.—*Origin.*—From the upper part of the side of the spine of the epistropheus (axis).

Structure and insertion.—The fiber-bundles form a fusiform belly which is inserted by a short tendon into the lower part of the tip of the transverse process of the atlas.

The obliquus capitis superior.—*Origin.*—From the back of the upper part of the transverse process of the atlas.

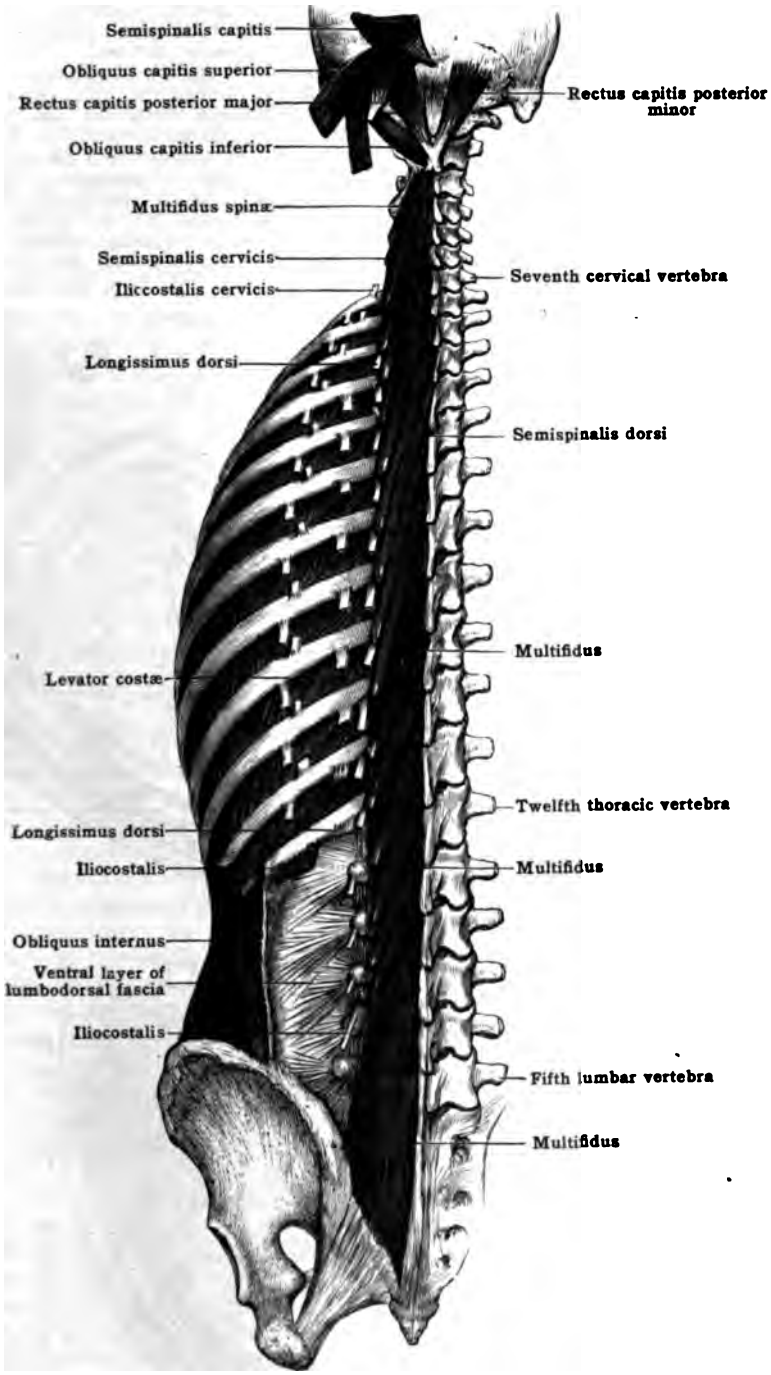
Structure and insertion.—The fiber-bundles diverge to form a flat, triangular muscle, inserted into the lateral third of the inferior nuchal line of the occipital bone, and above the lateral part of the insertion of the rectus capitis posterior major.

Nerve-supply.—These muscles are all supplied by the posterior branch of the suboccipital (first cervical) nerve. The branch to the two rectus muscles passes across the dorsal surface of the major rectus and supplies branches to the middle of the dorsal surface of each muscle. The branch to the superior oblique muscle enters the middle of the medial margin, that to the inferior oblique about the middle of its superior margin. The inferior oblique and major

rectus muscles usually, the other muscles occasionally, receive branches from the second cervical nerve.

Relations.—The two oblique muscles with the rectus major serve to bound a small triangular space, the suboccipital triangle, through which pass the dorsal division of the suboccipital nerve and the vertebral artery. The two minor recti lie on the atlanto-occipital

FIG. 414.—THE TRANSVERSOSPINAL MUSCLES.

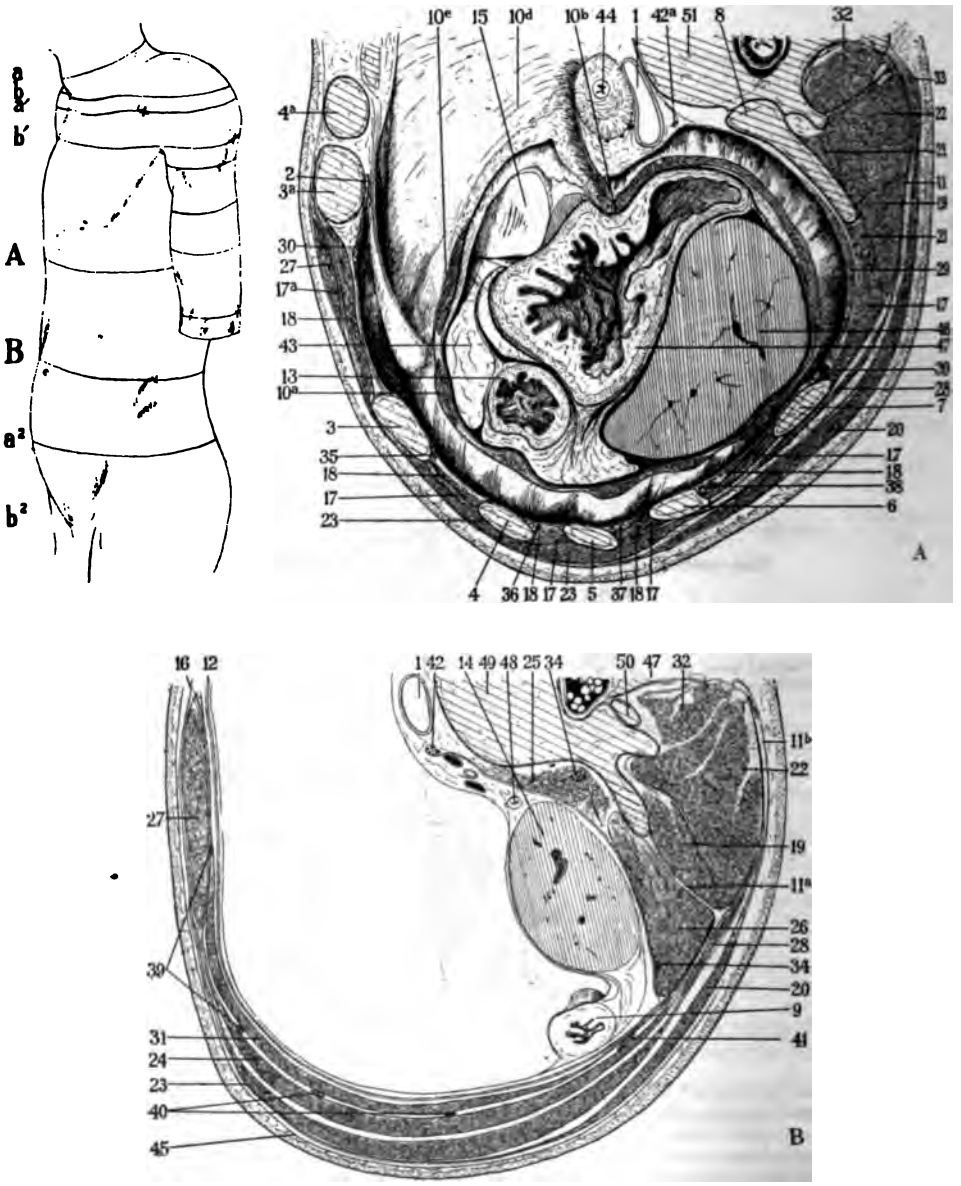


membrane in the upper part of the space bounded by the major recti. The muscles are covered medially by the semispinalis capitis (complexus), laterally by the longissimus and splenius capitis. In front of the two oblique muscles and the major rectus runs the vertebral artery. The great occipital nerve runs between the semispinalis capitis (complexus) and the inferior oblique and the two recti in a dense fatty connective tissue containing the extensive suboccipital venous plexus.

FIG. 415, A and B.—SECTIONS THROUGH THE LEFT SIDE OF THE TRUNK IN THE REGIONS SHOWN IN THE DIAGRAM.

The muscles of the body wall have been slightly pulled apart in order to reveal the relations of muscles, fasciæ, and aponeuroses. *a* and *b* in the diagram indicate sections A and B, fig. 382; a^1 and b^1, sections A and B, fig. 388; a^2 and b^2, sections A and B, fig. 438.

1. Aorta. 2. Arteria mammaria interna. 3. Costa VI—a, cartilage. 4. Costa VII—a, cartilage. 5. Costa VIII. 6. Costa IX. 7. Costa X. 8. Costa XI. 9. Descending colon. 10. Diaphragm—a, costal portion; b, lumbar portion; c, sternal portion; d, centrum tendineum. 11. Fascia lumbodorsalis—a, anterior layer; b, posterior layer. 12. Fascia transversalis. 13. Flexura colica sinstra (splenic flexure). 14. Kidney. 15. Liver. 16. Linea alba. 17. Musculi intercostales externi—a, ligament. 18. Mm. intercostales interni. 19. M. iliocostalis. 20. M. latissimus dorsi. 21. M. levator costæ. 22. M. longissimus dorsi. 23. M. obliquus abdominis externus. 24. M. obliquus abdominis internus. 25. M. psoas major. 26. M. quadratus lumborum. 27. M. rectus abdominis. 28. M. serratus posterior inferior. 29. M. subcostalis. 30. M. transversus thoracis. 31. M. transversus abdominis. 32. Mm. transversospinales. 33. M. trapezius. 34. Nervus lumbalis I. 35. N. thoracalis VI. 36. N. thoracalis VII. 37. N. thoracalis VIII. 38. N. thoracalis IX. 39. N. thoracalis X. 40. N. thoracalis XI. 41. N. thoracalis XII. 42. Sympathetic trunk—a, great splanchnic nerve. 43. Omentum majus. 44. Esophagus. 45. Scarpa's fascia. 46. Spleen. 47. Stomach. 48. Ureter. 49. Vertebra lumbalis II. 50. Vert. lumbalis III. 51. Vert. thoracalis X.



Action.—The rectus muscles and the superior oblique draw the head backward. The ctus major and the inferior oblique, when acting on one side, rotate the face toward that side.
Variations.—Each of these muscles may be doubled by longitudinal division. Accessory ps may connect the two recti with the semispinalis capitis. The **atlantomastoid** is a small uscle frequently found. It passes from the transverse process of the atlas to the mastoid ocess.

IV. THE THORACOABDOMINAL MUSCULATURE

The thoracic and abdominal viscera are contained within cavities, the ventro- teral walls of which may be contracted and expanded by muscular action. The eletal support for the intrinsic musculature of these walls consists of the ribs, e sternum and the vertebral column and the pelvis. The intrinsic musculature the thoracic walls is situated chiefly between the ribs (*intercostal muscles*, figs. 6, 417) while in the region of the abdomen it extends in broad sheets from the wer part of the thorax to the pelvis (the *quadratus lumborum* and the *external* id *internal oblique*, *transverse*, and *rectus* muscles, figs. 418, 420, 421, 437). Be- ween the two cavities, attached to the lower part of the thorax and to the lumbar rtebræ lies the dome-shaped diaphragm (fig. 422). The thoracic cavity ex- nds on each side slightly above the first rib. The abominal cavity extends ownward and backward into the pelvis, as the pelvic cavity.

The function of the intercostal muscles is to expand and contract the thoracic vity for the sake of respiration. The shape of the ribs and their articulations ith the vertebræ are such that a slight rotation of the neck of each rib will cause e shaft to swing outward and upward or in the reverse direction. The costal rtilages are elastic enough to permit this movement, and at the same time are rong enough to make the thorax an effective skeletal apparatus. Ninety joints e called into play in the movements of the thorax (24 between the heads of e ribs and the vertebræ, 20 between the tuberosities and the transverse pro- sses of the vertebræ, 24 between the ribs and costal cartilages, 14 between the stal cartilages and the sternum, 6 between the costal cartilages and 2 intraster- al). When the shafts of ribs are swung outward and upward the thorax is en- rged in the anteroposterior and transverse axes. In the adult when standing ie sternum may be raised nearly 3 cm., and protruded 1 cm. The cartilages the lower ribs may be raised 4 to 5 cm. The sides of the thorax at the level the second rib may be protruded 3 cm., and at the level of the eighth rib nearly far. This extent of movement, however, is found only in forced respiration. n ordinary quiet respiration it is far less, the sternum being raised merely 3 or mm., and protruded 2 mm., and the thorax is enlarged at the sides merely 5 mm. R. Fick). The chief muscles used in quiet inspiration are the external intercostals nd the intercartilaginous parts of the internal intercostals.

During inspiration the diaphragm contracts so that the thoracic cavity is rther enlarged perpendicularly. The extent of movement of the upper part f the diaphragm is estimated by R. Fick at from $1\frac{1}{2}$—3 cm.

The ventrolateral abdominal muscles contract the thoracic cavity by depress- ig the thorax and by pushing the diaphragm upward. They directly contract ie abdominal cavity. Contraction of the abdominal cavity is of aid in defe- ation and parturition. The abdominal muscles are also of value in flexion, bduction, and rotation of the vertebral column and pelvis.

The thorax, with its intrinsic musculature, is in large part covered by the uusculature which extends from the trunk to the shoulder girdle and arm; orsally by the trapezius and rhomboids, ventrally by the pectoral muscles, and terally by the serratus anterior and the latissimus dorsi, as well as by the sca- ula and the muscles which pass from it to the humerus. The upper extremity n each side is largely supported from the spine by the trapezius, rhomboid and vator scapulæ muscles but it none the less exerts some pressure on the thorax nd interferes to some extent with respiration. If the girdle and arm are fixed raised the muscles which pass from them to the thorax are an aid in forced in- piration. Advantage of this is taken when in artificial respiration the arms are ised so as to lift the ribs through traction by the latissimus dorsi, the pectoralis uscles and the subclavius. Some of the muscles of the neck, especially the scalene uscles and the sternocleidomastoid, are likewise of value in forced inspiration.

Expiration is produced not only by the part of the internal intercostals

which lie between the bony ribs, and by the abdominal muscles, but also by the lumbar iliocostales and by the quadratus lumborum.

The intrinsic muscles of the thorax and abdomen are derived from the twelve thoracic myotomes and the first one or two lumbar and are innervated by the corresponding nerves, while the musculature of the shoulder girdle and arm which covers the intrinsic muscles of the thorax is of cervical origin and is innervated by cervical nerves. The diaphragm is likewise of cervical origin and is innervated by the phrenic nerve from the cervical plexus.

The intrinsic muscles of the back extend over the thoracic musculature (external intercostals and levators of the ribs, fig. 414) and in turn are in part covered by muscles which extend dorsally from the thoracic region (posterior serrate muscles, fig. 411).

The intrinsic thoracoabdominal muscles are composed laterally of three layers of sheet-like muscles.

In the **external layer** the fiber-bundles run downward and ventralward. This layer is represented in the thoracic region by the external intercostal muscles, the levators of the ribs and the posterior serrate muscles. The fiber-bundles of the **external intercostals** (fig. 416), extend between each pair of ribs but between the costal cartilages are replaced by fibrous tissue, the *external intercostal ligaments*. The **levatores costarum** (fig. 414), extend from the transverse process of one vertebra to the rib which articulates with the next vertebra below and in some instances the fiber-bundles are continued to the second rib below.

The **serratus posterior superior and inferior** (fig. 411), are derivatives of the external oblique which during development wander in part over the intrinsic dorsal musculature. The *superior serrate* arises from the spines of the last two cervical and first two thoracic vertebræ and is inserted into the second to the fifth ribs. The *inferior serrate* muscle arises from the spines of the last two thoracic and first two lumbar spines and is inserted into the last four ribs. The fiber-bundles of this muscle therefore take a direction opposite to that of the other muscles of the group. These muscles aid in inspiration. In the abdominal region the external layer is represented by the **external oblique** muscle (fig. 418). This arises by digitations from the last seven ribs and is inserted into the crest of the ilium and by means of a broad flat aponeurosis into the linea alba in the midventral line and into the inguinal ligament below. The external intercostal, levatores costarum, and posterior serrate muscles are innervated from branches which arise near the tubercles of the ribs. The external oblique muscles are innervated by branches which in large part arise in conjunction with or from the lateral branches of the anterior divisions of the last seven thoracic nerves and frequently also by branches from the iliohypogastric.

The **middle layer** of the lateral thoracoabdominal musculature is composed of fiber-bundles which run downward and backward obliquely across the fiber-bundles of the external layer. In the thoracic region it is represented by the internal intercostal and subcostal muscles. The **internal intercostal** (fig. 416) muscles lie between the costal caritlages and between the ribs as far dorsalward as the angles, beyond which they are replaced by membranous tissue and by the **subcostal muscles.** The latter, instead of extending from one rib to the next rib below, extend to the second or third rib below. They are best developed in the lower part of the thoracic cavity. In the abdominal region the middle layer is represented by the **internal oblique muscle** (fig. 419). This arises from the lumbodorsal fascia, the crest of the ilium and the inguinal ligament and is inserted into the sheath of the rectus abdominis muscle and into the inferior margins of the ventral extremities of the three lower ribs. The aponeurosis, which helps to form the sheath of the rectus, divides in the upper abdominal region into two layers, one of which passes in front and the other of which passes behind the rectus to be inserted into the linea alba in the midventral line. In the lower third of the ventral abdominal wall both layers pass in front of the rectus. The fiber-bundles which compose the internal oblique muscles do not all follow the usual course of the fiber-bundles of this layer. At the level of the iliac crest they pass nearly transversely across the body and below here they slant downward and forward. Just above the inguinal ligament and medial to its center the internal oblique muscle is continuous with the thin **cremaster muscle** (fig. 420), which is prolonged over the spermatic cord and the tunica vaginalis of the testis and epididymis in the male and over the ligamentum teres in the female. The cremaster muscle is attached laterally

the inguinal ligament, medially to the outer layer of the sheath of the rectus ar the insertion of the latter.

The **inner layer** of the thoracoabdominal musculature is composed of fiber-ndles which take a course transversely across the body. In the thoracic region is represented by the **transversus thoracis** (fig. 417), a slightly developed muscle hich arises from the costal cartilages of the third to sixth ribs and is inserted into he lower part of the sternum and into the xiphoid process. In the upper portion f the muscle the fiber-bundles extend obliquely downward and forward instead of transversely. In the abdomen this layer is represented by the **transversus abdominis** (fig. 421) which arises from the cartilages of the lower seven ribs, from the lumbodorsal fascia, the iliac crest and lateral part of the inguinal ligament and is inserted into the linea alba by means of an aponeurosis which lies behind the rectus in the upper two-thirds of the ventral wall of the abdomen and in front in the lower third. It is intimately fused with the aponeurosis of the internal oblique.

The main trunks of the anterior divisions of the last five or six thoracic nerves give rise to branches which supply the muscles both of the middle and inner layers f the lateral thoracoabdominal musculature. In the abdominal region these runks run in the main between the two layers. Some muscular branches are sually also supplied from the iliohypogastric and ilioinguinal nerves. In the oracic region the intercostal nerves run external to the subcostal muscles, rough the substance of the costal part of the internal intercostal muscles, and ternal to the parts of the internal intercostals which lie between the costal rtilages. Eisler includes the subcostal muscles and that part of the internal tercostals which lies internal to the nerve trunk, with the inner rather than with e middle layer of the thoracic musculature.

The ventral part of the muscular thoracoabdominal wall is represented by a gle muscle on each side, the rectus abdominis muscle, except just above the mphysis pubis where the rudimentary pyramidalis is usually found. The **rectus dominis muscle** (fig. 419), is a band-like muscle which arises from the ventral rfaces of the fifth to the seventh costal cartilages and from the xiphoid process d is inserted into the superior ramus of the pubis. It is ensheathed by the oneuroses of the lateral abdominal musculature described above. The compo-nt fiber-bundles run nearly parallel with the midsagittal line. Transverse scriptions partially divide the muscles into segments. It is innervated by the t six or seven thoracic nerves. The **pyramidalis** (fig. 419) is a small muscle hich arises from the superior pubic ramus and is inserted into the linea alba for out a third of the distance to the umbilicus.

The lateral intertransverse muscles of the lumbar region described on p. 449 obably belong to the ventrolateral musculature of the trunk. The nerves pplying them come from the junction between the posterior and anterior visions of the spinal nerves.

The inguinal (Poupart's) ligament and the **inguinal canal** (fig. 420), described detail below, are of considerable practical interest because of the frequency of rnias in this region. In the quadrupeds the pressure of the weight of the ab-minal viscera centers toward the umbilicus while in man it centers toward the ntral part of the line of attachment of the abdominal wall to the pelvis. The wer margin of the aponeurosis of the external oblique muscle is here strength-ed to form the inguinal (Poupart's) ligament which extends from the anterior-perior iliac spine to the pubic tubercle. Near the latter it is reflected (curves edialward) to the pubic crest forming the triangular **lacunar ligament** (Gimber-t's). The medial half of the inguinal ligament helps to bound a slit-like space, **guinal canal,** through which in the male the spermatic cord passes to the scrotum, d in the female, the round ligament passes to the labium majus. This canal gins on the inner side at the (internal) abdominal ring, which is situated above d medial to the center of the inguinal ligament. The canal, which is about 4 n. long, extends medialward and downward to the subcutaneous (external dominal) ring, a slit-like opening in the aponeurosis of the external oblique just ove the inguinal ligament. The canal is bounded ventrally by the aponeurosis the external oblique and the cremaster muscle, below by the reflected portion the inguinal ligament, dorsally by the transversalis fascia and above by the ansversus, internal oblique, and cremaster muscles.

The **quadratus lumborum** (fig. 437), which extends from the twelfth rib to the ilium and iliolumbar ligament, is supplied by direct branches of the lumbar nerves in series with the nerves supplying the musculature of the abdominal wall. It will, therefore, be taken up with the intrinsic thoracoabdominal muscles. It depresses the thorax and abducts and extends the spine. The **psoas muscle**, on the other hand, which also lies at the back of the abdominal cavity, represents an extension of the intrinsic musculature of the limb to the spinal column (see p. 487).

The **diaphragm** (fig. 422), a dome-shaped muscle which is attached to the lower margin of the thorax and to the upper lumbar vertebræ, and separates the thoracic and abdominal cavities, arises in the embryo in the region of the neck, and maintains cervical relations through its innervation by the phrenic nerves, which spring one on each side usually from the third to fifth cervical nerves. It does not belong morphologically with the other muscles considered in this section, but is here included because of its physiological and anatomical relations and the convenience of treating it in connection with the intrinsic thoracoabdominal muscles. A diaphragm completely separating the thoracic from the abdominal cavities is found only in the mammals. The central portion of the diaphragm is an aponeurosis or central tendon with a convex ventral and concave dorsal margin. Into this tendon is inserted the musculature which arises on each side from the xiphoid cartilage, the cartilages and tips of the last six or seven ribs and by means of three crura from the sides of the first four lumbar vertebræ.

In fishes and tailed amphibians the musculature of the body wall is composed of metamerically segmented musculature. In all higher vertebrates it is likewise at an early embryonic stage segmental, being composed of the ventrolateral portions of the myotomes. The ventral ends of the myotomes give rise to a ventral longitudinal muscle which runs on each side of the body next the midline in front, and retains more or less of the primitive segmentation. The rectus abdominis and the infrahyoid muscles represent this system in man. Very frequently traces of the system may also be seen on the upper thoracic wall in the form of slender muscular and aponeurotic slips. The rectus muscle in man is usually developed from the last seven thoracic myotomes. The pyramidalis becomes split off from its lower end. The lateral part of the ventrolateral portions of the thoracic myotomes usually gives rise to several strata of muscles which vary somewhat in different vertebrates, although quite similar among the mammals. In man the twelve thoracic and first two lumbar myotomes give rise to the lateral musculature of the thoracoabdominal wall.

The quadratus lumborum represents the ventrolateral portions of the lumbar myotomes with the exception of that portion of the first two which enter into the lateral abdominal musculature and of the fifth, which probably undergoes retrograde metamorphosis.

It will be noted that the abdominal wall is composed of musculature which has an origin chiefly from the thoracic myotomes. At an early stage of embryonic development both the thoracic and the abdominal viscera are covered by a non-muscular membrane. The myotomes extend into this from the thoracic region, and as the musculature is differentiated, it approaches the median line in front and extends distally to the pelvis. Owing to the rotation of the limbs the abdominal musculature is stretched ventrally over an area corresponding to the lumbar and sacral regions dorsally. The last part of the thoracoabdominal wall to be furnished with musculature is that about the umbilicus. Occasionally the process fails to be completed in this region.

Each spinal nerve supplies primarily the musculature derived from the myotome which lay caudal to it, and at first the musculature lies wholly superficial to the nerves. With subsequent differentiation the metamerism is somewhat obscured by anastomosis of nerves and fusion of myotomes; and a part of the internal oblique layer and all the transverse layer of the lateral musculature comes to lie on the inner side of the main nerve-trunks.

The **fasciæ** and the topographical relations of the thoracoabdominal muscles may be followed in the sections shown in figs. 388, 415, and 438.

FASCIÆ

Tela subcutanea.—As mentioned above, most of the intrinsic thoracic musculature is covered by other muscles, while the superficial layer of the abdominal musculature is subcutaneous. A panniculus adiposus, **Camper's fascia**, in which much fat may be deposited is usually easily distinguishable, especially in the lower part of the ventral wall of the abdomen, from a membranous fascial sheet which is loosely attached to the underlying fascial envelopment of the muscles. To this membrane has been applied the term **Scarpa's fascia**. Near the groin it is separated from the panniculus adiposus by blood-vessels and lymphatic glands. It is closely bound to the linea alba between the two rectus muscles, to the fibrous structures in front of the pubic bone, to the fascia lata below the inguinal ligament, and to the crest of the ilium.

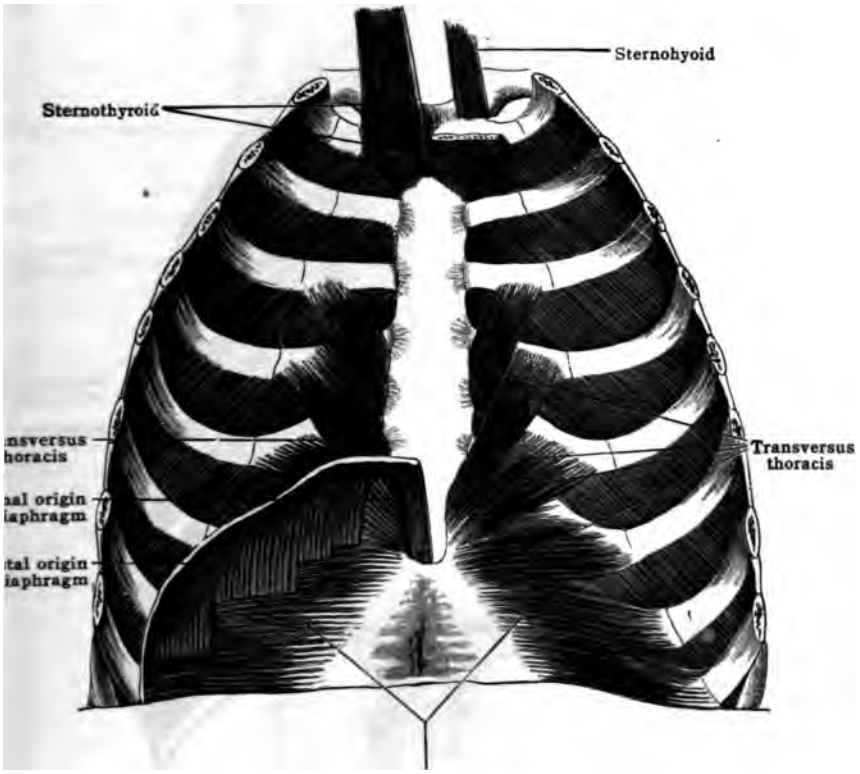
Over the scrotum of the male and vulva of the female both layers of the tela subcutanea are continued. In the male the fat of the more superficial layer disappears and the two layers blend with the fundiform (suspensory) ligament and fascia of the penis and the dartos and septum of the scrotum.

scle fasciæ and sheaths.—The posterior serrate muscles (fig. 411) are enveloped by two
nt layers of an aponeurotic sheet that extends as a single membrane between them and is
ed lateralward to the ribs and medialward to the spines of the thoracic vertebræ. The
rane between the muscles may represent the rudiment of a primitive continuous muscle
s is found in some lower vertebrates. This membrane may usually be easily separated
he aponeurosis of the latissimus dorsi on its superficial surface and the lumbodorsal fascia
h.

e intercostal muscles are covered by delicate, adherent membranes on each surface.
ternal intercostal muscles are continued as aponeurotic bands between the costal carti-
These serve here as fasciæ for the internal intercostals.

e external oblique muscle is covered externally by a dense, adherent membrane and in-
y by a more delicate membrane except where the muscle is attached to the ribs or fused
he external intercostal muscles. Ventrally and distally these membranes are fused be-
he fleshy portion of the muscle to the broad aponeurosis that serves to ensheath the rectus
and cover the lower part of the abdominal wall (fig. 420). Dorsally the membranes

FIG. 416.—THE INTERCOSTAL MUSCLES.



Transversus abdominis

part attached to the ribs and in part are fused to form a membrane which becomes ad-
to the deep surface of the latissimus dorsi in the thoracic region and to the lumbodorsal
in the lumbar region.

e internal oblique muscle and the transversus abdominis have similar membranous
ngs which are fused to the aponeuroses of origin and insertion of these muscles. The
ranes on the muscles are, however, much more delicate than that of the external oblique.
or less fusion between the two muscles with disappearance of the membranes covering
posing surfaces takes place, especially in the lower part of the abdominal wall. The super-
nuscle fasciæ of the external oblique and the fasciæ of the internal oblique are continued
ie thin *cremasteric fascia* which covers the cremasteric muscle, spermatic cord and testis.

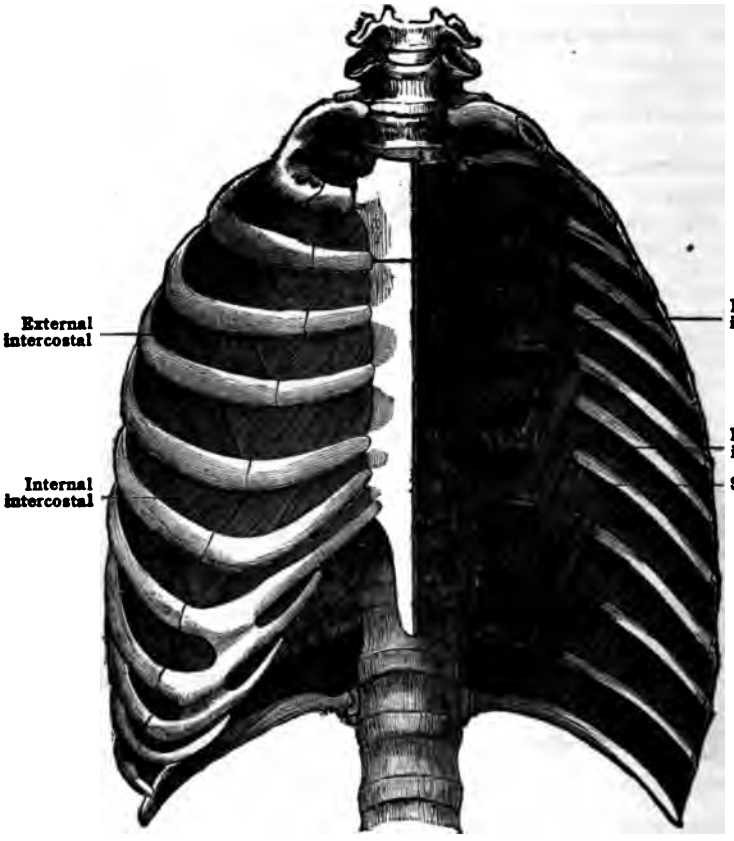
e diaphragm is covered on each surface by a more or less well-marked adherent membrane.

e **transversalis fascia** is a thin membrane which lies external to the peritoneum of the ab-
al wall. It covers the peritoneal surface of the transversus muscle and its aponeurosis.
ally it is continued across the median line internal to the rectus abdominis. In the lum-
gion the fascia divides at the lateral margin of the quadratus lumborum (fig. 415), one
of it passing dorsal to this muscle to be attached to the lumbodorsal fascia. The other
extends over the ventral surface of the quadratus and becomes fused with the psoas

Proximally the transversalis fascia becomes fused with the fascial membrane adherent
diaphragm. In the region of the iliac fossa the transversalis fascia is reflected from the
ersus muscle to the iliopsoas fascia, with which it usually becomes fused. Sometimes,
er, it may be traced as a very delicate membrane over the iliac artery and vein. As
essels pass below the inguinal ligament a process from the transversalis fascia is usually
ed into their sheath.

The sheath of the rectus (figs. 415, 438) is formed externally in the upper portion of its extent by the aponeurosis of the external oblique which fuses below the costal margin with the external layer of the aponeurosis of the internal oblique. In the lower portion of the abdomen this fusion takes place nearer the linea alba than in the upper portion. In the lower third of its extent the rectus is covered ventrally by the fused aponeuroses of the two oblique muscles conjoined with that of the transversus. Internally the rectus is covered in the upper two-thirds of the abdomen by the inner layer of the aponeurosis of the internal oblique conjoined with that of the transversus and by the transversalis fascia. In the lower third of the abdomen the aponeurosis of the internal oblique, together with that of the transversus, passes in front of the rectus, leaving the rectus in this portion of its abdominal surface covered merely by the transversalis fascia and the peritoneum. The line which marks the lower limit of the dorsal ensheathment of the rectus by the aponeurosis of the transversus muscle is called the linea semicircu-

FIG. 417.—THE MUSCLES ATTACHED TO THE BACK OF THE STERNUM.



laris, or fold of Douglas. Between the transversalis fascia and the rectus just above the pubis there is a space filled with loose connective tissue or with fat.

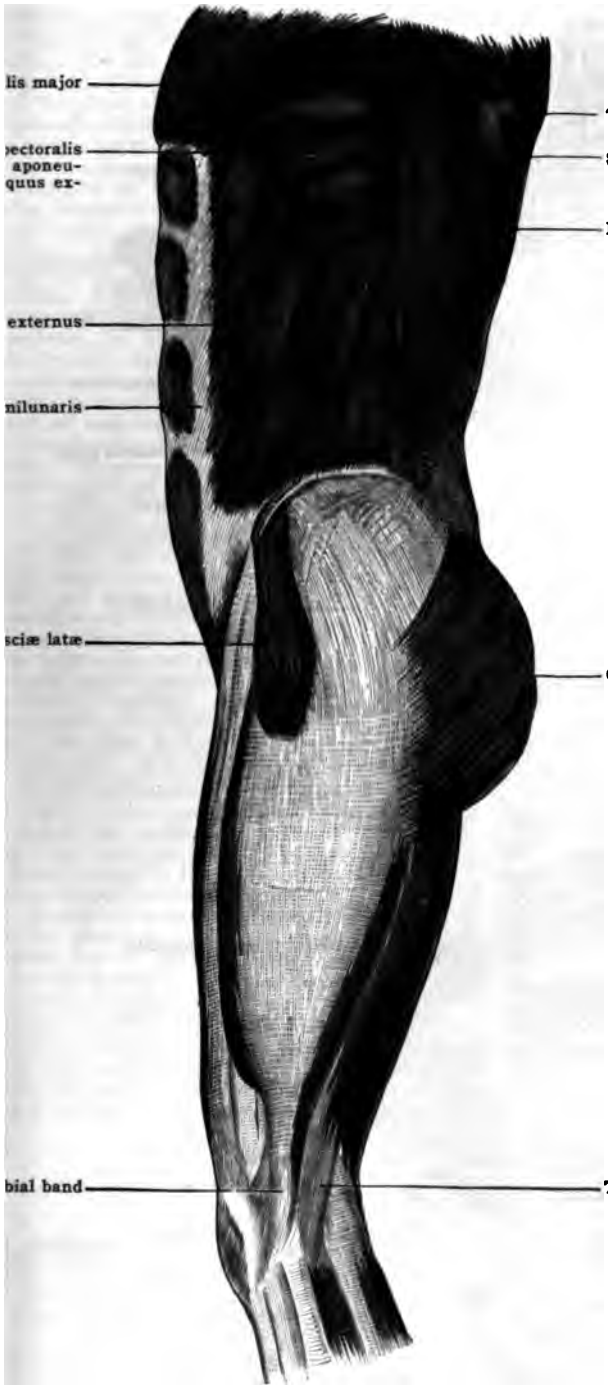
The pyramidalis lies beneath the ventral layer of the sheath of the rectus. From the latter it is sometimes separated by a distinct fascial layer.

Between the rectus muscles of each side the investing aponeuroses are firmly united into a dense tendinous band, the linea alba (figs. 415B, 420). This is broadest opposite the umbilicus. Above this it gradually grows narrower toward the xiphoid process to the ventral surface of which it is attached. Hagenton has shown that the linea alba varies much in width. It is relatively wide in fat people and in fetuses. From the tip of the xiphoid process it is often separated by a bursa. Toward the symphysis pubis it extends as a narrow line. Just above the symphysis it divides to be attached on each side to the tubercle (spine) of the pubis. Behind it broadens into the *adminiculum lineæ albæ* which is attached on each side to the pubis. The linea alba is composed mainly of the interlacing of the fibers which pass into it from the aponeurotic sheaths of the rectus abdominis. From it and Scarpa's fascia, a few centimeters above the symphysis, there arises a broad elastic band, the *fundiform ligament* (superficial suspensory ligament) of the penis, which sends a fasciculus on each side of the penis. Below the penis these fasciculi unite. At the umbilicus there is a circular opening encircled by dense fibrous tissue and filled with a thick connective tissue, extending from the tela subcutanea to the subserosa.

The *ventral layer of the lumbodorsal fascia* and its relations to the abdominal muscles also merit attention. This lies between the intrinsic dorsal musculature and the quadratus lumborum muscle and extends from the twelfth rib to the iliolumbar ligament. It is strengthened by the lumbocostal ligament, which extends between the transverse processes of the first and

ar vertebræ and the twelfth rib, and by fibrous processes which extend into it sverse processes of the lumbar vertebræ to which it is attached. With the lateral s ventral layer the dorsal layer of the lumbodorsal fascia is fused. The dorsal f the transversus muscle is united to the lumbodorsal fascia at the line of junction l and dorsal layers. The internal oblique muscle, covered externally by a fascia

FIG. 418.—SUPERFICIAL MUSCULATURE OF ABDOMEN AND THIGH.

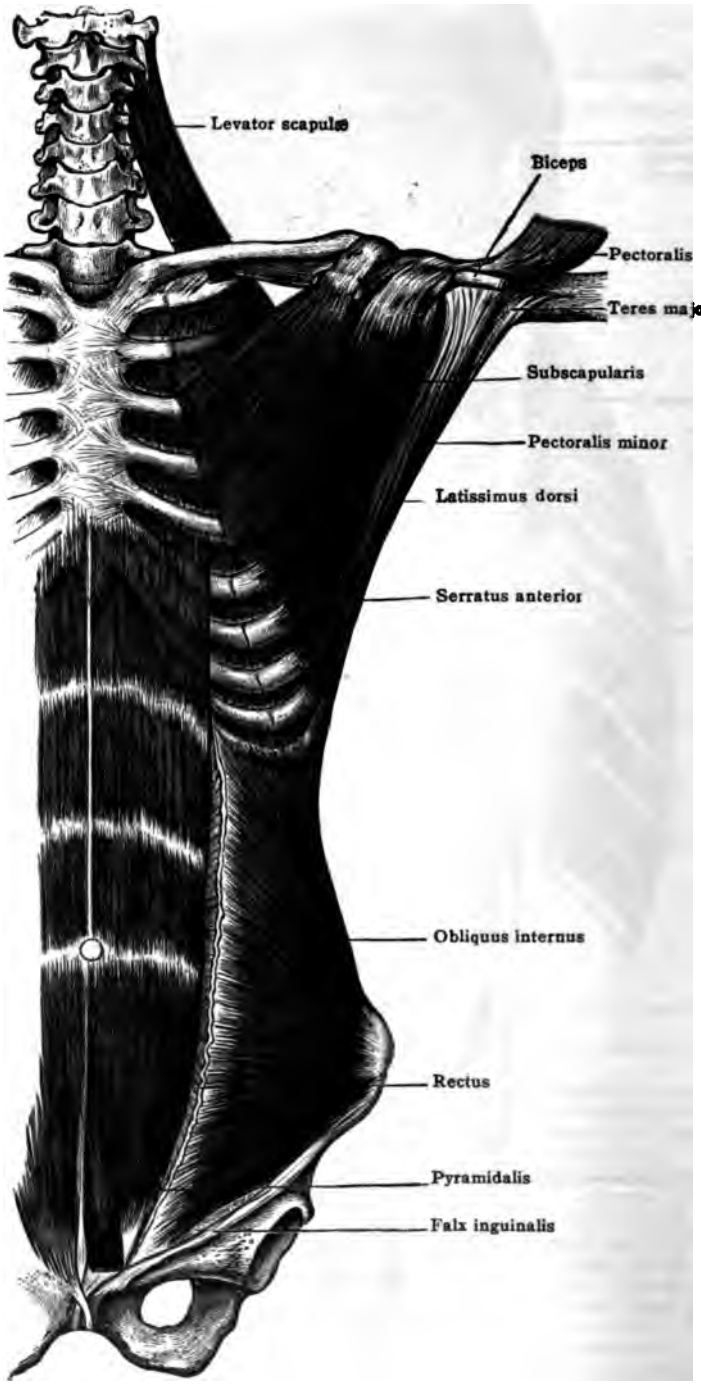


sally from the external oblique, arises in part from the dorsal layer of the lumbo-
ear the junction of the two layers.

al ligament (Poupart's ligament) (figs. 418, 420, 421, 1109) is a strong band which the lower margin of the aponeurosis of the external oblique from the anterior-spine to *the pubic tubercle.* *Internally* the iliac fascia is fused to it. Distally

the fascia lata of the thigh is attached to it. The deeper lateral abdominal muscles in part arise from it. Medially near the attachment of the ligament to the pubic tubercle (spine) diverging fibers are given off which pass inward and upward to the pecten (crest) of the pubis and give rise to the triangular **lacunar ligament** (Gimbernat's ligament). This is fused with the

FIG. 419.—THE PECTORALIS MINOR, OBLIQUUS INTERNUS, PYRAMIDALIS, AND RECTUS ABDOMINIS.



fascia of the pectineus muscle and bounds the femoral ring. Above **the inguinal ligament near** its medial extremity lies the external opening of the inguinal canal, **the subcutaneous (external) inguinal ring** [annulus inguinalis subcutaneus]. This opening **is formed by the diverging of the** lower medial fibers which compose the aponeurosis of the **external oblique muscle. The** upper fibers form the upper boundary, superior crus, of the ring **and pass to the front of the**

s pubis. The inferior fibers form the inferior boundary, *inferior crus*, of the ring and
e pubic tubercle (spine). Between these two fiber-bands *intercrural* (intercolumnar)
about the lateral boundary of the ring and serve to strengthen the anterior and infe-
of the inguinal canal. Some of the fibers of the superior crus, intermingled with other
s to the opposite side of the body and are inserted into the tubercle (spine) and
he pubis and into the superior crus of the opposite side. The structure thus formed
he **reflected inguinal ligament** (Colles's ligament, or triangular fascia).

al canal [canalis inguinalis].—This term is applied to the slit in the lower margin of
minal wall through which, in the male, the spermatic cord passes, and in the female, the
m teres. It is not a true canal. The inner end begins at the (internal) **abdominal**
ulus inguinalis abdominalis] (fig. 1108). This is situated just above and slightly medial
ddle of the inguinal (Poupart's) ligament. Below the ligament in this region lies the
anal through which the femoral vessels pass into the thigh. The (internal) abdominal
vered by the peritoneum and the transversalis fascia. The latter here sends a shallow
e extension outward to be attached to the spermatic cord. The base of this funnel-
ession toward the inguinal (Poupart's) ligament is formed by a thickened band of
e *tractus iliopubicus*. Medially and laterally the bundles of fibrous tissue which con-
is tract spread out fan-like, medially over the sheath of the rectus and toward the
terally over the transversus muscle and toward the crest of the ilium. The trans-
lominal muscle arises from the inguinal ligament nearly as far as the lateral margin of
minal ring. The fiber-bundles of this portion of the muscle course ventralward above
of the funnel mentioned above and are inserted by tendons forming a more or less
aponeurosis, the 'conjoined tendon' [falx inguinalis], common to it and the internal
nto the ventral sheath of the rectus abdominis muscle, into the tubercle, crest and
the pubis and sometimes into the pectineal fascia or the lacunar (Gimbernat's)
. Tendinous bands from the transversalis muscle curve downward medial to the
abdominal ring and help to strengthen the transversalis fascia here. These bands
e the *interfoveolar ligament* [ligamentum interfoveolare, Hesselbachi]. The fibrous
nstituting this ligament are attached to the lacunar ligament and the pectineal fascia.
the abdominal ring the spermatic cord (or in the female the ligamentum teres) passes
d and foward in a space (inguinal canal) about 4 cm. long and then through the sub-
s (external abdominal) ring which has been described in connection with the inguinal
. The ventral wall of the inguinal canal is composed of the aponeurosis of the external
the intercrural fibers, and the cremaster muscle. Laterally it is also covered by the
ortions of the internal oblique and transversus muscles. The caudal wall or floor of
is formed chiefly by the lacunar (Gimbernat's) ligament and laterally also by the ilio-
ct. Cranialward the lateral part of the space is covered by the transversus and internal
nuscles, the medial part by the cremaster muscle. The dorsal (internal) wall is formed
y the transversalis fascia. Medially the lacunar (Gimbernat's) ligament and the con-
endon (falx inguinalis), when this is well developed, help to form the dorsal wall.
o these structures the dorsal wall is thinner but may be strengthened by a well developed
tract. Near the (internal) abdominal ring it is strengthened by the interfoveolar
, and sometimes by muscle slips (interfoveolar muscle).

minal fossæ in the inguinal region (cf. fig. 923).—The hernias so frequent in this region
special study of the inner surface of the abdominal wall of considerable practical im-
. Medial to the abdominal (internal) inguinal ring the inferior internal epigastric
ive rise to a slight fold (*plica epigastrica*) which slants medialward and upward toward
is muscle. From the lateral margin of the tendon of insertion of the rectus muscle
oward the umbilicus over the obliterated umbilical artery there extends a better marked
plica umbilicalis lateralis. Lateral to the plica epigastrica lies the **fovea inguinalis**
with the abdominal inguinal ring. Between the plica epigastrica and the plica
lis lateralis lies the **fovea inguinalis medialis**. In the latter region the fascia trans-
which here forms the inner wall of the inguinal canal is strengthened by two longitudinal
ands belonging to the aponeurosis of the transversalis muscle and described above, the
olar ligament at the medial side of the (internal) abdominal ring, and the falx inguina-
oined tendon) lateral to the rectus muscle. These bands vary in width. When they are
he part of the internal wall of the inguinal canal covered merely by the thin transversa-
and the peritoneum is relatively large and, since this region lies behind the subcuta-
xternal abdominal) ring, opportunity is offered for direct inguinal hernia.

MUSCLES

A. Ventral Division

rectus abdominis (fig. 419).—*Origin.*—Ventral surface of the fifth to seventh costal
s, the xiphoid process, and the costoxiphoid ligament.

tion.—The upper border of the body of the pubis and the ventral surface of the
sis. (The origin and insertion are often described as reversed.)

ture.—The muscle is long, flat, and somewhat triangular in form. Cranialward it is
nd thin; caudalward it becomes thicker as it converges toward the insertion. The
ndles of the muscle have a longitudinal course. It is crossed by several incomplete,
transverse tendinous bands, **inscriptiones tendineæ**, better developed on the ventral
the dorsal surface of the muscle and intimately united to the ventral sheath of the rectus.
hese, corresponding segmentally to the tenth rib, is usually situated opposite the um-
Another, corresponding to the ninth rib, is situated midway between this and the lower
of the thoracic wall, and one corresponding to the seventh rib is found at the level of the
process. Between *this and the one corresponding* to the ninth rib an additional inscrip-

tion is frequently found. Below the umbilicus an inscription corresponding with the eleventh rib is often found (30 per cent.). In these inscriptions many of the fiber-bundles have their origin and insertion. The thoracic attachments take place by means of band-like fasciculi which extend upward from the highest inscription, the fiber-bundles of these fasciculi being inserted by short tendinous bands. The pubic attachment of the muscle takes place by a short, thick tendon, usually divisible into two portions, of which the broader, lateral portion is inserted into a rough area extending from the pubic tubercle (spine) to the symphysis, while the more slender medial portion is attached to the fasciæ in front of the symphysis pubis, where its fibers interdigitate with those of the opposite side. In addition to the attachments mentioned, some of the fiber-bundles are attached to the sheath of the rectus and many, after interdigitating, terminate in the intramuscular framework.

Nerve-supply.—The anterior branches of the six or seven lowermost intercostal nerves enter the deep surface of the muscle near its lateral edge. The cutaneous branches pass obliquely through its substance, while the muscular branches give rise to an intramuscular plexus. As a rule, the chief ventral branch of the tenth thoracic nerve enters the substance of the muscle slightly below the umbilical transverse inscription. The branches of the eleventh and twelfth nerves enter at a lower level. The main branch of the ninth nerve enters slightly below the preumbilical inscription; the eighth nerve, between this and the lower margin of the thorax. Either the sixth or seventh nerve may supply the fasciculi of origin. In addition to the main branches other smaller branches of the nerves of the abdominal wall are also usually distributed to the muscle. Each segment, either directly or through intramuscular plexuses, has a supply from more than one spinal nerve.

Action.—To depress the thorax and flex the spinal column. When the thorax is fixed the rectus serves to flex the pelvis upon the trunk.

Relations.—It lies between the transversalis fascia and the tela subcutanea and is ensheathed by the aponeuroses of the lateral abdominal muscles, as above described. The epigastric artery runs on its deep surface.

Variations.—The rectus muscle varies in the number of its tendinous inscriptions and in the extent of its thoracic attachment. It may extend farther than usual on the thorax. Frequently aponeurotic slips or slips of muscle on the upper part of the thorax indicate a more primitive condition in which the muscle extended to the neck. Absence of a part or the whole of the muscle has been noted. The muscles of the two sides may be separated by a considerable interval in the neighborhood of the umbilicus. The muscle is relatively thicker in men than in women.

The pyramidalis (fig. 419).—*Origin.*—Upper border of the body of the pubis.

Structure and insertion.—The fiber-bundles extend toward and are inserted into the linea alba for about a third of the distance to the umbilicus, and give rise to a flat, triangular belly.

Nerve-supply.—Usually through a branch of the twelfth thoracic, which may extend into the muscle through the rectus abdominis. Not infrequently a special branch extends into the muscle from the iliohypogastric or ilioinguinal, or rarely from the genitofemoral.

Action.—To draw down the linea alba in the median line.

Relations.—It lies between two laminæ of the anterior layer of the sheath of the rectus.

Variations.—It is missing in about 16 per cent. of instances (Le Double). Dwight has found it absent in 81 out of 450 males and in 60 out of 223 females dissected at the Harvard Medical School. It may extend upward to the umbilicus or be but very slightly developed. It may be double. In many of the mammals it is missing. It is well developed in the marsupials and monotremes.

B. Lateral Division

1. *Serratus Group* (fig. 411)

The serratus posterior superior.—*Origin.*—By a broad, thin aponeurosis from the ligamentum nuchæ and the spines of the last one or two cervical and the first two or three thoracic vertebræ.

Structure and insertion.—The fiber-bundles take a nearly parallel course downward and lateralward and give rise to a flat belly which ends by four fasciculi on the upper margin of the second to the fifth ribs, lateral to the iliocostalis.

Nerve-supply.—Through branches from the first four intercostal nerves. These nerves give rise to a plexus which passes across the deep surface of the muscle in the middle third between the tendons of origin and insertion.

Action.—To elevate the ribs to which the muscle is attached, and through them to enlarge the thorax.

Relations.—It lies upon the wall of the thorax and the intrinsic dorsal musculature and beneath the levator scapulæ, rhomboids, serratus anterior, and trapezius. Its fasciculi extend on the ribs to those of the serratus anterior (magnus).

The serratus posterior inferior.—*Origin.*—Through an aponeurosis, fused medially and inferiorly with the lumbodorsal fascia, from the last two or three thoracic and first two or three lumbar spines.

Structure and insertion.—From the aponeurosis arise four flat bands which are successively attached to the inferior margins of the last four ribs, lateral to the iliocostalis.

Nerve-supply.—From the ninth to eleventh intercostal nerves arise branches which form a plexus that extends across the deep surface of the muscle in the middle third between the tendons of origin and insertion.

Action.—To draw outward the four lower ribs and through them to enlarge the thorax. Together with the serratus posterior superior and the connecting aponeurotic fascia it aids in keeping the intrinsic dorsal muscles in place.

Relations.—It lies upon the intrinsic dorsal musculature, the lower dorsal part of the thorax and the lumbodorsal fascia, and beneath the latissimus dorsi, the trapezius, and their aponeuroses.

Variations.—The fasciculi of both muscles vary in number and may be replaced by aponeurotic slips. Aberrant muscle fasciculi, **supracostales posteriores**, may be found in the fascia which connects the two muscles. In several of the lower mammals the two muscles are normally continuous.

2. *External Oblique Group*

The intercostales externi (fig. 416).—These muscles extend in the intercostal spaces from the tubercles of the ribs to the costal cartilages. The intermediate muscles do not, however, often quite reach the cartilages. The first intercostal muscle may extend to the sternum. The others are continued through the intercostal region by thin aponeuroses, the **external intercostal ligaments**, the fibers of which have a direction corresponding to that of the muscle fiber-bundles. Dorsally the muscles are fused with the levatores, and ventrally the lower seven muscles are more or less fused with the corresponding fasciculi of the external oblique.

Origin.—From the lower margin of each rib external to the costal sulcus.

Structure and insertion.—The fiber-bundles take a parallel course obliquely forward and downward to the upper margin of the next rib. The proximal fiber-bundles are more oblique than the distal, and the muscles are best developed in the dorsal part of the intercostal spaces.

Nerve-supply.—By several branches from the corresponding intercostal nerves.

Action.—To elevate the ribs and enlarge the thorax. Acting on one side, they abduct toward that side and rotate toward the opposite side.

Relations.—They are covered externally by the pectoral muscles, the serratus anterior, and serrati posteriores, the levatores costarum, the sacrospinalis (erector spinæ), and the external oblique muscles. Internally they are separated by a slight amount of loose tissue from the internal intercostals, the membranes which continue these muscles medially, and from the subcostal muscles.

Variations.—When the twelfth rib is very small or is lacking, the eleventh intercostal muscle may be missing. When there is a supernumerary cervical or thirteenth thoracic rib, there may be an extra external intercostal muscle. Next to the first intercostal, the fourth most frequently reaches the sternum.

The levatores costarum (fig. 414).—These consist of a series of flat, triangular muscles, each of which *arises* from the tip and inferior margin of a transverse process and extends laterally with diverging fiber-bundles to be *inserted* into the dorsal surface of the rib below, from the tubercle to the angle. The first extends from the transverse process of the seventh cervical vertebra to the first rib. They increase successively in size from this to the last, which is attached to the twelfth rib. Those arising from the transverse processes of the eighth to the eleventh thoracic vertebræ send their more medial fiber-bundles across the rib below to join the lateral margin of the succeeding muscle (levatores longi). The levatores costarum are closely united to the external intercostals and are innervated by the intercostal nerves of the corresponding intercostal spaces. The first muscle is innervated by the eighth cervical nerve.

Action.—To bend laterally and extend the spinal column, and to rotate it toward the opposite side.

Relations.—They are covered dorsally by the longissimus dorsi and the iliocostalis.

Variations.—The first levator may be continued into the scalenus posterior. When greatly developed, the series of levators forms a serrate muscle.

The obliquus abdominis externus (fig. 418).—*Origin.*—By eight fleshy digitations from the external surface of the lower eight ribs immediately lateral to where they join the cartilages. The first five slips interdigitate with the serratus anterior (magnus), the last three with the latissimus dorsi.

Insertion.—(1) By a strong aponeurosis which extends over the rectus to the linea alba, where the more superficial fibers interdigitate across the median line, and to the inguinal (Poupart's) ligament; and (2) directly into the outer lip of the crest of the ilium. The aponeurosis over the rectus is usually partly fused with the aponeurosis of the internal oblique.

Structure.—The fiber-bundles which compose the flat fasciculi of origin diverge slightly as they pass forward and downward, and by fusion of their edges give rise to a flat sheet of muscle. The fasciculus taking origin from the fifth rib passes nearly directly ventrally, but the succeeding fasciculi incline somewhat downward, those from the seventh to the ninth ribs showing the greatest downward inclination. The lower margin of the fasciculus which arises from the seventh rib terminates opposite the umbilicus, that from the ninth rib extends toward the anterior superior spine of the ilium, and those from the last three ribs descend to the iliac crest. The first two fasciculi extend over the lateral margin of the rectus, the next two to its lateral edge. The fourth and fifth usually terminate along a line extending ventrally from the anterior superior iliac spine toward the rectus.

Nerve-supply.—The external oblique is supplied by rami from the lateral branches of the lower seven intercostal nerves and usually from the iliohypogastric as well. The rami of the first two or three nerves usually extend on the external surface of the muscle, while the others extend on the deep surface of the muscle as the cutaneous branches are passing through it toward the skin. The nerves of the external oblique take a more transverse direction than the fasciculi of the muscle. Thus the branch from the tenth intercostal nerve extends toward the umbilicus and that of the twelfth toward a point midway between the umbilicus and the symphysis pubis. The nerves have a segmental distribution corresponding with the primitive segmental condition of the muscle.

Action.—(1) To compress the abdomen; (2) to depress the thorax; (3) to flex the spinal column; and (4) to rotate the column toward the opposite side. With the thorax fixed it serves to flex and rotate the pelvis.

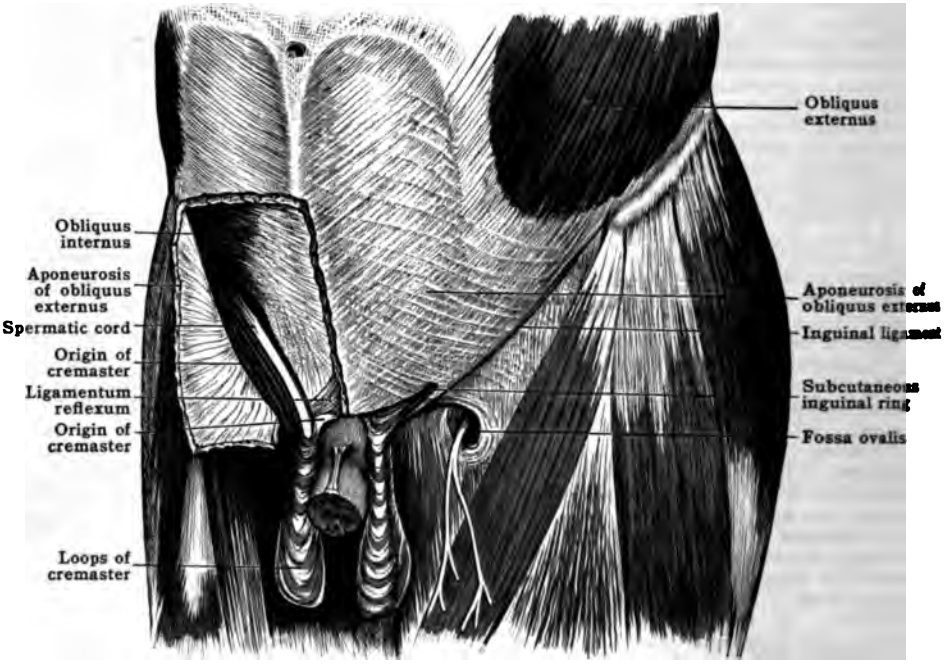
Relations.—It lies superficial to the lower ventrolateral margin of the thorax and the internal oblique muscles. It is partly covered by the latissimus dorsi muscle behind. Otherwise it is subcutaneous.

Variations.—It may have a more or less extensive origin from the ribs. Broad fasciculi not infrequently are separated by loose tissue from the main belly of the muscle either on its deep or superficial surface. Occasionally tendinous inscriptions are found. These transverse inscriptions are constant in many of the smaller mammals. The **supracostalis anterior** is a rare fasciculus sometimes found on the upper portion of the thoracic wall. It is usually supplied by branches of the upper thoracic nerves and seems to be a continuation upward of the external oblique muscle. In some prosimians the external oblique extends normally to the first or second rib.

3. *Internal Oblique Group*

The intercostales interni (figs. 416, 417, 419).—These extend in the intercostal spaces from the angles of the ribs to the sternal ends of the spaces. The upper and lower muscles are usually continued dorsally slightly beyond the angles of the ribs, while the intermediate muscles frequently do not quite reach them. Dorsomedially the internal intercostals are continued in the form of thin fascial sheets across the inner surface of the external intercostals and become fused with the subcostals.

FIG. 420.—STRUCTURES OF INGUINAL REGION.



Origin.—Near the angles of the ribs they arise from the internal lip of the costal sulcus. More ventrally they arise mainly from the external lip of the sulcus, but also in part from the internal lip.

Structure and insertion.—The fiber-bundles take a parallel course downward and dorsalward to the upper margin of the rib below. They are less obliquely placed than those of the external intercostals. The muscles are thicker in front and grow thinner dorsally. They contain less fibrous tissue than the external intercostals.

Nerve-supply.—From numerous branches of the corresponding intercostal nerves.

Actions.—Investigators disagree as to the functions. It is probable that the portions of the muscles between the ribs contract, those between the costal cartilages expand, the thorax.

Relations.—Between the ribs they are covered by the external intercostal muscles and between the costal cartilages by the external intercostal ligaments. Between the internal and external muscles there is some loose areolar tissue. Proximally, for a short distance, the intercostal nerve in each interspace runs between the external and internal intercostal muscles, but more distally it runs first in the substance of and then on the internal surface of the internal intercostal. Eisler distinguishes that portion of the internal intercostal muscle which lies external to the nerve as the intercostalis intermedius, that which lies internal as the true internal intercostal. The terminal branches of the first six nerves, however, pass through the muscle on their way to the skin, while the last six pass beneath the inferior margin of the thorax. Internal to the internal intercostal muscle lie the transversus (triangularis sterni) and subcostal muscles, the diaphragm, and the pleural membranes. The more distal internal intercostal muscles are continuous with the internal oblique and the subcostal muscles.

Variations.—The tenth and eleventh internal intercostal muscles normally are but slightly developed and often may be wanting. The internal intercostals of the first three spaces may extend to the vertebræ.

The subcostales (figs. 416).—These muscles are due to an extension over two or more intercostal spaces of those fiber-bundles of the internal intercostal muscles which lie in the proximal part of the interspaces. They arise near the angles of the ribs, and are usually well developed only in the lower part of the thorax. The component fiber-bundles keep the general direction of the internal intercostals, but they converge toward the tendons of insertion, which are attached in each case to the second or third rib below, between the angle and the neck.

Nerve-supply.—The main nerve of supply for each muscle comes from the intercostal nerve running below the rib from which the muscle takes origin.

Action.—To depress the ribs and contract the thorax.

Relations.—They lie on the inner side of the internal and external intercostals and the ribs, and are covered by the pleural membranes.

Variations.—They vary much in development. Next to the lower fasciculi, the fasciculi in the cranial part of the thorax are those usually best developed.

The obliquus abdominis internus (fig. 419).—*Origin.*—From the lumbodorsal fascia the intermediate lip of the ventral two-thirds of the iliac crest, and the lateral half of the inguinal ligament.

Structure and insertion.—From the origin the fiber-bundles radiate forward in a flat sheet. The most dorsal extend to the lower three ribs, where they become continuous with the internal intercostals. The rest extend toward the lateral margin of the rectus, the upper ones toward the xiphoid process, the intermediate toward the umbilicus, the lower ones somewhat obliquely downward across the lower part of the abdomen. The fiber-bundles which extend toward the rectus terminate in an aponeurosis which in its upper two-thirds divides into two layers, one of which passes in front of and the other behind the rectus muscle to the linea alba. In the lower third the aponeurosis passes as a single membrane in front of the rectus. In the neighborhood of the subcutaneous inguinal (external abdominal) ring the muscle is continued into the cremaster. Medial to the ring some fasciculi are attached to the tubercle of the pubis and to the symphysis.

Nerve-supply.—From branches of the last three intercostal and the iliohypogastric, ilioinguinal and genitofemoral (?) nerves as these pass between this muscle and the transversus.

Action.—To depress the thorax, flex the vertebral column, and bend and rotate it toward the side on which the muscle is placed. When the thorax is fixed, the muscle serves to flex and rotate the pelvis.

Relations.—It lies between the external oblique and the transversus. The **trigonum lumbale** (triangle of Petit) is an area, variable in size, between the posterior margin of the external oblique, the lateral margin of the latissimus dorsi, and the crest of the ilium. In this area the internal oblique is subcutaneous.

Variations.—The attachments and the extent of development of the fleshy part of the muscle vary considerably. Occasionally tendinous inscriptions are found in the muscle which indicate a primitive segmental condition.

The cremaster (fig. 420).—The cremaster muscle is found well developed only in the male. It represents an extension of the lower border of the internal oblique muscle and possibly also of the transverse over the testis and spermatic cord.

Origin.—(1) Lateral, thick and fleshy, from about the middle of the upper border of the inguinal ligament, and (2) medial, thin and tendinous, from the sheath of the rectus muscle and the tubercle (spine) of the pubis.

Structure.—The lateral head is applied to the lateral side, the medial head to the medial side, of the spermatic cord. Both pass with this through the subcutaneous (external abdominal) ring of the inguinal canal and become spread in loops over the testis. Ensheathing the muscle and between the somewhat scattered fiber-bundles which compose it, there extends a thin membranous layer of connective tissue, the **cremasteric (Cowper's) fascia.**

Nerve-supply.—The genital nerve (external spermatic), usually joined by a ramus from the ilioinguinal nerve, gives rise to branches which spread over the muscle.

Action.—To lift the testis toward the subcutaneous inguinal (external abdominal) ring.

Relations.—It is covered by the aponeurosis of the external oblique, the cremasteric fascia, the dartos, and the skin. It covers the spermatic cord and the testis.

Variations.—In the female the muscle is represented by a few fasciculi on the round ligament. It may arise wholly from the transversalis fascia or be somewhat fused with the transversus muscle. The latter condition is especially frequent in muscular individuals.

4. *Transversus Group*

The transversus thoracis (triangularis sterni) (fig. 416).—*Origin.*—By aponeurotic bands from the dorsal surface of the lower half of the body of the sternum and the xiphoid process.

Structure and insertion.—The muscle is composed of several flat, thin fasciculi, partly fibrous, more or less isolated, which are inserted by aponeurotic bands into the dorsal surface of the cartilages of the second or third to the sixth ribs, and occasionally also into the tips of the bony portions of the ribs. The lower fasciculus is closely related to the cranial margin of the transversus abdominis.

Nerve-supply.—By rami from the ventral portions of the second to the sixth intercostal nerves. These nerves give rise to a longitudinal plexus across the deep surface of the muscle near the middle of the constituent fasciculi.

Action.—To depress the ribs in expiration.

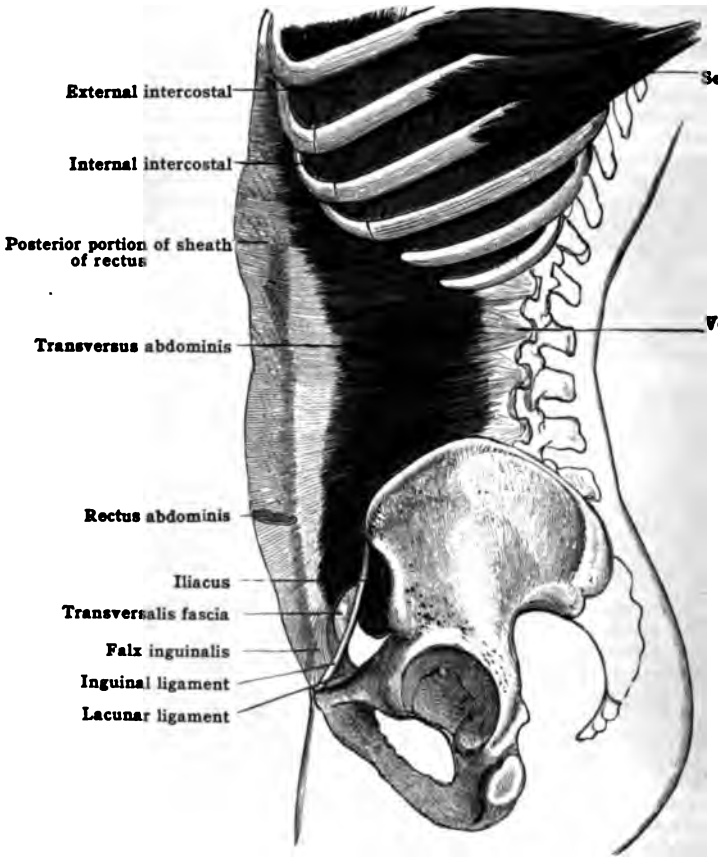
Relations.—The sternum, the costal cartilages, internal intercostal muscles, and the internal mammary vessels lie in front and the pleura and pericardium behind the muscle.

Variations.—It is an exceedingly variaole muscle, both in the extent of its attachment and in the development of the individual fasciculi. The fasciculi vary in number from one to six. With this muscle Eisler would class the subcostal muscles and those portions of the internal intercostal muscles which lie internal to the intercostal nerves.

The transversus abdominis (figs. 417, 421).—*Origin.*—Directly from—(1) the inner side of the cartilages of the lower six ribs by dentations which interdigitate with the attachments of the diaphragm; (2) the internal lip of the iliac crest and lateral half of the inguinal ligament; and (3) through an aponeurosis from the lumbodorsal fascia.

Structure and insertion.—The fiber-bundles give rise to a broad, thin belly and take a nearly transverse course across the inner side of the abdominal wall. The lowermost fibers, however, are inclined obliquely toward the pubis. The fleshy portion of the muscle terminates in a strong aponeurosis along a curved line, which extends above well under the rectus and emerges lateral to the rectus opposite the umbilicus, whence it extends toward the middle of the inguinal ligament. In the upper two-thirds of the abdomen the aponeurosis extends behind the rectus

FIG. 421.—TRANSVERSUS ABDOMINIS AND SHEATH OF RECTUS.



to the linea alba and fuses with the inner lamina of that of the internal oblique. In the lower third of the abdomen it extends in front of the rectus to the linea alba, and is here also fused with the aponeurosis of the internal oblique. Some of the fibers are continued into the aponeurosis of the muscle of the opposite side. The lower attachment of the muscle is somewhat more complex. The fiber-bundles here bend around the spermatic cord, on the medial side of which they are spread out to be attached to the lacunar (Gimbernat's) ligament and pectineal fascia, the pubis, and the sheath of the rectus. The attachment to the lacunar ligament and pectineal fascia takes place by means of an aponeurotic band, the more lateral fibers of which are dense and curve below the spermatic cord to the lacunar ligament and the pectineal fascia below this. This band is called the interfoveolar ligament. It is composed partly of bundles of fibers prolonged from the aponeurosis of the opposite transversus, and bounds the abdominal ring medially and below. Medially the transversus is united to the upper part of the os pubis, and to the sheath of the rectus by an aponeurotic band, the falx inguinalis (conjoined tendon). Between the interfoveolar ligament and the falx inguinalis the transversalis fascia forms the posterior wall of the inguinal canal. In this area a detached band of muscle-fibers is sometimes found. This is called the musculus interfoveolaris.

Nerve-supply.—The transversus is supplied with nerves by the last five or six thoracic and the iliohypogastric, ilioinguinal and genitofemoral nerves as these course forward between this muscle and the internal oblique.

Action.—The chief function is to compress the abdominal viscera. Through the portions extending between the lower margins of the thorax on each side it serves to contract the thorax and so may aid in expiration.

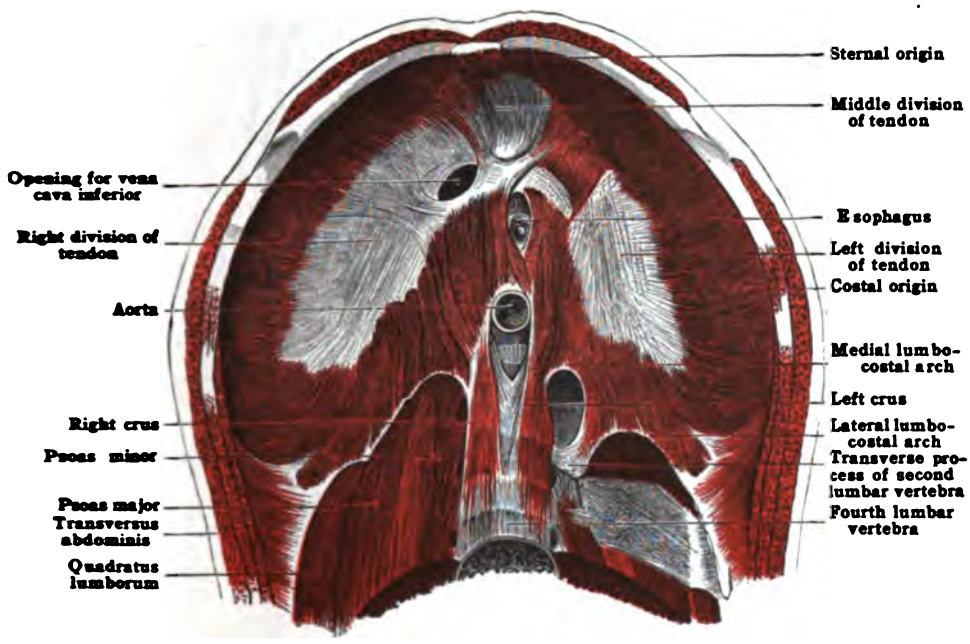
Relations.—It lies on the inner side of the lower ribs, the internal oblique and rectus muscles, and is covered on the deep surface by the transversalis fascia.

Variations.—It is very rarely absent. It shows considerable variation in the extent of its development. The **pubotransversalis** is a small muscle which may extend from the superior ramus of the pubis to the transversalis fascia near the abdominal inguinal ring. The **puboperitonealis** is a similar muscle which may pass from the pubic crest to the transversus near the umbilicus. The **tensor laminæ posterioris vaginæ musculi recti abdominis**, essentially like the preceding, may extend from the inguinal ligament to the rectus sheath on the deep surface of the rectus muscle near the umbilicus. The **tensor laminæ posterioris vaginæ musculi recti et fasciæ transversalis abdominis** likewise extends from the transversalis fascia near the abdominal inguinal ring to the fold of Douglas.

C. Lumbar Muscle

The quadratus lumborum (fig. 437).—*Origin.*—From—(1) the internal lip of the iliac crest near the junction of the middle and dorsal thirds, and the iliolumbar ligament; (2) the transverse processes of the three or four lower lumbar vertebræ; and (3) the lumbodorsal fascia.

Fig. 422.—Diaphragm.



Structure and insertion.—From the origins there arises a complex quadrangular muscle belly from which spring the fasciculi of termination. These extend to—(1) the transverse processes of the upper three or four lumbar vertebræ; (2) to the fiber-bands which extend out laterally in the lumbar fascia from the transverse processes; and (3) to the medial part of the lower border of the twelfth rib.

Nerve-supply.—Through direct branches from the first three or four lumbar nerves.

Action.—It serves primarily to produce lateral flexion of the spinal column. When both muscles act together, they produce extension of the column. The muscle also serves to depress and fix the twelfth rib.

Relations.—It rests posteriorly on the lumbodorsal fascia and the transverse processes of the lumbar vertebræ. Its medial edge is partly covered by the psoas. In front of it also lie the kidney, the intestines, and the lumbar arteries and nerves. It is ensheathed by membranes continued over each surface from the transversalis fascia. Of these, the anterior is the better marked and is called the **lumbar fascia.**

Variations.—There is much individual variation in the internal structure of the muscle and in its attachments. Its insertion may extend to the eleventh rib.

The **psoas major** and **minor** belong essentially to the musculature of the lower limb and are there described (p. 487).

D. The Diaphragm

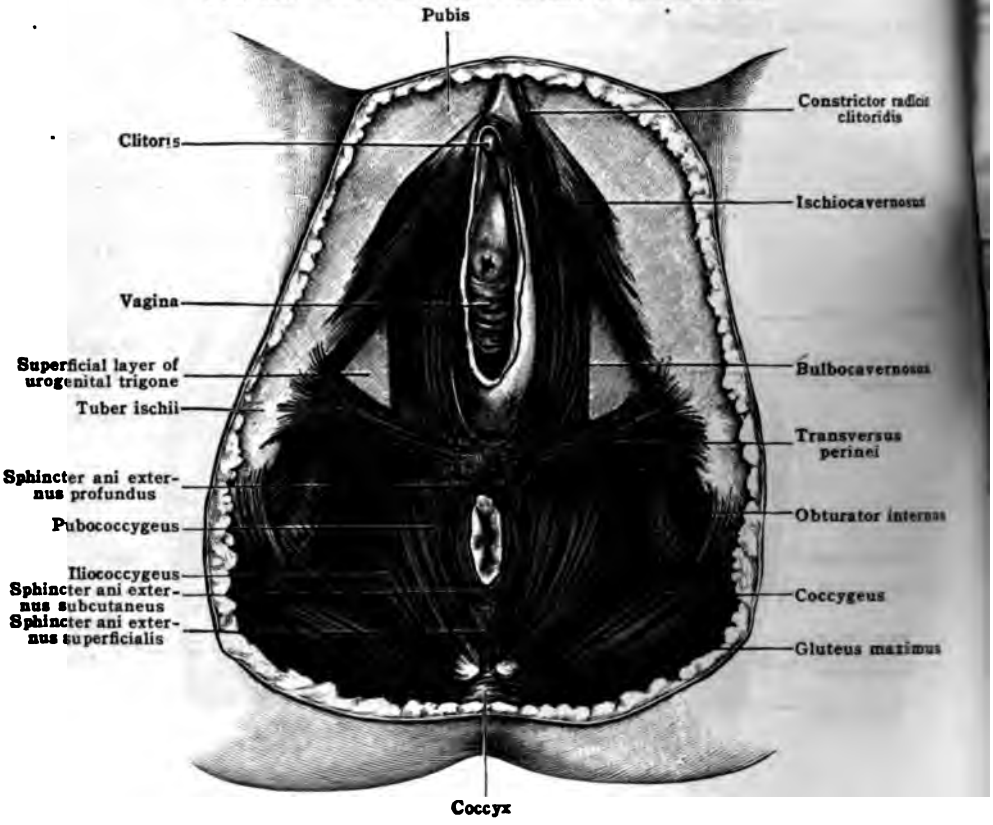
The diaphragm (figs. 417, 422).—This dome-shaped musculomembranous sheet has, when seen from above, something of the outline of a kidney. It consists of a pair of muscles which arise one on each side from the thoracic wall and are inserted into a central tendon. Lateral

to the tendon the diaphragm projects higher into the thoracic cavity than in the central area. On the right, in moderate expiration, it extends in adults to the height of the medial extremity of the fifth rib, and on the left to the fifth interspace.

Origin.—On each side from—(1) the lower border and back of the xiphoid process and the adjacent aponeurosis of the transversus abdominis or from the tendinous arch extending from the tip of the xiphoid process to the cartilages of the fifth and sixth ribs, (*sternal portion*); (2) the lower border and inner surfaces of the cartilages of the seventh and eighth ribs, the cartilages and osseous extremity of the ninth rib and the osseous extremities of the last three ribs (*costal portion*); and (3) from the lumbar vertebræ (*lumbar portion*). The lumbar portion is divided somewhat irregularly into three crura, between which pass blood-vessels and nerves.

The **lateral crus** arises from the lateral surface of the bodies of the first two lumbar vertebræ and from fibrous thickenings of the fascia over the psoas and quadratus lumborum muscles. Of these, one, the **medial lumbocostal arch** (internal arcuate ligament), extends from the body of the second lumbar vertebra to the transverse process of the same vertebra; the other, the

FIG. 423.—THE PERINEAL MUSCLES IN THE FEMALE.



lateral lumbocostal arch (external arcuate ligament), extends from the tip of the transverse process of the second lumbar vertebra to the twelfth rib. The lateral crus is only inconstantly attached to this. The **intermediate crus** arises from the ventrolateral surface of the body of the second lumbar vertebra from the sides of the bodies of the first two lumbar vertebræ and from the intervening disks. The **medial crus** arises from the front of the bodies of the third and the fourth lumbar vertebræ. On the left side it usually extends only to the third vertebra, and it does not always extend to the fourth on the right. The extremity and medial margin of this crus are tendinous, the lateral portion fleshy. On the second, third, and fourth, and the lower part of the first lumbar vertebræ the medial crus of each side is separated from its fellow by the **hiatus aorticus** (for the aorta and thoracic duct). Over the first lumbar vertebra they are fused by a process which extends from the right crus into the lower ventral surface of the left. Above here the right crus may be divided into two parts, one of which, fused with the left crus, passes on the left of the **hiatus esophageus**, while the other passes on the right. Sometimes the hiatus esophageus lies between the right and left crura. Frequently the left crus gives off a slip which passes to the ventral surface of the right below the **hiatus**.

The **costal portion** arises by a series of dentations which do not correspond perfectly in number with the ribs. Some costal cartilages have two dentations attached to them. It interdigitates with the transversus abdominis but in part arises from tendinous arches which bridge the origin of the transversus in the last three interspaces.

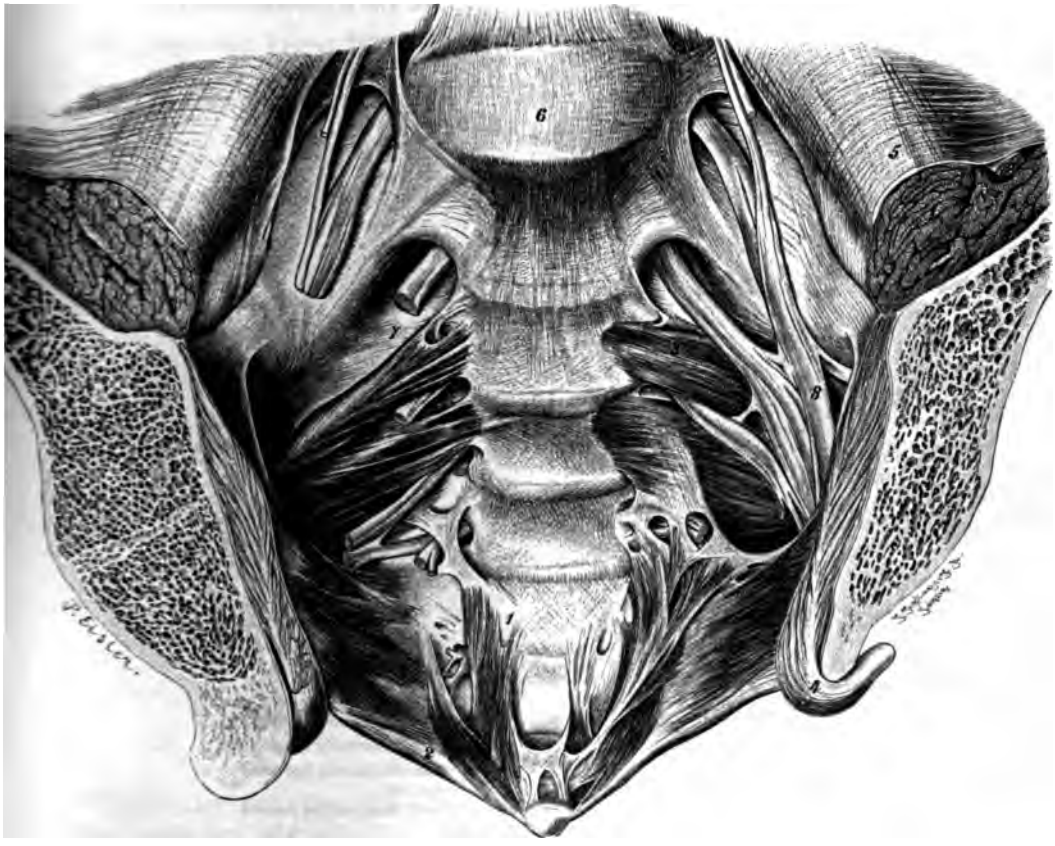
Structure and insertion.—The central tendon has somewhat the shape of a trifoliate leaf, the place of the stem being taken by the region occupied by the vertebral column, one leaflet lying on each side of this and one in front. The ventral part is usually placed somewhat to the

left and is more or less completely fused with the left leaflet. Between the ventral and the right leaflets there is a large opening through which passes the inferior vena cava, the **foramen venæ cavæ**. The leaflets are fused in front and behind this.

The fleshy portion of the muscle is composed of fiber-bundles which pass at first nearly vertically upward and then arch over to be attached to the margins of the central tendon. The sternal portion of the muscle is the shortest. It is often separated from the costal portion by a small space through which the superior epigastric vessels pass.

Nerve-supply.—From the phrenic nerves, one of which arises on each side from the third to the fifth cervical nerves. Each nerve penetrates the diaphragm lateral to the central tendon and breaks up into an extensive plexus on the inferior surface of the muscle. Some of the lower intercostal nerves also contribute to the sensory innervation of the margin of the muscle and possibly also slightly to the motor innervation. The sympathetic nerves furnish fibers for the blood-vessels.

FIG. 424.—VENTRAL COCCYGEAL MUSCLES (After Eisler.)—1. M. sacrococcygeus anterior. 2. M. coccygeus. 3. M. piriformis. 4. M. obturator internus. 5. Fascia iliaca, above the iliopsoas. 6. Fibrocartilago intervertebralis lumbosacralis. 7. Ventral trunk of first sacral nerve. 8. Sacral plexus.



Action.—To enlarge the thoracic cavity and thus cause inspiration. According to R. Fick, however, the diaphragm plays a less important part in inspiration than is usually assumed for it. The middle part of the central tendon is united to the pericardium and through this to the cervical fascia, and is, therefore, not very moveable. In the contraction of the muscle it is the dorsal and lateral portions which in the main are flattened. The diaphragm aids in defecation, parturition and vomiting, by the pressure it exerts on the abdominal viscera. It also acts as a constrictor of the esophagus.

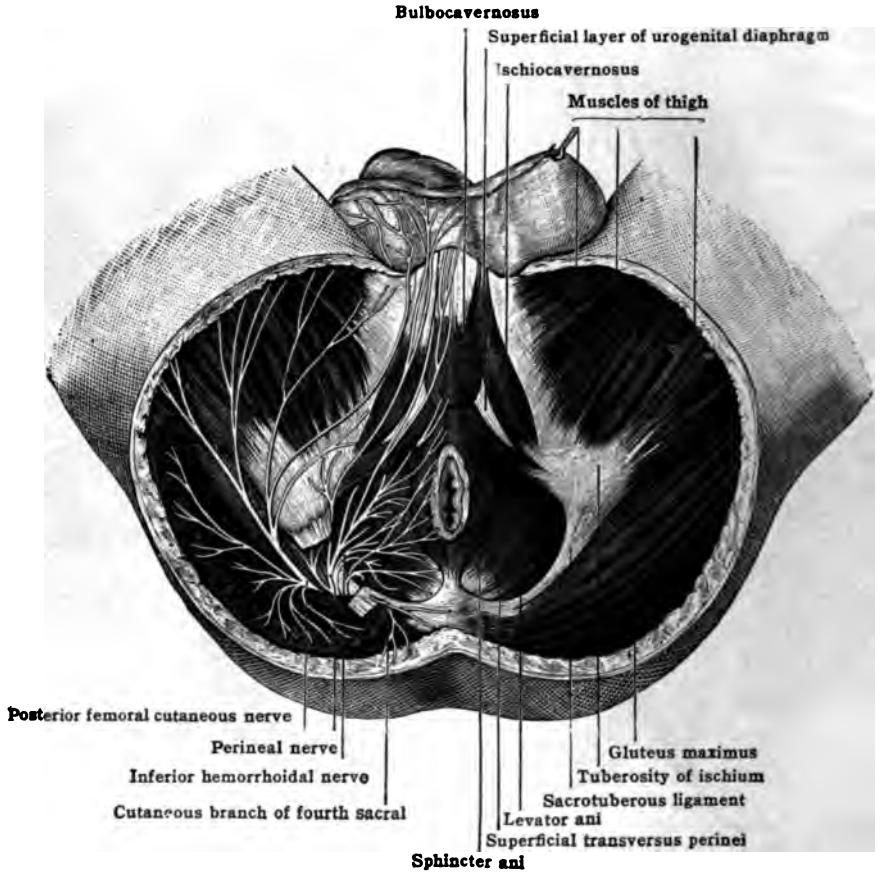
Relations.—Above lie the heart and the lungs; below lie the liver, stomach, duodenum, pancreas, spleen, kidneys, and suprarenal bodies.

Variations.—The sternal portion of the muscle is frequently absent. Infrequently the diaphragm is incompletely developed dorsally on the left side. This condition is rarer on the right side. The extent of the various insertions of the diaphragm shows considerable individual differences. The vertebral portion of the muscle may be slightly fused with the psoas or with the quadratus lumborum. Some fusion of the ventral portion of the muscle with the transversus thoracis has also been seen. Small fasciculi may pass to neighboring structures: the esophagus, stomach, liver, mesentery, etc. Muscle fasciculi are frequently found in the central tendon.

V. MUSCULATURE OF THE PELVIC OUTLET

In order to understand the musculature of the pelvic outlet it is necessary first to consider briefly the structure of the pelvis minor. It is bounded laterally and in front by the ilium below the terminal (iliopectineal) line, the ischium and the pubis, and by the obturator membrane and the sacrospinous (small sciatic), sacrotuberous (great sciatic) and the interpubic ligaments. The pubis, ischium and the obturator membrane are covered by the obturator internus muscle (figs. 423, 432) which here takes its origin and which converges toward and passes through the lesser sciatic notch on its way to its insertion on the great trochanter of the femur. The piriformis muscle (figs. 424, 427), which arises from the sides of the pelvic surface of the sacrum, from the posterior border of the great sciatic

FIG. 425.—THE MALE PERINEUM. (Modified from Hirschfeld and Leveillé.)



notch and the neighboring part of the sacrotuberous (great sciatic) ligament nearly fills up the great sciatic notch on its way to its insertion on the great trochanter. The walls of the pelvis are thus padded by muscles which belong to the limb. The muscles are covered by fascia best developed over the obturator internus muscle as the obturator fascia. The gluteus maximus muscle (figs. 418, 425, 431, 432), which arises from the back of the ilium, the sacrum, and the coccyx, and is inserted into the femur and the fascia of the thigh overlaps to some extent the sacrotuberous ligament, and in the standing position the tuberosity of the ischium so that its lower margin forms an accessory boundary to the pelvic outlet.

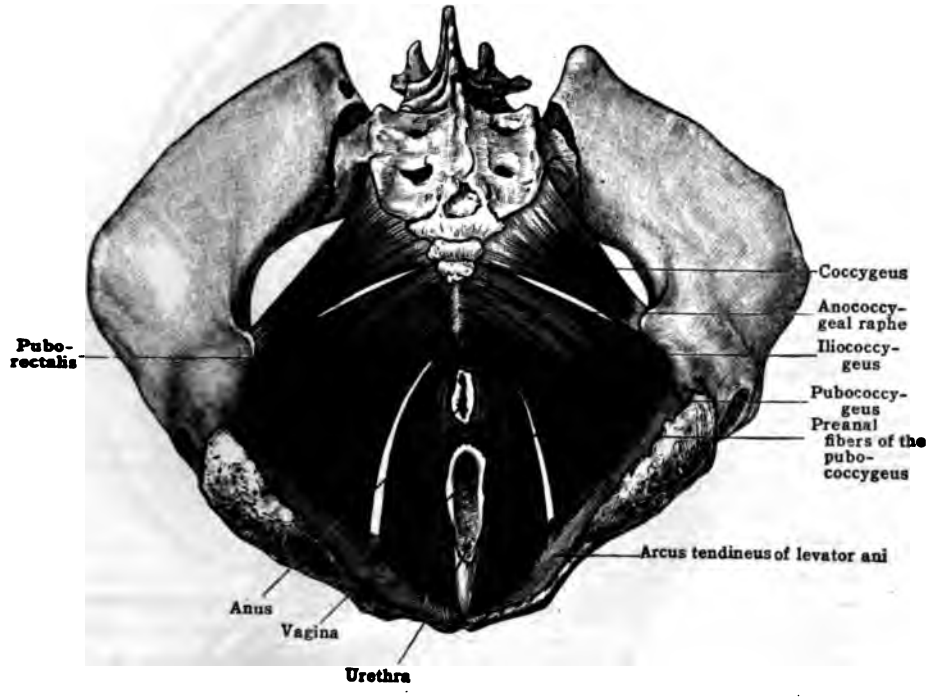
The outlet of the pelvis thus bounded by bone, ligaments and by muscles belonging to the lower extremity presents two triangles (figs. 423, 425), an anterior or urogenital triangle, with the base between the two ischial tuberosities and the apex below the symphysis pubis, and a posterior or rectal with the base between the ischial tuberosities and the apex at the coccyx. The outlet is closed by a

cial musculature forming the pelvic floor and divisible into three groups of mus- and fascia; those of the pelvic diaphragm and anus, those of the urogenital phragm, and those of the external genitalia.

The *pelvic diaphragm* [diaphragma pelvis] extends from the upper part of the vic surface of the pubis and ischium to the rectum which passes through it to be rounded by the external sphincter. The urogenital trigone or *urogenital dia-agm* [diaphragma urogenitale] lies between the ischiopubic rami superficial to pelvic diaphragm and surrounds the membranous urethra and in the female o the vagina. The *external genital* muscles lie superficial to the trigone.

The muscles of the **pelvic diaphragm** are two in number on each side, the coccy-us, and the levator ani (figs. 426–428). The **coccygeus** arises from the ischial pine and is inserted into the lateral margin of the lower sacral and the upper coccygeal vertebræ. It is closely applied to the pelvic surface of the sacro-spinous (small sciatic) ligament. In so far as it is active it flexes and abducts the coccyx.

FIG. 426.—THE PELVIC DIAPHRAGM IN THE FEMALE, FROM BELOW AND BEHIND.

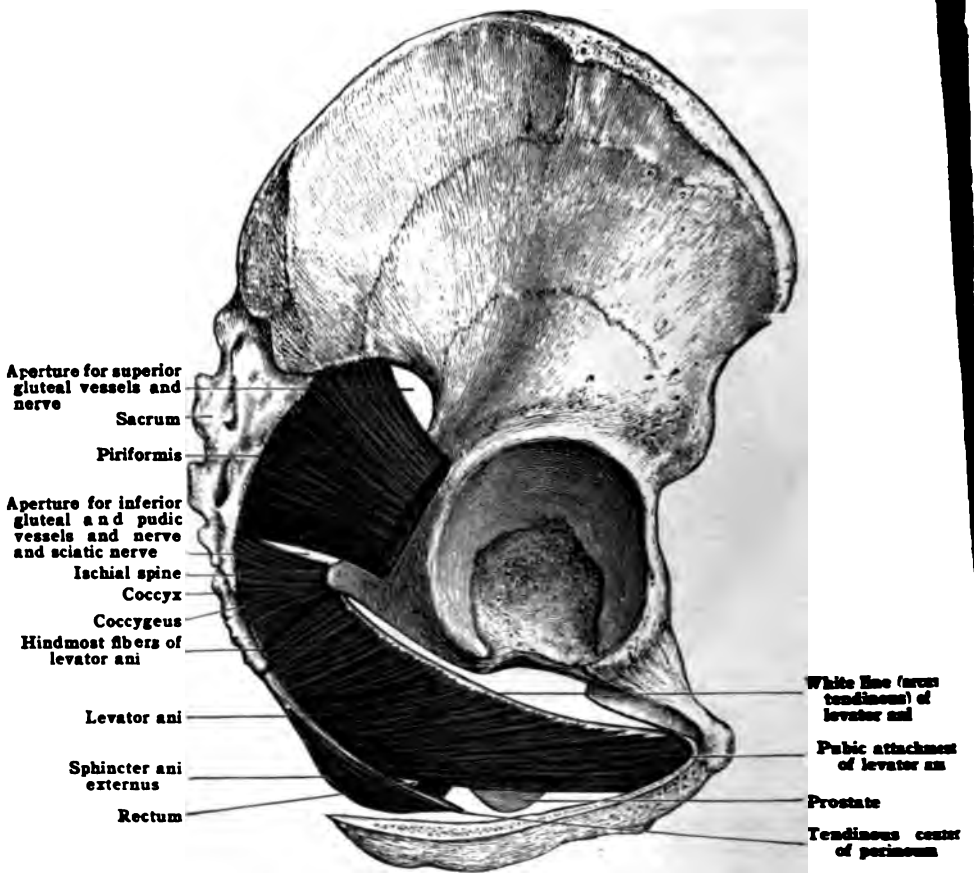


The **levator ani** (figs. 426-428) arises from the inner side of the pubis, along a line extending laterally from the inferior margin of the symphysis to the obturator canal, and from the obturator fascia along a line, the *arcus tendineus*, extending from the pubis to the spine of the ischium. The levator ani is inserted into the median raphé back of the anus, the anococcygeal raphé, into the tip and sides of the coccyx and into an aponeurosis, which is attached to the anterior sacrococcygeal ligament. It is divisible into three portions, a *pubococcygeal*, an *iliococcygeal*, and a *puborectal*. The levator ani muscles of the two sides are separated by a slit which extends from the rectum to the symphysis pubis and in which in the male lie the lower part of the prostate, and the membranous urethra (fig. 427), and in the female the vagina and urethra (fig. 426). Back of the rectum some of the fiber-bundles from the muscles of the two sides interdigitate, while others terminate in the anococcygeal raphé. A few fiber-bundles also interdigitate across the median line, in front of the rectum (pubococcygeal, fig. 426) and some are inserted into the walls of the rectum. The levator ani and coccygeal muscles of the two sides form a funnel-shaped muscular support for the pelvic viscera (fig. 430). When the abdominothoracic diaphragm contracts, as during inspiration, the pressure on the viscera is transmitted to the pelvic diaphragm

which resists the pressure and elevates the viscera when the abdominothoracic diaphragm relaxes. The levator ani muscle also constricts the rectum and pulls it forward and in the female constricts the vagina from side to side.

As it passes through the pelvic diaphragm, the rectum for about two and a half centimeters is surrounded by a special **external sphincter** muscle (figs. 424, 425, 428), divisible into three concentric layers as described below. This muscle, especially differentiated from the primitive sphincter of the cloaca, serves to close the rectum. It is supplemented by a sphincter of smooth muscle which lies immediately beneath the mucous membrane of the anus. It is attached behind to the coccygeus, and in front to the central tendon of the perineum described below.

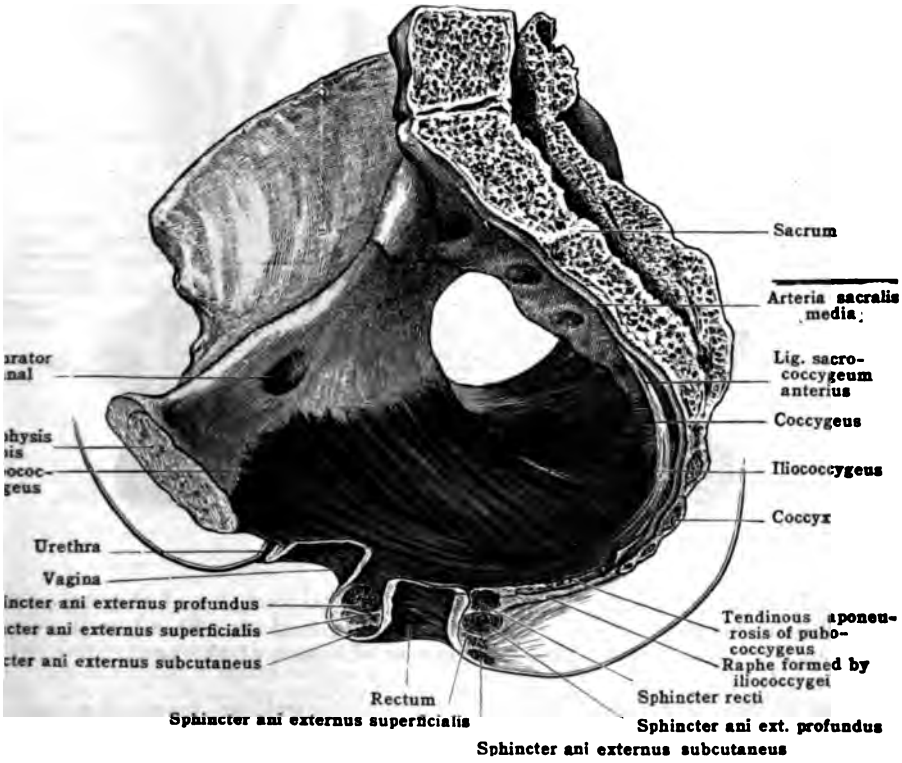
FIG. 427.—LATERAL VIEW OF MUSCLES OF THE FLOOR OF THE PELVIS.
(A portion of the ischial and pubic bones sawn away.)



The lateral origin of the levator ani, as above described and as shown in figs. 427, 428, 430, is considerably above the osseous and muscular margin of the pelvic outlet. The muscles of each side converge toward the postanal region so that a space is left between the lateral wall of the pelvis, and the levator ani and external sphincter (fig. 430). This space, the **ischiorectal fossa**, is filled with fat (figs. 431, 433, 1101). It is deepened laterally by the lower margin of the gluteus maximus muscle (fig. 431). In the fascial canal (Alcock's canal) in the lateral wall of the fossa run the internal pudic (pudendal) vessels and nerves (fig. 432). Above the pelvic diaphragm in the median part of the pelvic cavity are found the bladder, the ampulla of the rectum, and the prostate gland (in the male) or the vagina and uterus (in the female). Laterally on each side there is a subperitoneal space, filled with connective tissue and containing blood-vessels and nerves (fig. 433). Fasciæ invest each surface of the pelvic diaphragm (*diaphragmatic fascia*) and extend about the viscera (*endopelvic fascia*).

he muscular apparatus of the anterior or urogenital triangle of the pelvic it is much more complicated than that of the posterior or rectal triangle just ribed. We have seen that between the levator ani muscles of each side in t of the rectum there is a slit which extends to the symphysis pubis and that gh it, the lower part of the prostate and the urethra extend in the male, the ra and the vagina in the female. Between the ischiopubic rami there is ched a triangular muscular and fibrous membrane, which likewise surrounds urogenital ducts and which serves to strengthen the pelvic wall in this n. This structure is known as the **urogenital diaphragm** (**trigone**) ('triangular ient') (figs. 429, 431, 434). The musculature within it includes two muscles 429), the sphincter urogenitalis (urethræ) and the deep transverse perineal le. The *sphincter* embraces the urethra and associated structures. The onent fiber-bundles arise chiefly from the fibrous tissue in the angle beneath ymphysis pubis, but partly also from the descending pubic rami. They pass

28.—Sagittal Section of the Pelvis to Show the Pelvic Diaphragm and External Sphincter Ani.



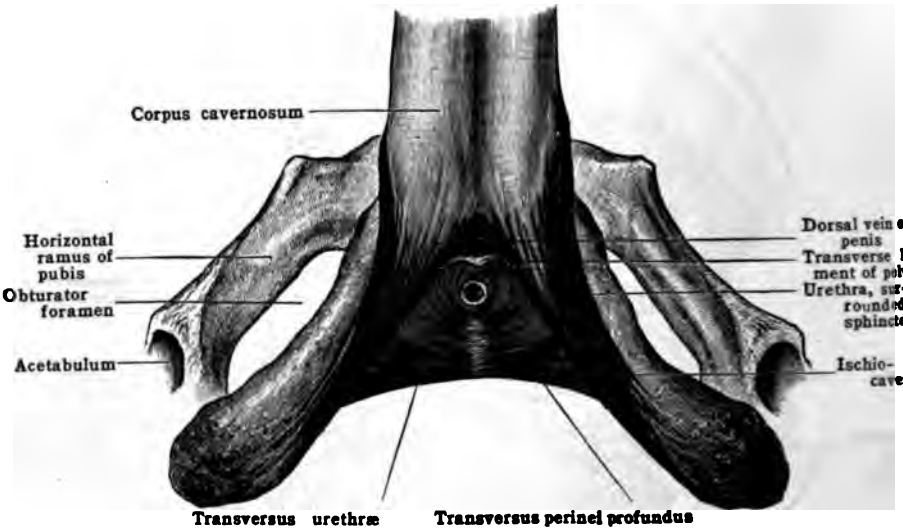
ard and medialward on each side of the urethra and then partly interdigitate the median line, partly terminate in a median raphe. Some fiber-bundles ce in the male the lower part of the prostate and Cowper's gland. In male the fiber-bundles of the sphincter partly terminate in the wall of the a. Some of them are continued downward on each side of the vagina and ligitate with fiber-bundles from the deep transverse perineal muscle. The *ransverse perineal* muscle (fig. 429) arises on each side from the ischiopubic s. It constitutes a flat band of muscle, the fiber-bundles of which in part ligitate across the median line, and in part are inserted into a median raphe. ne musculature of the urogenital diaphragm is enclosed between two well ed **fascial layers** (**fig.** 431, 434), the deep (superior) and superficial (inferior) of the urogenital diaphragm. The anterior margins of the two fascial are fused to form the transverse ligament of the pelvis which extends be- the inferior pubic rami, beneath the dorsal nerves and veins of the penis ris). At the anal margin of the musculature these two layers are also fused

with one another. The deep layer of the urogenital diaphragm forms the floor of the anterior recess of the ischiorectal fossa (fig. 431).

Superficial to the urogenital diaphragm lie the external genitalia (figs. 424, 425). Voluntary muscle is here found in connection with the crura of the penis (clitoris) and the bulb of the penis (vestibule). Although the musculature in the two sexes is fundamentally similar, nevertheless, owing to the differences in the structure of the genitalia in the two sexes, it is convenient to take up first the external genital musculature in the male and then that in the female.

In the male the crus penis, the posterior part of the corpus cavernosum, is relatively large. It lies in the groove between the ischiopubic ramus and the urogenital diaphragm (fig. 429), to the former of which it is firmly united. It is enwrapped on its free medial surface by the **ischiocavernosus** muscle (erector penis) (figs. 429, 433). The fiber-bundles of this muscle arise from the ischial tuberosity and from the ischiopubic ramus on each side of the attachment of the

FIG. 429.—MUSCLES OF THE UROGENITAL DIAPHRAGM (MALE).



crus. It is inserted into the medial and ventral surfaces of the crus near the attachment of the suspensory ligament. Some of the fiber-bundles may frequently be traced to the dorsal surface of the root of the penis (levator penis muscle).

The corpus spongiosum [corpus cavernosum urethræ terminates posteriorly in the bulb which lies on the urogenital diaphragm between the two crura (figs. 425, 433). It is united to the superficial layer of the trigone (fig. 433). It is enveloped by the **bulbocavernosus** muscle, composed of right and left halves united by a median raphe on the superficial surface of the bulb (fig. 425). Each half consists of several superimposed layers of fiber-bundles described below. The component fiber-bundles arise from the superficial layer of the urogenital diaphragm, from fibrous tissue on the dorsum of the bulb in the angle between the two crura, from the lateral surface of the corpus cavernosum penis in front of the ischiocavernosus and from the dorsal surface of the penis. It is inserted into a tendinous structure situated in front of the anus, the central tendon of the perineum, and into the median raphe on the free surface of the bulb. By its contraction the bulbocavernosus forces semen or urine from the bulbous part of the uretha.

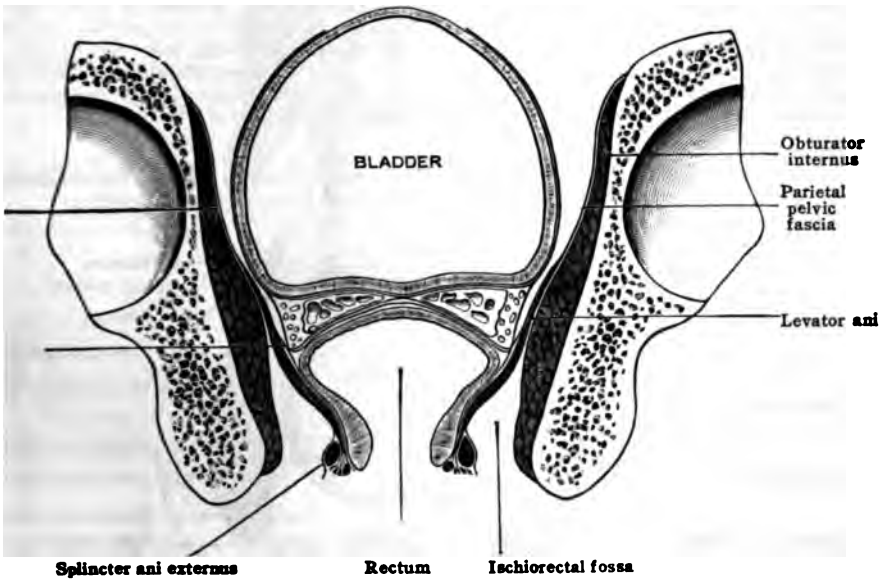
The **superficial transverse muscle** of the perineum (figs. 423, 425) arises on each side from the ascending ramus of the ischium and is inserted into the central tendon of the perineum. It is frequently weakly developed. It acts with the deep transverse perineal muscle in fixing the perineum and thus offering support for the action of other muscles.

he female (fig. 423) the *ischiocavernosus* does not differ markedly from that male although usually smaller. The superficial transverse muscles are, other hand, usually relatively better developed. The central tendon of ineum is likewise usually better developed in women and is more elastic, a teristic of value in childbirth.

e chief difference in the musculature in the two sexes is found in the *vernosus* (fig. 433). This, in the female, arises from the back of the clitoris, pus cavernosum and the trigone. It covers the outer side of the bulb of tibule and the gland of Bartholin. It is inserted into the central tendon of ineum. The chief function of the pair of muscles is to constrict the vagina.

e external genital muscles are covered by a deep layer of the tela subcutanea, fascia, which is firmly fused with the urogenital diaphragm at the anal l of the latter.

430.—Diagram to show the Fasciæ of the Pelvis in Section. (After Holl.)



MORPHOLOGICAL REMARKS

e the shoulder-girdle and the muscles which extend from this and from the trunk to the ıtremity are superficially placed with respect to the trunk, and do not interrupt the ıusculature the reverse is true of the hip-girdle and the musculature of the lower ex-

The hip-girdle is firmly united to the spinal column at the sacrum. The muscles ise from the trunk and are attached to the lower limbs are few in number compared with the upper extremity and, unlike the latter, are deeply placed. Thus the psoas major fig. 437) arises on each side of the lumbar region of the spinal column at the back of the al cavity and is inserted into the femur and the piriformis (fig. 437) arises from the front crum at the back of the pelvic cavity and is inserted into the great trochanter of the

The skeleton and musculature of the lower extremity, furthermore, markedly inter- the continuity of the trunk musculature which in the lower vertebrates and in the hu- bryo may be followed continuously to the caudal end. The interruption is much less behind than in front. The intrinsic dorsal spinal musculature extends well down over of the sacrum, but on the back of the lower end of the sacrum and on the back of the here is found merely the inconstant sacrococcygeus posterior. Of the ventrolateral ture the musculature of the abdominal wall, as is indicated by its innervation, is de- m the lower thoracic and the first one or two lumbar myotomes; the quadratus lum- at the back of the abdominal cavity (fig. 437), from the first three or four lumbar es. Beyond here there is an interruption until we come to the musculature of the tlet which, in part, may be looked upon as modified trunk musculature belonging to the e sacral myotomes. The intervening region is 'cut out' for the reception of the base of r extremity.

of interest to note that more and more of the ventrolateral wall of the trunk is 'cut the midventral line is approached. Thus while the quadratus lumborum behind ts spinal segments as far caudal as the third or fourth lumbar, the rectus abdominis represents segments merely as far caudal as the twelfth thoracic. Similarly while the s at the back part of the pelvic outlet represents the third and fourth sacral segments, or ani at the front represents chiefly the fourth.

The musculature which in the tailed mammals is used to move the tail as well as to wall the pelvic cavity and close rectal and urogenital openings, in man is modified wholly for latter functions. It constitutes the pelvic diaphragm.

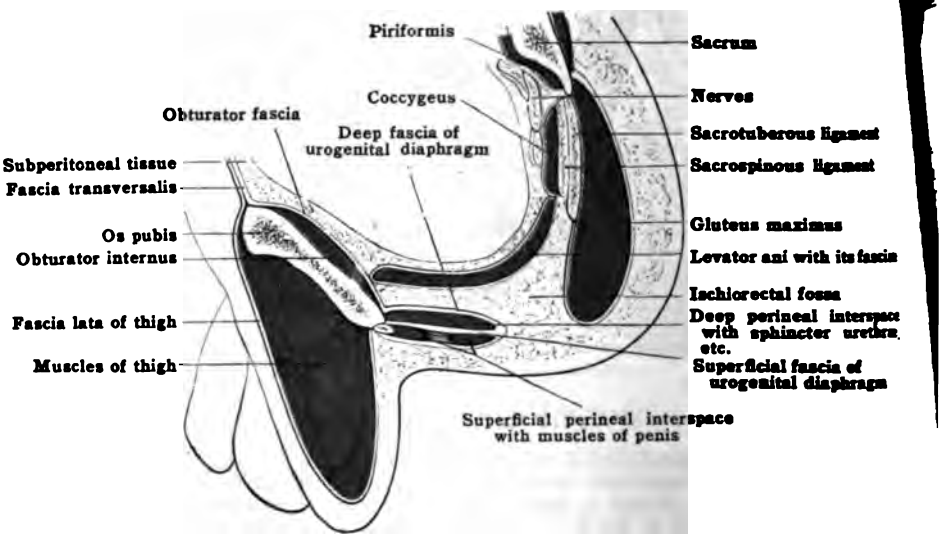
The musculature of the urogenital diaphragm of the external genitalia and anus in ma differentiated from the primitive sphincter of the cloaca.

FASCIÆ

The **tela subcutanea** in the male perineal region contains many bundles of smooth muscle fibers continuous with and similar to the dartos of the scrotum (corrugator cutis ani). At the sides where it passes over the lower margin of the gluteus maximus it contains a large amount of fat, but in the dorsal region over the coccyx and sacrum, as in the midperineal region, the fat is limited in amount. In the labia majora of the female perineum there is much fat in the tela subcutanea.

The **ischiorectal fossa** (figs. 431, 432, and 433) is bounded laterally by the obturator internus muscle and fascia, the tuberosity of the ischium and the ischiopubic ramus, medially by the levator ani and coccygeus muscles and fasciæ, ventrally by the dorsal aspect of the urogenital diaphragm and dorsally by the gluteus maximus muscle. An *anterior recess* extends forward well toward the body of the pubis between the levator ani, the ischiopubic ramus and the urogenital diaphragms. A *posterior recess* may likewise be traced backward beneath the lower edge of the gluteus maximus (figs. 431, 432). The fossa is filled with loose fatty tissue continuous with that of the tela subcutanea. Through it pass the hemorrhoidal, and long and short perineal branches of the pudic artery and nerve. The main trunks of these vessels and nerves lie in a special fascial compartment (Alcock's canal) in the lateral wall, fig. 432.

FIG. 431.—SAGITTAL SECTION THROUGH THE UROGENITAL DIAPHRAGM AND ISCHIORECTAL FOSSA TO THE LEFT OF THE MIDDLE LINE. (Diagrammatic.)



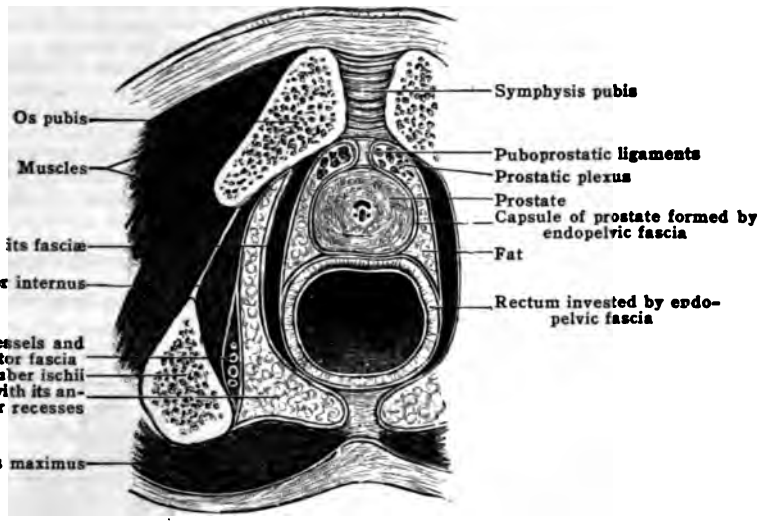
The external genitalia are covered by a special deep layer of the tela subcutanea, the **superficial perineal (Colles') fascia** (fig. 433). This is attached on each side to the lower margin of the ischiopubic ramus and to the ischial tuberosity. At the posterior margin of the superficial transverse perineal muscle it fuses with the two fascial layers of the trigone. It is adherent to the central tendon of the perineum and to the raphe of the bulb. Anteriorly it is continuous with the deep layer of the tela subcutanea covering the scrotum, the penis, and the lower part of the abdominal wall. In rupture of the urethra urine is prevented, by the attachments of the tela, from getting further back than the posterior edge of the trigone, but anteriorly it may extend to the surface of the abdomen. Here it may extend upward for a considerable distance, but it is kept from the thighs by the attachments of the deep layer of the tela subcutanea (Scarpa's fascia) to the inguinal ligament. Beneath the superficial perineal fascia are found the crura of the penis and their muscles, the bulb of the corpus spongiosum and its muscles, the superficial transverse perinei muscles, and the perineal vessels and nerves (fig 433).

Muscle fasciæ.—The muscles of the urogenital diaphragm, the urogenital (urethral) sphincter and the transversus perinei profundus, are contained between two fascia layers, which constitute the superficial (inferior) and deep (superior) layers of the urogenital diaphragm (trigone) (the superficial or inferior and the deep or superior layers of the triangular ligament).

The *superficial (inferior) layer* (figs. 423, 425, 431, 433, 434) which lies between the external genitalia and the urogenital diaphragm, is composed of strong bands of fibrous tissue which extend transversely across the subpubic arch and are attached to a ridge on the ischiopubic rami. It is separated from the arcuate (subpubic) ligament by a mass of fibrous tissue through which the dorsal veins and nerves of the penis (clitoris) run, and in which there is a venous plexus.

[illegible]ath this tissue a fibrous band, the *transverse ligament* of the pubis, extends between the [illegible]ding pubic rami. This represents a region of fusion of the deep and superficial layers of [illegible]fascia of the trigone. Posterior to the deep transverse muscle the two layers are likewise [illegible]d. The superficial layer is better developed in the front than in the back part of the space. [illegible]pierced by the urethra (about 3 cm. below the symphysis) by the ducts of the bulbourethral [illegible]wper's) glands, the arteries of the bulb, and the dorsal nerves and arteries of the penis. [illegible]the female it is pierced by the vagina as well as by the structures mentioned above.

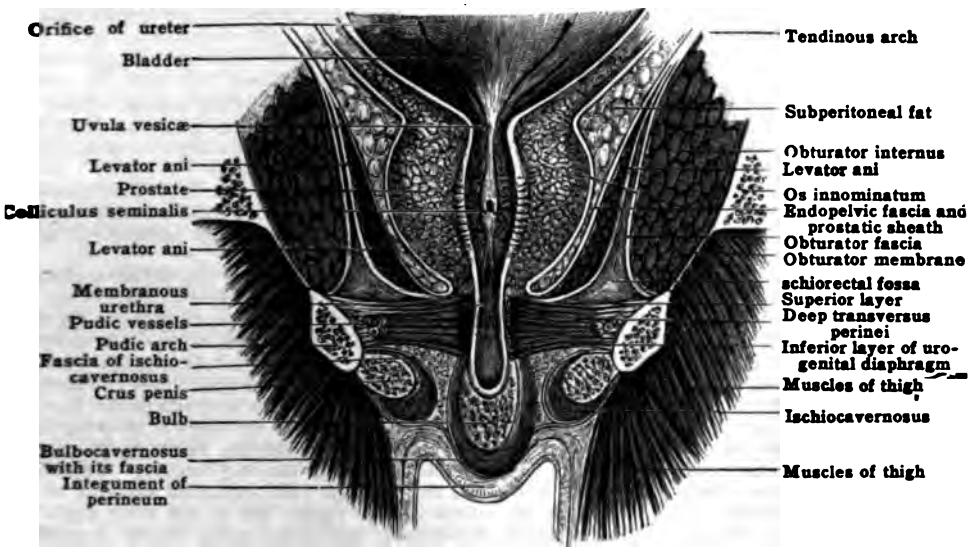
FIG. 432.—SECTION SHOWING THE ISCHIORECTAL FOSSA AND ITS RELATIONS.



Beneath the superficial layer of the fascia of the trigone, in addition to the muscles of the urogenital diaphragm, there are found the membranous urethra, the bulbourethral glands. (Cowper's), the internal pudic arteries and the pudic nerves (in part).

The *deep (superior) layer of the urogenital diaphragm* (figs. 431, 433, 434) lies between the muscles of the urogenital diaphragm and the ischiorectal fossa and levator ani. It may be looked upon as a continuation of the obturator fascia across the pubic arch. Posterior to the

FIG. 433.—VERTICAL FRONTAL SECTION OF THE PELVIS, SHOWING FASCIÆ.
(Modified from Braune.)



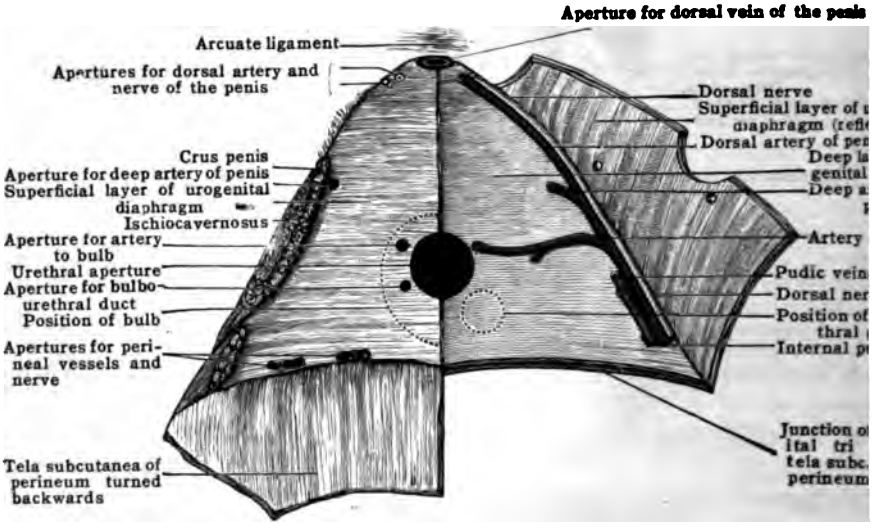
deep transverse perineal muscle it fuses with the superficial layer of the fascia of the urogenital diaphragm. In this region in the male it fuses with a fascial membrane, the *prostaticoperineal* fascia, which extends upward between the rectum and prostate, and is attached to the posterior wall of the latter. In the female it is fused with the fibrous tissue which lies between the vagina and the rectum.

The **muscle fasciæ of the pelvis** (figs. 430-433, 438B) have been described in vari by different authors. They may be subdivided into parietal and diaphragmatic. The **parietal fasciæ** (fig. 430) cover the muscles which extend from the interior of tl to the thigh (the obturator internus and piriformis muscles). Above, the fascia on e is attached to the linea terminalis and is continuous with the fascia transversalis and fascia. It is attached to the margins of the greater and lesser sciatic notches and to th pubic ramus and the body of the pubis. Between the ischiopubic rami it is stretche the subpubic arch and forms the superior or deep layer of the urogenital diaphragm d above. The portion of parietal pelvic fascia over the obturator internus muscle is c obturator fascia.

The **diaphragmatic pelvic fasciæ** cover both surfaces of the pelvic diaphragm an flected upon the viscera. The fasciæ covering the two surfaces of the levator ani are to the parietal (obturator) fascia along the line of origin of the muscle.

The line of attachment of the levator ani divides the obturator fascia into two p 430), a pelvic part above the line of attachment, covered by peritoneum, and an isc part below the line of attachment. The latter bounds the lateral wall of the ischiorec The former part is much the thicker. It consists morphologically of two fused membr obturator fascia proper and the aponeurosis of the iliococcygeal portion of the lev which although usually fused with the obturator fascia, may frequently be traced to minal (iliopectineal) line from which in tailed mammals this portion of thelevator tak

FIG. 434.—DIAGRAM OF THE SUPERFICIAL AND DEEP LAYERS OF THE UROGENITAL DIA



The two layers of fascia also become continuous at the medial margin of the muscle faces the urogenital passage (fig. 430). Posteriorly, the inner layer fuses with the insertion of the pubococcygeus portion of the muscle and the fasciæ of the muscles of are continuous. It also fuses with a fascia covering the coccygeus muscle.

The thin perineal layer of the levator fascia behind the rectum fuses with that of th side and is attached to the coccyx and the anococcygeal raphe. About the anus i form a covering for the external sphincter. Ventrally it is attached to the ischiop It forms the medial wall of the ischiorectal fossa.

Endopelvic fascia (figs. 432, 433).—The peritoneum is reflected from the pelvic the viscera much higher up than the level at which the viscera are attached to the phragm. Between the pelvic fascia covering the deep surface of the pelvic diaphragm ani and coccygeus muscles) and the peritoneum there is thus left a space, subperitor In the median plane in this region in the male are found the bladder, prostate, semin the ureter and ductus deferens in their course near the bladder, and the ampulla of th In the female we find here the bladder, the vagina, the uterus, and the ampulla of th Between these medially placed viscera and the lateral wall of the pelvis there is an i shaped space, *cavum pelvis subperitoneale*, bounded above by peritoneum, below by covering the pelvic diaphragm and filled with connective tissue of varying density. in this space in the female is continuous with that between the two peritoneal surfa broad ligament. Between the viscera in the subperitoneal region and about their connective tissue is more or less definitely condensed into membranes which the endopelvic fascia, variously described by different authors. The fascia covering diaphragm, especially that on the deep surface, is fused to the endopelvic fascia whe cera pass through the pelvic diaphragm. In the connective tissue of the subperitor are found the hypogastric artery and vein and their chief branches, and various viscer The subperitoneal space above the pelvic diaphragm is to be compared with the sub space below the pelvic diaphragm known as the ischiorectal fossa and described abo

MUSCLES

A. Muscles of the Pelvic Diaphragm, Coccyx, and Anus

The coccygeus (figs. 424, 426, 427, 428).—*Origin.*—From the ischial spine and the neighboring margin of the great sciatic notch. *Structure and insertion.*—The fiber-bundles diverge to be inserted partly directly, partly by means of an aponeurosis, into the lateral margin of the fourth and fifth sacral vertebræ and of the coccyx. Usually the muscle is composed in considerable part of tendinous connective tissue, especially on the dorsal side of the cranial portion, and on the ventral side of the caudal portion.

Nerve-supply.—From the pudendal plexus several small nerves enter the cranial margin and pelvic surface of the muscle. They arise usually from the third and fourth sacral nerves.

Action.—Insofar as the muscle is active it flexes and abducts the coccyx.

Relations.—Ventrally the muscle bounds the pelvic cavity, from which it is separated by the pelvic fascia, beneath which runs the nerve to the levator ani muscle. The dorsal surface is partly covered by the sacrospinous (lesser sciatic) ligament and helps to bound the ischiorectal fossa (posterior recess).

Variations.—The muscle varies greatly in the extent of its fleshy development. It may be doubled. It may be partially fused with the levator ani. Occasionally it is absent.

The sacrococcygeus anterior (fig. 424).—This inconstant muscle, when well developed, arises from the sides of the fourth and fifth sacral and from the front of the first coccygeal vertebra and from the sacrospinous ligament. The short fiber-bundles which compose it make up a somewhat irregular belly which is inserted into the anterior sacrococcygeal ligament and into the second to fourth coccygeal vertebrae dorsal to the insertion of the levator ani. The innervation is from the fourth and fifth sacral nerves.

The sacrococcygeus posterior is an inconstant muscle consisting of a few muscle bundles which extend from the dorsal surface of the lower sacral vertebræ or from the posterior iliac spine to the dorsal surface of the coccyx. It lies beneath the superficial layer of the sacrotuberous (great sciatic) ligament.

The levator ani (figs. 423, 425,–427, 430, 432) is divisible into three portions, the iliococcygeus, the pubococcygeus and the puborectalis.

The *iliococcygeus* (fig. 428) *arises* from the ischial portion of the arcus tendineus (white line). This extends from the ischial spine and posterior part of the arcuate line to the superior ramus of the pubis near the obturator canal, curving downward for a variable distance below the obturator canal. The constituent fiber-bundles form a muscular sheet which is inserted into the side of the coccyx and into the median raphe (anococcygeal) which extends from the tip of the coccyx to the rectum. Many fiber-bundles cross the median line.

The *pubococcygeus* (figs. 426, 428) *arises* from the inner surface of the os pubis, along a line extending from the lower margin of the symphysis pubis to the obturator canal, and from the arcus tendineus as far backward as the origin of the iliococcygeus. The fiber-bundles form a sheet of muscle which passes backward, downward, and medialward past the urogenital organs and the rectum on each side and is *inserted* by means of an aponeurosis into the anterior sacrococcygeal ligament. Back of the rectum some of the fiber-bundles of the muscle sheets of each side interdigitate across the median line. Some of the more superficial fibers are inserted into the deep part of the anococcygeal raphe. Some of the fiber-bundles which arise nearest the symphysis are inserted on each side into the rectum. The pubococcygeus lies to some extent on the pelvic surface of the insertion of the iliococcygeus.

The *puborectalis* (fig. 426) *arises* (a) from the body and descending ramus of the pubis beneath the origin of the *pubococcygeus*, (b) from the neighboring part of the obturator fascia and (c) from the fascia covering the pelvic surface of the urogenital diaphragm. The fiber-bundles form a thick band on each side of the rectum behind which those of each side are inserted into the anococcygeal raphe. Many fiber-bundles may be traced into the muscle of the opposite side. Some of the more superficial fiber-bundles are reflected medialward in front of rectum and may be followed into the superficial transverse perineal muscle, others may be followed into the sphincter ani externus, or even to the skin.

Nerve-supply.—By a special nerve which arises usually from the fourth sacral, runs across the pelvic surface of the muscle and gives a special branch to each portion.

Action.—To flex the coccyx, raise the anus and constrict the rectum. It resists the downward pressure which the thoracoabdominal diaphragm exerts on the viscera during inspiration.

Relation.—Between the right and left muscles in front lie the urethra and the lower part of the prostate in the male, the urethra and vagina in the female. In the triangle between the ischiopubic rami of each side lies the urogenital diaphragm separated from the puborectal part of the muscle by the deep layer of the trigone from which some of the fibers of the latter arise. Back of the urogenital diaphragm the muscle helps to bound the ischiorectal fossa.

Variations.—The muscle shows great individual variation in structure which causes it to be variously described by different authors.

The sphincter ani externus (figs. 423, 425, 427, 428, 430) is made up of bundles of muscle fibers which surround the anus for nearly two centimeters. It is elliptical in form. Behind the anus the fiber-bundles of each side in part interdigitate, forming a ring. They are attached to the skin, and in part are attached through a tendon, the *ligamentum anococcygeum*, to the back of the coccyx. In front of the anus the fiber-bundles also in part interdigitate with one another, in part are inserted into the skin and in part interdigitate with the fiber-bundles of the transverse perineal and bulbocavernosus muscles. At the point where these muscles meet, about two and a half centimeters in front of the anus, there may be a visible mass of fibrous tissue, the *central tendon of the perineum*, but this is not always distinct. It is usually better developed in the female than in the male perineum. The external sphincter is divisible into three portions, a subcutaneus, a superficial and a deep (fig. 428). The three parts are connected by

fiber-bundles, and are not always distinct. The *subcutaneous division* is small and immediately encircles the anal orifice. The *superficial division* lies external to the subcutaneous ring and descends further toward the rectum. It is shown in figs. 423, 425. It is the only part attached to the coccyx. In front it is attached to the central tendon of the perineum, but some fibers are continued into the bulbocavernosus. The *deep portion* forms a heavy ring above the rectum beneath the superficial part. It is distinctly, though not completely, separated from the puborectal portion of the levator and by fascial tissue containing the inferior hemorrhoidal vessels. Some of the fiber bundles of the deep portion may be traced in front of the anus across the midline to the ascending ramus of the opposite side and form part of the superficial transverse transverse perineal muscle.

Nerve-supply.—From the inferior hemorrhoidal branches of the pudendal (internal pudic) and frequently also by a perineal branch from the fourth sacral.

Action.—To keep the anus closed.

Relations.—Externally it is surrounded by the fat of the ischiorectal fossa, internally near the skin it surrounds the sphincter ani internus, composed of smooth muscle, deeper it lies next the mucous membrane, for a distance of two centimeters from the skin.

Variations.—The muscle shows considerable individual variation in structure.

The *rectococcygeus* or muscle of Treitz, is a triangular bundle of smooth muscle-fibers. The origin of the muscle is from the second and third coccygeal vertebræ. It is inserted by its apex into the posterior wall of the rectum and the perirectal fascia. It retracts and elevates the rectum.

B. Muscles of the Urogenital Diaphragm

The urogenital diaphragm (or trigone) is composed of two closely united muscles, the deep transverse perineal muscle and the urogenital sphincter.

The **transversus perinei profundus** (fig. 429) is a flat muscle which *arises* from the inner side of the inferior ischial ramus and is *inserted* into the median raphé. Many of the fiber-bundles interdigitate with those of the opposite side and some may be followed into the external sphincter of the anus and into the urogenital spincter and other perineal muscles.

Nerve-supply.—By the perineal branch of the pudendal (internal pudic).

Action.—The pair of muscles draw back and fix the central tendon of the perineum and thus give firm support for the action of the urogenital sphincter.

Relations.—The inferior surface is separated (often incompletely) by the inferior layer of the urogenital trigone from the superficial transverse perineal muscle. The superior surface is covered by the deep layer of the urogenital trigone, into which the superficial layer is reflected about the anal margin of the muscle.

Variations.—The muscle is variable in structure and may be absent. It is more frequently absent in the female than in the male.

The **sphincter urogenitalis** differs in the male and female owing to the passage of the vagina through the perineum in the latter. In each sex it is convenient to consider the muscle as divided into two parts, a periurethral and an infraurethral (vaginal).

In the male (fig. 429) the periurethral part, the *m. sphincter urethrae membranaceæ* is composed of fiber-bundles which are circularly placed about the membraneous urethra. The more external fiber-bundles are attached to the crura of the penis near their junction, to the transverse ligament of the pubis and to the fasciae of the trigone. Some of them partially ensheath the lower part of the prostate, and others envelop the bulbourethral (Cowper's) glands. Some of the fiber-bundles take a longitudinal course along the urethra. Bundles of smooth muscle fibers are intermingled with the striated, and the fibrous framework of the musculature is marked by the large amount of elastic tissue which it contains. The infraurethral part, the *m. transversus urethræ* is closely associated with the urethral part. The fiber-bundles arise on each side from the inferior ramus of the pubis. They pass for the greater part beneath the urethra and interdigitate with those of the opposite side or are inserted into a median raphe. A few fiber-bundles may pass above instead of below the urethra. The transverse urethral muscle, first described by Guthrie (On the anatomy and diseases of the neck of the bladder, London, 1834) is inconstant. Its existence as a normal constituent of the male perineal musculature has been disputed by Delbet (Poirier and Charpy) and others.

In the *female* the periurethral part, *sphincter urethrae*, differs in no essential respects from the corresponding muscle in the male. Some of the fiber-bundles form a true sphincter about the urethra. The *infraurethral* part, on the other hand, seems to vary greatly in different individuals so that the descriptions given by different authors are somewhat contradictory. It is better developed in women who have not borne children than in those who have. It may be looked upon as composed of two portions, a *m. transversus vaginae* and an *m. constrictor vaginae*. The *transversus vaginæ* arises from the ischiopubic rami and is inserted into the lateral wall of the vagina. Some of the fiber-bundles pass above and some below the vagina. This muscle corressponds with the transversus urethræ of the male but is, apparently, seldom fully developed The *m. constrictor vaginæ*, on the other hand, seems to be more constant. It is composed of fiber-bundles which embrace the lateral wall of the vagina and are inserted above into the periurethral framework, below into the raphe between the two deep transverse perineal muscles. Some of the fiber-bundles are attached to the vaginal wall. Some interdigitate with the sphincter urethræ, others with the deep transverse perineal muscle and with the transversus vaginæ.

Nerve-supply.—By a branch from the perineal nerve.

Action.—To compress or close the urethra and in the male to compress the prostate and Cowper's glands, in the female to compress the vagina and Bartholin's glands.

Relations.—On the pelvic side it is separated from the levator ani by the deep layer of the urogenital diaphragm, and on the perineal side it is separated from the superficial muscles by the

superficial layer of the fascia. Toward the anus it is closely associated with the deep transverse perineal muscle. Venous plexuses are well developed near the sphincter urethræ in both sexes, but especially in the female.

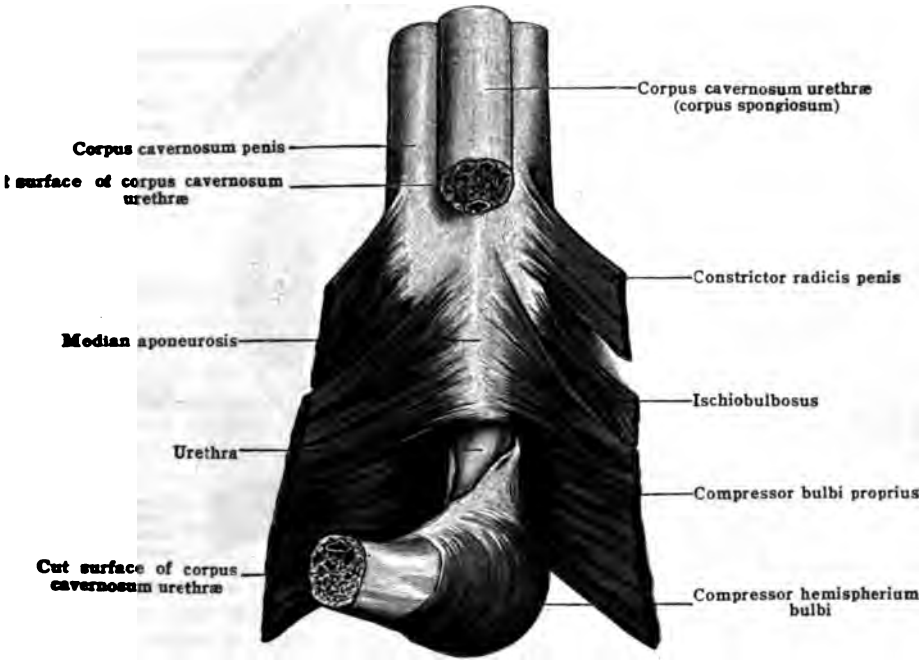
Variations.—It has already been pointed out that there is considerable variation in the muscles composing urogenital sphincter. Occasionally a rudimentary *ischiopubicus* is found arising from the ischiopubic ramus and terminating in a tendon which unites with that of the opposite side beneath the dorsal vein of the penis (clitoris). The tendon may be present as the transverse ligament of the pelvis when the muscle itself is absent. It represents the compressor of the dorsal vein found in lower mammals.

C. External Genital Muscles

The **bulbocavernosus** (figs. 425, 435) in the male ensheaths the bulb. The fiber-bundles arise from the dense tissue covering the corpus cavernosum at the root of the penis and from the subpubic connective tissue dorsal to the bulbar part of the urethra and are *inserted* into its median raphé on the ventral side of the bulb and into the central tendon of the perineum. Several parts may be more or less clearly distinguished.

Fig. 435.—Bulbocavernosus in the Male.

The two halves have been reflected from the median raphé, and the bulb turned downward after division of the corpus spongiosum. (The ischiobulbosus is not present on the right side.)



1. *The constrictor radicis penis arises* usually from the lateral surface of the corpus cavernosum penis at the base of the penis, but may arise from the under surface or from the dorsal surface, or even from the suspensory ligament of the penis. The fiber-bundles pass obliquely backward and medialward and are *inserted* into the median raphé on the perineal surface of the bulb.

2. The *compressor bulbi proprius arises* (1) from a strong fibrous aponeurosis situated between the corpus spongiosum and the united crura of the penis and firmly adherent to the former, and (2) from the superficial layer of the trigone. The fiber-bundles ensheath the bulb and are *inserted* into the posterior part of the median raphé and into the central tendon of the perineum. To a greater or less extent, depending on the development of the two muscles, the compressor covers the more posterior part of the constrictor.

3. The *compressor hemispherium bulbi arises* from a tendon common to the muscles of the two sides on the dorsum of the bulbous part of the urethra near the membranous part. The fiber-bundles embrace the hemisphere of the bulb and are inserted into the median raphé. This muscle is covered by the preceding. It not only compresses the bulb, but also is a sphincter of the urethra.

4. The *ischiobulbosus* is placed by Holl in this group. It *arises* from the pelvic surface of the tuberosity and of the inferior ramus of the ischium and when well developed is inserted into the median raphé, superficial to the compressor bulbi proprius or the constrictor radicis penis. Frequently, however, it does not extend over the bulb but is *inserted* into the inferior surface of the corpus cavernosum. It is more frequently absent than present. (See fig. 435.)

Nerve-supply.—The perineal division of the pudic nerve sends several branches to the bulbocavernosus.

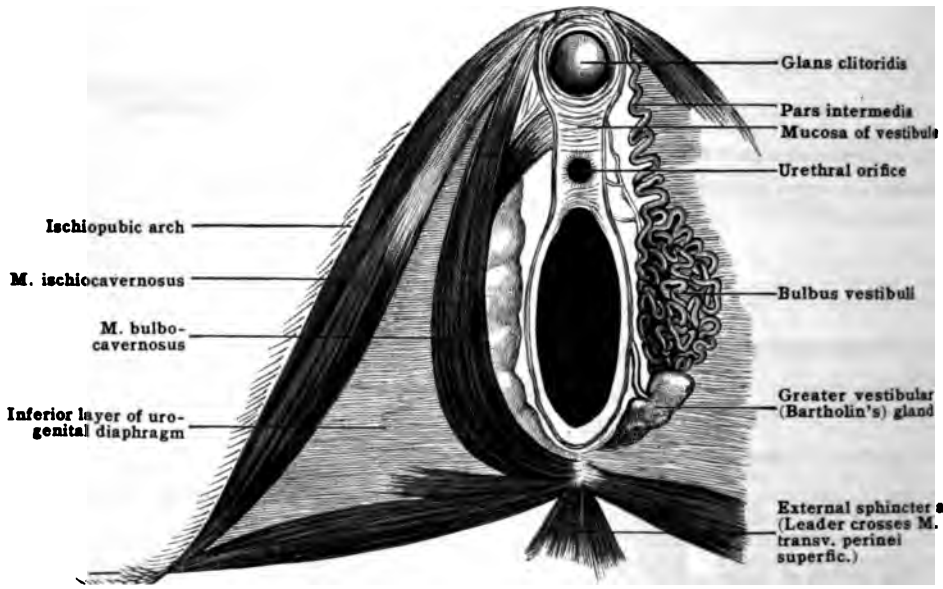
Action.—It compresses the bulb and at the same time the bulbous portion of the urethra. The turgescence of the penis is thus increased and urine or semen is expelled from this portion of the urethra.

Relations.—It lies beneath the skin and subcutaneous tissue.

Variations.—The muscle is variable in structure as is indicated by the different descriptions given by different authors. The *compressor venæ dorsalis* described by Houston is composed of a few fasciculi which arise from the sheath of the corpus spongiosum, and from the median raphé and are united to those of the opposite side by a tendon which passes over the dorsal vein.

The *bulbocavernosus* (*sphincter vaginæ*) (figs. 423, 436) in the female arises (1) from fibrous tissue dorsal to the clitoris, (2) from the tunica fibrosa of the corpus cavernosum and from the superficial layer of the urogenital diaphragm in the angle between the crura of the clitoris. The fiber-bundles form a band of tissue about two centimeters wide at the side of the vagina and are inserted into the posterior part of the superficial (inferior) layer of the trigonum and into the central tendon of the perineum where some of the fiber-bundles interdigitate with those of other muscles attached here. The fiber-bundles arising from the back of the clitoris correspond with those of the constrictor radicis penis in the male. The other fiber-bundles correspond with those of the compressor bulbi proprius in the male.

FIG. 436.—DIAGRAMMATIC REPRESENTATION OF THE PERINEAL STRUCTURES IN THE FEMALE



Nerve-supply.—From the perineal division of the pudic.

Action.—To compress the vagina.

Relations.—It covers the bulb of the vestibule and the great vestibular gland (Bartholin's). It is covered by skin and superficial fascia.

The **ischiocavernosus** (figs. 429, 436) (erector penis or clitoridis) *arises* from the pelvic surface of the tuberosity and inferior ramus of the ischium, back and on each side of the attachment of the crus. The fiber-bundles form a thin sheet which is spread over the crus into the medial and inferior surfaces of which it is *inserted* near the symphysis pubis. It is better developed in the male than in the female.

Nerve-supply.—By branches of the perineal nerve.

Action.—By constricting the crus to maintain turgescence of the penis or clitoris.

Relations.—Superficially it is covered by skin and subcutaneous tissue. Laterally it lies next the ischiopubic ramus. Medially it bounds a space lying between the crus and the bulb and filled with fat.

Variations.—The muscle in the male is much larger than in the female. Some of the more anterior fiber-bundles may extend to the dorsal surface of the penis (clitoris) and form a *pubocavernosus* or levator penis muscle.

The **transversus perinei superficialis** (figs. 423, 425, 436) arises from the inferior ischial ramus. The fiber-bundles extend in front of the rectum superficial to the deep transverse muscle and are inserted into the central tendon of the perineum. Some cross to the opposite side. Some of the fiber-bundles are continuous with those of the external sphincter or of the puborectalis of the opposite side.

Action.—It acts with the deep transverse muscle in fixing the central part of the perineum.

Nerve-supply.—By a branch from the perineal division of the pudic.

Variations.—It is frequently absent or poorly developed.

VI. MUSCULATURE OF THE LOWER LIMB

The lower limbs are used chiefly for the support and propulsion of the body. Variety of movement is subordinated to strength and precision. In contrast with the upper limbs, which perform a vast variety of complex movements under conscious control, the lower limbs are called upon to perform chiefly the relatively simple movements which are used in walking or running, without our paying much attention to them.

The contrast between the two extremities is best marked in the girdles, the relations of which to the trunk have already been described, p. 477. The shoulder-girdle is constantly called upon for movements in various directions which increase the freedom of action of the whole extremity. The sternoclavicular and acromioclavicular joints are movable so that the scapula can be carried in various directions over the thorax. The bones of the hip-girdle on each side, on the other hand, are ossified into a single hip-bone (os innominatum). The two hip-bones are almost immovably united to one another in front by the symphysis pubis and behind each is united to the sacrum by a joint which, although a diarthrosis, likewise permits but slight movement. The sacrum in turn is composed of vertebræ firmly ossified together. The pelvis, composed of the two hip-bones and the sacrum forms a strong support for the trunk. Such movements as it makes are due chiefly to the lumbosacral joint and to a less extent to the joints between the lumbar vertebræ. These joints permit the pelvis, in a limited manner, to be flexed and extended, abducted, adducted, and rotated. Flexion is produced by the rectus and the oblique muscles of the abdomen (fig 418) and by the psoas muscles (fig 437), extension is produced by the quadratus lumborum (fig 437) and the sacrospinalis (fig 412). Rotation and abduction are produced when these muscles act on one side only. The weight of the body in the sitting posture is transmitted through the sacrum and hip-bones to the ischial tuberosities. In this position the pelvis is flexed. The weight of the body in the standing position s transmitted to the femora through the acetabulum on each side. In this osition the pelvis is extended. In walking the pelvis is rotated forward toward he limb that is being advanced.

The hip-joint is a true ball-and-socket joint, but freedom of movement is reatly limited by the powerful musculature which surrounds it, as well as by the gaments. Movements here, however, are freer than at the shoulder-joint, if ie shoulder girdle be left out of consideration. At the hip-joint the most fre- uent and most free movements are those of flexion and extension, the main ovements in walking or running; but abduction, adduction, circumduction, id rotation are of the greatest importance in balancing the body.

At the knee-joint the main movements are also those of flexion and extension id the musculature is so arranged that the chief flexors of the knee which lie at ie back of the thigh are extensors of the hip (fig. 439) while the extensor mus- ulature of the knee which lies at the front of the thigh flexes the hip (fig. 442). lexion of the hip, however, through the action of gravity on the foot passively rings about flexion at the knee, while flexion of the knee likewise passively rings about flexion of the hip, since the flexed knee tends to swing forward. hese passive movements, due to gravity, are of importance in walking. The astrocnemius (fig. 444), the most powerful extensor of the ankle-joint, is also a owerful flexor of the knee-joint. At the knee-joint, in addition to flexion and xtension, some rotation is possible, best marked when the knee is flexed. This otation is of value in walking over rough ground in that it helps to accommodate ie foot to the ground. It is also of value in sitting on a flat surface. While iere is thus some rotation at the knee-joint not found at the elbow-joint, the free ovement of the radius about the ulna which accompanies pronation and supina- on in the forearm, is unrepresented in the leg where the fibula is firmly united the tibia at each end.

The joint between the bones of the leg and the tarsus permits merely of flexion id extension in contrast to the wrist-joint which also permits of adduction and oduction. Flexion and extension are also more limited at the ankle than at the rist. On the other hand, the movements of inversion and eversion which take ace in the intertarsal joints are not needed in the wrist because of the prona-

tion and supination of the forearm. Inversion and eversion of the foot are of value in walking on rough ground.

The movements of the toes resemble those of the fingers except that they are, in most individuals, far more restricted. The greatest restriction is seen at the joint between the metatarsal of the big toe and the tarsus, as compared with that between the metatarsal of the thumb and the carpus.

The musculature of the inferior extremity, like that of the superior, can be divided according to its development and innervation into two great subdivisions which correspond with the musculature on the dorsal and ventral sides of the shark's fin. The dorsal musculature is supplied by nerve branches which arise from the back of the lumbodorsal plexus (femoral, gluteal, and peroneal nerves), the ventral musculature by branches which arise from the front of the plexus (obturator and tibial nerves). Owing, however, to the rotation which the limb makes during embryonic development, the musculature which primitively lies on the dorsal side of the limb-bud comes to lie on the front and lateral side of the extremity and the musculature of the ventral side of the limb-bud comes to lie on the back and medial side of the extremity or in the sole of the foot. The side of the limb which primitively was toward the head becomes the medial side of the limb, and that which faced caudalward comes to lie laterally. While this makes the primitive relations of the musculature of the limb at first somewhat confusing, it is possible to approximate these primitive conditions by abducting the limb and rotating it so that the sole of the foot faces forward. An understanding of the innervation of the limb is thus greatly facilitated.

In the region of the hip the musculature of the **dorsal division is that which** arises from the spinal column and ilium and is inserted into the upper part of the femur and into the fascia of the thigh. It includes the chief flexor of the thigh, the *iliopsoas* (fig. 437), and the most powerful extensor, the *gluteus maximus* (fig. 444), as well as several important rotators and abductors, *gluteus medius* and *minimus*, *piriformis* and *tensor fasciæ latæ* (fig. 439). The iliopsoas is innervated by nerves from the back of the lumbar, the other muscles by nerves from the back of the sacral plexus. The musculature of the **ventral division arises from** the pubis and ischium, is inserted into the femur near the great trochanter and serves to adduct the thigh and rotate it lateralward, *obturator internus*, *gemelli*, *quadratus femoris* (fig. 439) and *obturator externus* (fig. 437). The obturator externus is innervated by the obturator nerve from the front of the lumbar plexus, the other muscles by special branches from the front of the sacral plexus.

In the thigh there are three groups of muscles, an **anterior or extensor group** (fig. 442), a **medial or adductor group** (fig. 442), and a **posterior or flexor group** (fig. 439). The anterior group belongs to the primitive dorsal division, the other two groups to the ventral division.

In the leg there are also three groups of muscles, an **anterior, a lateral and a posterior.** The two former belong to the dorsal division and are innervated by the peroneal nerve. The last belongs to the ventral division and is innervated by the tibial nerve.

In the foot one muscle on the dorsum represents the primitive dorsal division, the *extensor digitorum brevis* (fig. 449), supplied by a branch from the peroneal nerve. On the other hand the primitive ventral division is well represented in the sole of the foot, not only by the muscles associated with the long flexor tendons, quadratus plantæ, lumbricales (fig. 451), but also by the short flexor of the toes (fig. 450), by the special musculature of the big and little toes (fig. 452) and by the interosseous muscles (fig. 453).

The **muscle-fasciæ** of the inferior extremity are well developed. **The *fascia lata*, which** encloses the musculature of the back of the hip and the musculature of the thigh, is especially strong on the lateral side where it includes the longitudinal bundles of fibers which compose the iliotibial band [tractus iliotibialis]. From the fascia lata strong intermuscular septa extend on each side of the quadriceps group of muscles to the femur. Medially beneath the sartorius muscle (fig. 441), septa help to bound Hunter's canal in which lies the femoral artery on its way to the popliteal space behind the knee. In the leg there is likewise a strong cylindrical fascial sheath which encloses the musculature and sends septa on each side of the peroneal group to the fibula. A transverse septum also separates the deep from the superficial muscles of the calf. The fascia of the leg is especially well developed near the ankle where it helps to hold in place the tendons which pass from the muscles of the leg into the foot. Muscle-fasciæ are well developed both on the dorsum and in the sole of the foot.

A. MUSCULATURE OF THE HIP

1. Iliofemoral Musculature

The iliac blade divides these muscles into an **anterior group** (iliopsoas), supplied by nerves from the lumbar plexus, and a **posterior group** (the gluteal muscles, piriformis, and tensor fasciæ latæ), supplied by nerves from the sacral plexus.

In most of the limbed vertebrates these two groups of muscels are represented, but they present marked specific variations in the different forms. Primitively, the iliacus group lies on the proximal portion of the lateral surface of the ilium.

(*a*) Anterior Group
(Figs. 437, 442)

The fan-shaped **iliacus** muscle arises from the iliac fossa. The fusiform **psoas major** muscle arises from the sides of the last thoracic and of the lumbar vertebræ and extends along the medial margin of the iliacus muscle. The two muscles are inserted by a common tendon into the lesser trochanter of the femur. Together they constitute the **iliopsoas** muscle. The small, flat, fusiform **psoas minor** lies on the medial surface of the psoas major and extends from the twelfth thoracic vertebra to the iliopectineal eminence. The iliopsoas flexes the thigh at the hip and the pelvis on the trunk. The psoas minor aids in flexing the pelvis.

The iliopsoas muscle arises in the human embryo from a blastema which at first surrounds the femoral nerve and later extends proximally over the ilium (iliacus) and toward the lumbar vertebræ (psoas). The iliacus is phylogenetically the more primitive. In the shoulder it is probably represented by the infraspinatus. The psoas minor is much better developed in many of the lower mammals than in man.

FASCIÆ

The fasciæ and the relations of these muscles are shown in figs. 415 and 438.

The iliac and psoas muscles are covered by a dense fascia which is but slightly adherent to the underlying muscles. It is best developed in the pelvic region, where it extends from the iliac crest and iliolumbar ligament to the iliac portion of the linea arcuata and is called the **iliac fascia.** Superiorly it is continued over the psoas muscle as the **psoas fascia** and is attached medially to the sacrum and the lumbar region of the spinal column. Laterally it unites with the lumbar fascia and superiorly it is strengthened to form the medial lumbocostal arch (fig. 422). Inferiorly the **iliopectinal fascia** extends over the iliopsoas muscle to its femoral insertion. It is firmly united on each side of the muscle to the capsule of the hip-joint and to the femur. As it passes beneath the inguinal ligament it is united to this by tendinous processes. Beyond the ligament it is less dense than in the pelvic region.

MUSCLES

The psoas major (figs. 437, 442).—*Origin.*—(1) By a series of thick fasciculi from the intervertebral disks between the twelfth thoracic and the fifth lumbar vertebra, from the adjacent parts of the bodies of these vertebræ and from tendinous arches which bridge over the middle of the sides of the first four lumbar vertebræ; and (2) by a series of more slender fasciculi from the lower borders and ventral surfaces of the transverse processes of the lumbar vertebræ

Structure and insertion.—From these origins parallel fiber-bundles descend nearly vertically and give rise to a fusiform muscle which lies at the side of the vertebral bodies and extends along the border of the true pelvis toward its insertion. A tendon arises deep in the muscle near the last lumbar vertebra, and becomes free on its dorsolateral surface slightly above the inguinal (Poupart's) ligament. On the medial side the attachment of fiber-bundles continues to the insertion of the muscle into the small trochanter. The iliacus muscle is attached to the lateral side of the tendon from near the iliopectineal eminence downward.

Nerve-supply.—Delicate branches pass into the psoas muscle from the trunks which unite to form the femoral (anterior crural) nerve, i.e., from the fourth, third, second, and often the first lumbar nerves.

The iliacus (figs. 437, 442).—*Origin.*—(1) From the iliac crest, the iliolumbar ligament, and the greater part of the iliac fossa, the anterior sacroiliac ligaments, and often from the sacrum, and (2) from the ventral border of the ilium between the two anterior spines.

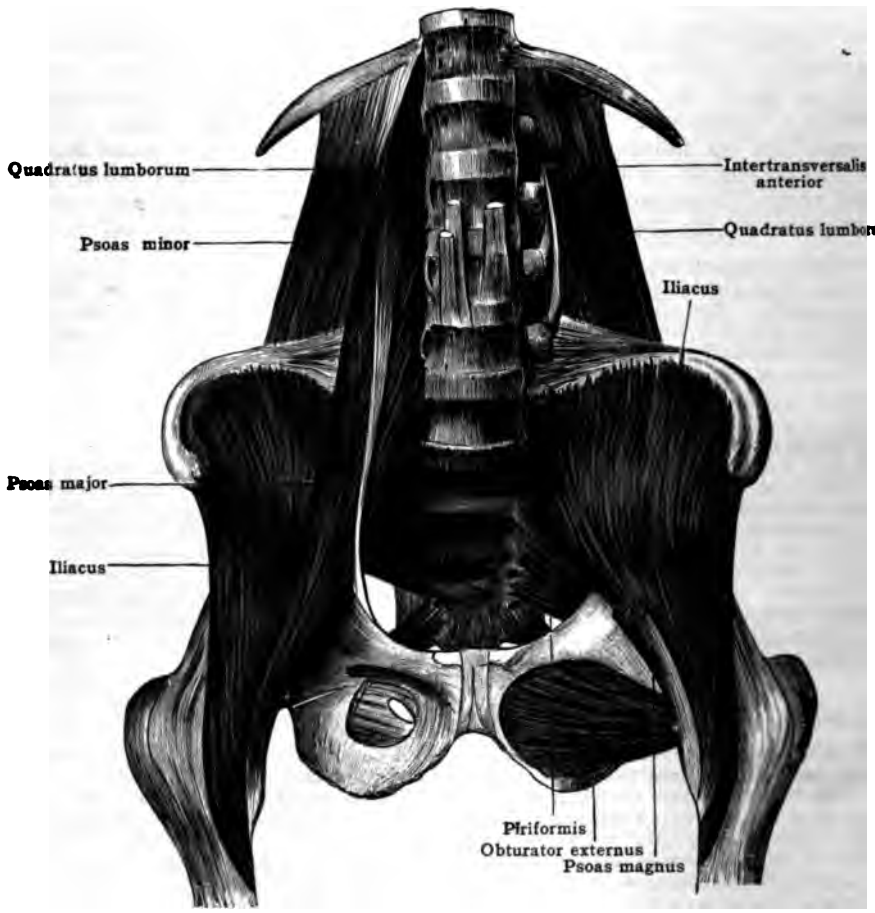
Structure and insertion.—From these areas of origin the fiber-bundles pass to be inserted—(1) in a penniform manner on the lateral surface of the tendon which emerges from the psoas above the inguinal (Poupart's) ligament, and (2) directly on the femur immediately distal to the small trochanter. The lateral portion of the muscle arises from the ventral border of the ilium and is adherent to the direct tendon of the rectus femoris and the capsule of the hip-joint. It is sometimes more or less isolated (*m. iliacus minor, ilio-capsulo-trochantericus*, etc.).

Nerve-supply.—Nerve branches, often united in a plexiform manner, arise from the femoral (anterior crural) nerve and pass *across the surface* of the iliacus muscle about midway between

the crest of the ilium and the combined iliopsoas tendon. Special nerve branches are usually likewise distributed from the main trunk of the femoral nerve to the fleshy portion of the muscle which extends over the acetabulum and the head of the femur.

Relations.—The psoas major lies lateral to the lumbar vertebræ and in front of the quadratus lumborum and intertransverse muscles. The psoas minor passes downward across its ventral surface. Both psoas muscles are crossed by the crura of the diaphragm. The kidney with its adipose capsule lies lateral to them opposite the first two lumbar vertebræ. For the rest, their fascia is covered ventrolaterally by retrointestinal and retroperitoneal tissue in which the vena cava inferior runs in front of them on the right side, the inferior mesenteric vein in front of them on the left side, and the ureter, the spermatic or ovarian, and the renal and colic vessels on each side. The external iliac artery lies medial to the psoas major in the pelvis, and beyond the inguinal (Poupart's) ligament the femoral artery lies ventral to it. The lumbar plexus arises between its origins from the vertebral bodies and disks and those from the transverse processes. The nerves springing from the lumbar plexus take courses subject to much individual variation

FIG. 437.—PSOAS, ILIACUS, AND QUADRATUS LUMBORUM.



through the muscle on the way to their destinations. Fasciculi of the muscle may thus be separated by the femoral (anterior crural) nerve or other branches of the lumbar plexus.

The iliacus muscle in the region of the pelvis is covered by retroperitoneal fat. The psoas muscle crosses its medial margin and from between the two muscles the femoral nerve usually emerges to pass into the thigh above the iliacus. Beyond the inguinal ligament the iliacus lies in front of the capsule of the hip-joint and the straight tendon of the rectus femoris, and is crossed by the sartorius.

Action.—The iliopsoas is a powerful flexor of the thigh at the hip and a weak medial rotator and adductor. It also serves to flex and abduct the lumbar region of the spine.

Variations.—The psoas muscle may be separated from the iliacus as far as the femoral insertion. The part of the psoas arising from the distal lumbar vertebræ may form a distinct muscle. Slips may pass from the psoas major to the psoas minor. A separate lamina of the iliacus muscle may be attached to the iliac fascia. From the anterior inferior iliac spine a small muscle slip may run to the intertrochanteric line or the iliofemoral ligament. To this slip the term iliacus minor has been applied as well as to the larger fasciculus mentioned above.

The psoas minor (fig. 437).—*Origin.*—From the twelfth thoracic and first lumbar vertebræ and the intervening disk

ture and insertion.—The fiber-bundles pass to be attached as far as the level of the fifth vertebra to a flat tendon which appears about the midlumbar region and is inserted iliopectineal eminence. It is intimately united to the iliac fascia.
e-supply.—The branch to the psoas minor arises usually from the first and second lum-res, often in company with the genitofemoral (genitocrural).
on.—To flex the pelvis.
tions.—It is closely applied to the ventral surface of the psoas major.
iations.—The muscle is inconstant in development and is frequently absent. Gruber nd it absent on both sides in 183 out of 450 bodies, on one side in 69.

Bursæ

liopectinea.—A large bursa between the iliopsoas muscle, the iliopectineal eminence, e capsule of the hip-joint. **B. iliaca subtendinea.**—A small bursa between the tendon tion of the iliopsoas and the lesser trochanter.

(*b*) Posterior Group
(Figs. 418, 438, 439, 444)

e muscles of this group arise from the ilium and and sacrum, cover the dorso- surface of the hip, and are inserted into the great trochanter and shaft femur and into the iliotibial band. They lie in three planes. In the **first** (fig. 418) are the flat, quadrilateral **tensor fasciæ latæ,** which arises from nt of the crest of the ilium and is inserted into the iliotibial band, and the rhomboid **gluteus maximus,** which arises from the dorsal portion of the a, the lumbodorsal fascia, the sacrum and coccyx, and the sacrotuberous sacrosciatic) ligament, and is inserted in part into the iliotibial band and into the back of the upper part of the shaft of the femur. The **iliotibial** tract) is a flat tendon which descends, closely fused with the fascia lata, to eral side of the upper extremity of the tibia. In the **second layer** (fig. 439) e flat, thick, triangular **gluteus medius** and the 'pear-shaped' **piriformis.** rmer arises from the upper and back part of the outer surface of the ala of ım, the latter from the ventral surface of the sacrum and the posterior of the great sciatic notch. Both are inserted into the top of the great nter. The **third layer** (fig. 440) is composed of the triangular **gluteus us,** which arises from the inferior ventral portion of the outer surface of ı of the ilium, and is inserted into the front of the great trochanter of nur.

e muscles of this group extend, flex, abduct, and rotate the thigh at the hip. luteus maximus and medius are in part extensors, the gluteus minimus e tensor fasciæ latæ are flexors of the hip-joint. All the muscles serve to t, the gluteus maximus acting thus when the hip is flexed. When the thigh nded the lower part of the gluteus maximus is an adductor. The gluteus ıus and posterior part of the gluteus medius and the piriformis act as , the anterior part of the gluteus medius, the gluteus minimus, and the fasciæ latæ as medial, rotators. The gluteus maximus and the tensor latæ through the iliotibial band keep the extended knee-joint firm. luteus maximus is supplied by the inferior gluteal nerve, the piriformis cial nerves, and the other muscles of the group by the superior gluteal

All these nerves arise from the upper part of the back of the sacral

gluteus medius, gluteus minimus, and piriformis form a group of muscles which in the have a common origin and are more or less fused in the adult. The gluteus maximus ı two distinct, though associated, portions, and the tensor fasciæ latæ as another dis-ırtion. The two muscles, however, are probably to be considered as parts of a primitive elvo-tibial musculature, while the gluteus medius group is represented in the lower forms iofemoral musculature. The former group is often closely associated with the extensor of the thigh in the lower forms (frog), and in some of the lower mammals extends its n to the plantar fascia (ornithorhynchus). In the arm this group is perhaps represented deltoid, the latissimus dorsi, and the teres major, while the gluteus medius group is ıted by the subscapularis.

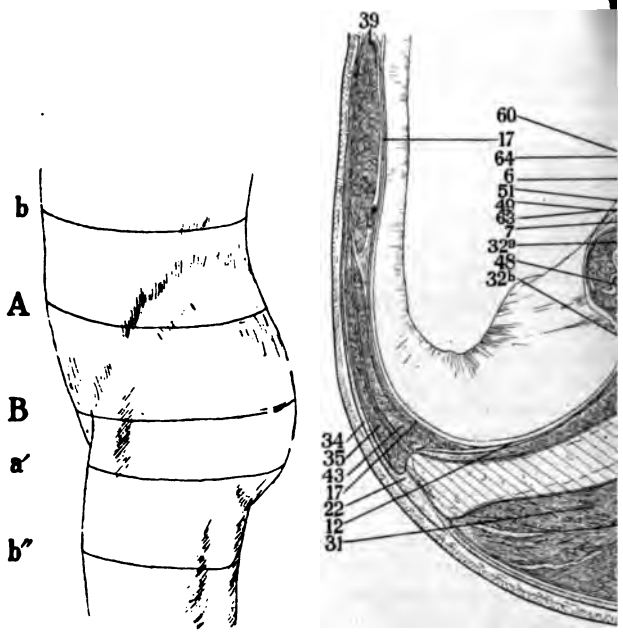
Fasciæ

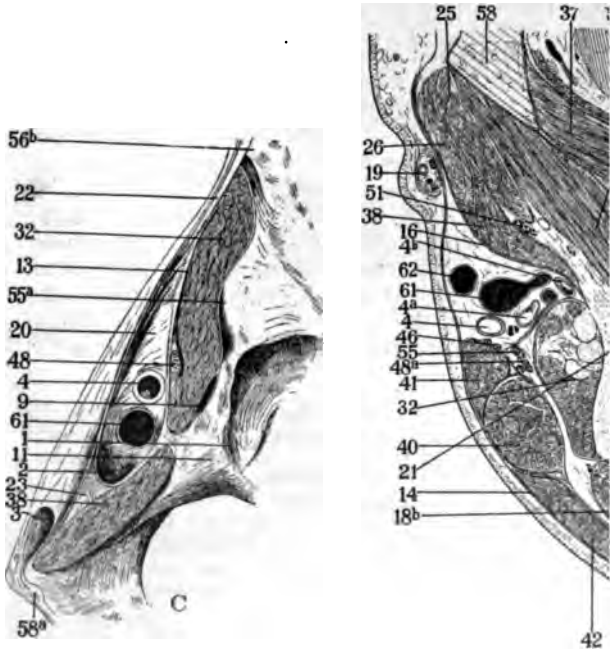
tela subcutanea of the gluteal region is very thick, contains much fat, and is often e into two layers, of which the deeper is closely adherent to the fascia lata and through he gluteus maximus. Over the great trochanter a subcutaneous bursa is usually found rochanterica subcutanea).

Muscle fascia.—The muscles of the hip and th
lata (figs. 418, 438). This arises from the tuber is
ligament, the back of the sacrum and the coccyx, the

FIG. 438, A and B.—TRANSVERSE SECTIONS THROUG
REGIONS INDICATED IN T

C. Section through the muscles of the left inguinal re
ligament (after Spalteholz). *b* in the diagram
indicate sections *A* and *B*, fig. 441. (For legends,





ligament, and the pubic and ischial rami, and extends to
muscles of the leg. It is composed mainly of bundles of fi
axis of the limb. In the region of the gluteal groove it is
which arises from the tuberosity of the ischium and
gluteus maximus muscle.

The superficial portion is the larger, and includes all of that part of the muscle which from the ilium and the more superficial portion of that arising from the sacrum and th part of the coccyx. The deep portion includes that part of the muscle attached to the the sacrum and the coccyx, and to the sacrotuberous ligament. The superficial porti some of the fiber-bundles of the deep portion terminate in the iliotibial band along a tending from the great trochanter to the end of the upper third of the femur. The de tion is inserted chiefly by a flat tendon into the gluteal tuberosity, and also directly i adjacent portion of the origin of the vastus lateralis.

FIG. 439.—THE LATERAL ROTATORS AND THE HAMSTRING MUSCLES.

Nerve-supply.—Two branches (inferior gluteal) arising from the sacral plexus eit rately or united, are usually given to the muscle. One of these curves anteriorly across surface of the proximal superficial portion of the muscle in the middle third between the of origin and insertion, the other descends to enter the middle third of the distal dee of the muscle.

Action.—It is the most powerful extensor of the thigh. It also serves slightly to limb lateralward and to make tense the fascia lata, and through the iliotibial band to extended knee-joint steady. When the thigh is extended the major part of the mu

ior but the upper part is a weak abductor. The whole muscle is an abductor when the s flexed. It is brought powerfully into play in climbing and in walking up hill.
lations.—It is covered by the fatty superficial tissue of the buttock. It extends over the ior portion of the ilium, the lateral surface of the sacrum and coccyx, the sacrotuberous nt, and the great trochanter. It covers the tuber of the ischium in the standing but not sitting position. Immediately beneath the muscle lie portions of the gluteus medius, mis, obturator internus, gemelli, quadratus femoris, obturator externus, and hamstring es, and of the gluteal vessels and nerves and the sciatic nerve.
riations.—Few anomalies are recorded. The deep distal portion of the muscle may be isolated than normal in the adult. A special coccygeofemoral muscle may run from the x to the linea aspera, or from the sacrotuberous ligament to the fascia of the leg. A l fasciculus, the **ischiofemoralis**, may arise from the tuberosity of the ischium and become ed into the lower border of the muscle near the great trochanter. The sacral, ischial, or geal origin may be lacking, or the origin of the muscle may be from the sacrum only.

II. Second Layer

ıe muscles of this layer are the gluteus medius and the piriformis.
ıe **gluteus medius** (fig. 439).—*Origin.*—From (1) the ventral three-fourths of the iliac and the outer surface of the ilium between the anterior and posterior gluteal lines and (2) vesting fascia.
ructure and insertion.—The fiber-bundles converge upon both surfaces of a broad tendon ' to its insertion on an oblong impression on the posterosuperior angle and the external e of the great trochanter. The more posterior fiber-bundles of the superficial stratum ventral portion of the muscle cross obliquely those of the deeper dorsal portion near ndon of insertion. From the tendon an aponeurotic extension is usually continued into ndon of the vastus lateralis.
rve-supply.—From the superior gluteal nerve a branch passes to the dorsal portion of the : and one or more twigs of the branch to the tensor fasciæ latæ enter the ventral portion of ıscle. The branches enter the middle third of the muscle between its tendons of origin sertion. The nerve-fibers arise usually from the fourth and fifth lumbar and first sacral . The branch to the dorsal portion of the muscle has a lower spinal origin than those ventral portion.
ion.—To abduct the thigh. The anterior portion of the muscle is a flexor and a medial ; the posterior a lateral rotator and an extensor. When the muscle acts as a whole, it is al rotator.
ations.—Upon the muscle lie the tensor fasciæ latæ and gluteus maximus muscles and the lata; beneath it lie the gluteus minimus muscle, the superior gluteal nerve and vessels, e great trochanter.
riations.—It may be divided into two distinct portions, or it may be fused with the nis or the gluteus minimus or both. A special fasciculus may extend to the superior ı of the great trochanter.
ə **piriformis** (fig. 439).—*Origin.*—From (1) the lateral part of the ventral surface of the , third, and fourth sacral vertebræ; (2) the posterior border of the great sciatic notch;) the deep surface of the sacro-tuberous (great sacrosciatic) ligament near the sacrum.
ucture and insertion.—The fiber-bundles converge upon a tendon which is inserted upon terior and inner portion of the upper border of the great trochanter. The insertion of undles continues nearly to the great trochanter. An accessory slip of insertion may pass gluteus minimus.
ve-supply.—From a nerve which arises either directly from the first or second sacral or from a loop between them. The nerve enters the deep surface of the muscle in its third. There may be two or more nerves.
tion.—It is an extensor, abductor, and lateral rotator of the thigh. It causes medial n when the hip is flexed.
ations.—Its ventral surface faces the sacral plexus, the rectum, and the hip-joint. It is l dorsally by the gluteus maximus. It lies between the gluteus medius and the superior us. Between the piriformis and the superior gemellus the sciatic nerve usually passes e thigh. The superior gluteal nerve and vessels pass dorsally above its superior margin; erior nerve and vessels beneath its inferior margin.
riations.—It is rarely absent. The origin may extend to the first sacral or to the fifth vertebra and the coccyx. It may be fused with the gluteus medius or minimus or more with the superior gemellus. Its tendon of insertion may be fused with that of the gluteus ı or the obturator internus. In about 20 per cent. of bodies it is divided partly or com- into two portions, between which the sciatic nerve or its peroneal (external popliteal) n usually passes. Rarely the tibial instead of the peroneal portion may pass between the sciculi, or the muscle may be divided into three or more fasciculi, between which the es of the sciatic nerve pass.

III. Third Layer

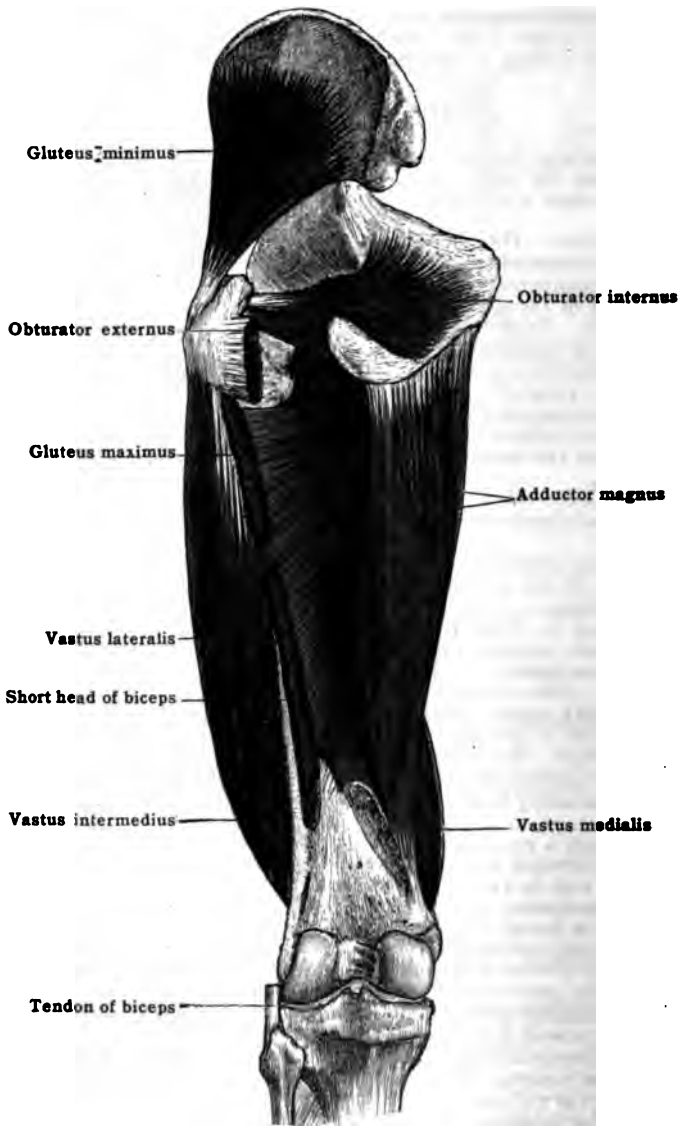
ə **gluteus minimus** (fig. 440).—*Origin.*—From the outer surface of the ilium between terior and inferior gluteal lines;(2) from the septum between it and the gluteus medius ıe anterior superior iliac spine; and (3) from the capsule of the hip-joint.
ucture and insertion.—The fiber-bundles converge upon a tendon which appears on the of the ventral border and gradually spreads over the lateral surface. The muscle is t in front, where it is usually bound by an intermuscular septum to the gluteus medius. ndon is inserted into the ventral surface of the great trochanter of the femur.

Nerve-supply.—From twigs of the branch of the superior gluteal nerve which goes to the tensor fasciæ latæ. These twigs enter the middle third of the muscle as the tensor branch passes across it.

Action.—To abduct the thigh and rotate it medialward. The anterior part of the muscle is a flexor, the posterior an extensor.

Relations.—It is covered by the gluteus medius and piriformis muscles. Beneath it lie the inferior part of the iliac ala, the hip-joint (to the capsular ligament of which it is bound), and the direct tendon of the rectus femoris muscle.

FIG. 440.—THE DEEP MUSCLES OF THE BACK OF THE THIGH.



Variations.—It may be fused with the gluteus medius or the piriformis. It may send a slip to the fascia lata or the vastus lateralis. It may be divided into two distinct divisions, an anterior and a posterior. Very frequently from the anterior margin of the muscle a special fasciculus is more or less isolated (the scansorius, invertor femoris, small anterior gluteal, etc.). The accessorius of the gluteus minimus is a small muscle fasciculus which may lie under cover of the gluteus minimus and extend to be inserted into the capsule of the hip-joint.

BURSÆ

B. ischiadica m. glutei maximi.—A small inconstant bursa between the tuber ischii and the gluteus maximus muscle. B. trochanterica m. glutei maximi.—A large bursa constantly present between the fascial tendon of the gluteus maximus and the posterior lateral surface of the great trochanter and the origin of the vastus lateralis muscle. B. gluteofemoralee.—

Two or three small bursæ on each side of the tendon of attachment of the gluteus maximus to the femur. **B. trochanterica m. glutei medii anterior.**—A small bursa constantly present between the tendon of the gluteus medius muscle and the lateral surface of the great trochanter. **B. trochanterica m. glutei medii posterior.**—A small bursa frequently present between the tendons of the piriformis and the gluteus medius. **B. trochanterica m. glutei minimi.**—A fairly large bursa generally present between the margin of the great trochanter and the tendon of this muscle. **B. m. piriformis.**—A small bursa frequently present between the tendons of the piriformis and superior gemellus muscles and the femur.

2. Ischio-pubo-femoral Musculature of the Hip

The muscles belonging to this group, the obturator internus, the two gemelli, the quadratus femoris and the obturator externus, extend from the pubis and ischium across the back of the hip-joint to the great trochanter and the neighboring part of the shaft of the femur. They are powerful lateral rotators of the thigh. The **obturator internus** (fig. 440), a large, flat, triangular muscle, arises from the pelvic surface of the innominate bone and from the obturator membrane. At the lesser sciatic notch its tendon is joined by the two **gemelli** (fig. 439), one of which arises on each side from the bony projections which make the notch, and the combined tendon is inserted into the trochanteric (digital) fossa. The **quadratus femoris** (fig. 439) passes from the tuber of the ischium to the femur behind and below the great trochanter. These muscles are supplied by special nerves which arise from the front of the sacral plexus and enter the deep surfaces of the muscles. A fifth muscle, attached to the greater trochanter and associated with this group, the **obturator externus,** is differentiated near the adductor muscles of the thigh and is supplied by a branch from the obturator nerve. It arises from the outer surface of the bones bounding the ventral two-thirds of the obturator foramen and is inserted by a tendon into the trochanteric (digital) fossa.

These muscles seem to have no certain representatives in the arm, where the shoulder-joint is entirely ensheathed by the dorsal musculature. It is possible that the pectoral group has a corresponding embryonic origin. The group is represented, with marked variations, in the lower extremities of amphibia and all higher vertebrates.

FASCIÆ

Within the pelvis the obturator internus lies on the obturator membrane. It is covered by the **obturator fascia,** which is attached to the body of the pubis, to the iliac portion of the arcuate line, to the ventral margin of the great sciatic notch, to the ischial spine, to the sacrotuberous (great sacrosciatic) ligament, and with the falciform process of that ligament, to the ischial and pubic rami. Near the upper part of the obturator foramen the fascia instead of being attached to bone is reflected over the muscle and attached to the obturator membrane. It here helps to bound the canal for the obturator vessels and nerve. The upper part of the fascia lies beneath the pelvic peritoneum and the levator ani. The lower part forms the outer boundary of the ischiorectal fossa. The fascia is continued as a thin, adherent membrane over the obturator internus and the gemellus muscles to their attachment. The quadratus femoris is invested by a thin adherent fascial sheet.

MUSCLES

The obturator internus (fig. 440).—*Origin.*—From (1) the pelvic surface of the pubic rami near the obturator foramen; (2) the pelvic surface of the ischium between the foramen and the great sciatic notch; (3) the deep surface of the obturator internus fascia; (4) the fibrous arch which bounds the canal for the obturator vessels and nerve; and (5) the pelvic surface of the obturator membrane except in the lower part.

Structure and insertion.—From this extensive area of origin the fiber-bundles converge toward the lesser sciatic notch and become applied to the broad tendon of insertion. At the notch the muscle curves laterally and extends outward and upward to its insertion into the fore part of the trochanteric fossa of the femur. The tendon is formed of five or six bands which begin high in the muscle and converge into a common tendon situated on the deep surface of the muscles as the latter curves about the ischium. The tendon bands at first throw the tendon into folds which run in ridges in the fibrocartilage which lines the notch. The attachment of fiber-bundles continues upon the dorsal surface of the tendon to half way between the lesser sciatic notch and the great trochanter.

Nerve-supply.—A special nerve to the obturator internus arises from the front of the sacral plexus, usually from the lumbosacral cord and the first and second sacral nerves. This nerve passes lateral to the sacrospinous (lesser sciatic) ligament, then re-enters the pelvis through the lesser sciatic notch and sends out branches of distribution on the pelvic surface of the obturator internus.

Action.—This muscle with its two companions, the gemelli, is a powerful lateral rotator of the thigh. It is also an extensor and abductor when the thigh is bent at a right angle.

Relations.—The chief pelvic relations have been described in connections with the obturator fascia which completely covers the medial surface of the muscle. The muscle passes out between the two sacroischial (sacrosciatic) ligaments. Outside the pelvis the gemellus muscles run on each side of the tendon, which is here closely applied to the capsule of the joint. Dorsal to it lie the gluteus maximus, the sacrotuberous (great sacrosciatic) ligament, the inferior gluteal (sciatic) vessels, and the sciatic and posterior cutaneous nerves. The nerve of the quadratus femoris runs beneath the obturator internus and gemellus muscles.

Variations.—It varies in the extent of its insertions. It may be divided into two parts, a pubic and an ischial. Fasciculi may be sent to the posteroinferior part of the iliopectineal eminence, the tendon of the psoas minor, the tuber ischii, the sacrotuberous (great sacrosciatic) ligament, the ischial spine, etc.

The gemellus superior (fig. 439).—*Origin.*—From the outer surface of the ischial spine and the neighboring edge of the lesser sciatic notch.

Structure and insertion.—The fiber-bundles encircle the upper border and ventral aspect of the tendon of the obturator internus. They are inserted into the upper border of this tendon, and sometimes also into the trochanteric fossa.

Nerve-supply.—From a small nerve which arises either directly from the plexus or as a branch of the nerve to the obturator internus or of that to the quadratus femoris. This nerve usually enters the deep surface of the muscle near the junction of its ischial and middle thirds.

Action.—It is essentially a part of the obturator internus.

Relations.—It lies between the piriformis and the tendon of the obturator internus. Proximally it adjoins its fellow beneath this tendon; distally, the two gemelli enclose the tendon in a musculotendinous sheath.

Variations.—It may be wanting or may have a more extensive origin than usual. It may be joined to the piriformis or to the gluteus minimus or be joined more closely than usual to the obturator tendon.

The gemellus inferior.—*Origin.*—From the upper part of the inner border of the tuberosity of the ischium, the sacrotuberous (great sacrosciatic) ligament and from the neighboring edge of the lesser sciatic notch.

Structure and insertion.—The fiber-bundles converge upon the inferior border of the tendon of the obturator internus, and are inserted by tendon-fibers into this or into the great trochanter below the obturator internus tendon.

Nerve-supply.—From a branch of the nerve to the quadratus femoris. This branch enters the deep surface of the muscle near the junction of the ischial with the middle third.

Action.—It is essentially a part of the obturator internus.

Relations.—It lies between the quadratus femoris and the tendon of the obturator internus.

Variations.—It is rarely absent. It may be joined to the quadratus femoris. It is frequently closely bound up with the obturator internus. It may be doubled.

The quadratus femoris (fig. 439).—*Origin.*—From the upper part of the outer border of the tuber of the ischium.

Structure and insertion.—The fiber-bundles take a nearly parallel course and are inserted into the vertical ridge which terminates above on the inferior dorsal angle of the great trochanter.

Nerve supply.—From a nerve which arises usually from the lumbosacral cord and the first sacral nerve and passes under the gemelli and the tendon of the obturator internus. The nerve enters the deep surface of the muscle near the junction of the ischial and middle thirds.

Action.—It is a powerful lateral rotator and a weak adductor of the thigh.

Relations.—It is covered by the gluteus maximus. Between this muscle and the quadratus femoris runs the sciatic nerve. The obturator externus muscle lies in front. The inferior gemellus extends along its superior border. The adductor minimus adjoins it distally.

Variations.—It is absent in from 1 to 2 per cent. of instances. (Schwalbe and Pfitzner.) It may be double near its femoral insertion. It may be fused with the inferior gemellus or the adductor magnus. It may send a fasciculus to the semimembranosus.

The **obturator externus** (figs. 438, 440, 443).—*Origin.*—From the lateral surface of the pubic and ischial rami, where they bound the obturator foramen, and from the surface of the obturator membrane.

Structure and insertion.—Often the muscle is distally divided into three fasciculi, a superior from the superior pubic ramus, a middle from the inferior pubic ramus and the obturator membrane, and an inferior from the ischium. The fiber-bundles converge upon a tendon which is at first deeply buried, then appears on the lateral surface of the muscle and is continued as a rounded tendon over the capsule of the joint to its insertion into the dorsal part of the trochanteric fossa.

Nerve-supply.—The obturator nerve gives rise, usually in the obturator canal, to a branch which bifurcates to enter the superior border and ventral surface of the muscle in its middle third.

Action.—It is a powerful lateral rotator of the thigh and is also a weak adductor.

Relations.—It is covered by the pectineus, the iliopsoas, and the adductor magnus muscles in front, and by the quadratus femoris behind near its insertion. It covers over the obturator membrane. The obturator nerve passes either above the muscle or through its upper portion.

Variations.—The reported variations are few. It may be joined by a slip from the adductor brevis.

BURSÆ

B. m. obturatoris interni.—A fairly large bursa constantly present between the tendon of the obturator internus muscle and the lesser sciatic notch. It may extend on each side beneath the gemellus muscles. **B. m. quadrati femoris.**—A small bursa frequently found between this muscle and the small trochanter. **B. m. obturatoris externi.**—A bursa is sometimes found between the tendon of this muscle and the capsule of the joint.

B. MUSCLES OF THE THIGH

In the thigh three groups of muscles may be recognized, an anterior or extensor (figs. 442, 443), a medial or adductor (figs. 440, 442, 443), and a posterior, flexor or hamstring group (figs. 439, 444).

In the proximal part of the thigh the anterior group of muscles is separated from the medial group by the iliopsoas muscle (fig. 442) and by the femoral blood-vessels and nerve, and from the posterior group by the gluteus maximus (fig. 444). More distally it is separated from the medial group by the medial intermuscular septum and from the posterior by the lateral intermuscular septum (see p. 499). The medial and posterior groups are closely associated. The adductor magnus belongs ontogenetically to both.

The three groups of muscles, with numerous modifications, are represented in the thighs of amphibia and all higher vertebrates. In the human arm they are likewise represented, the adductor group in a much reduced form by the coracobrachialis. The quadriceps is represented by the triceps in the arm, the long head of the triceps corresponding with the rectus femoris. The hamstring muscles are represented by the biceps and the brachialis.

FASCIÆ

The **fasciæ** and the relations of the musculature of the thigh may be followed in the cross-sections, figs. 438, 441, 445.

The **tela subcutanea** of the thigh varies considerably in thickness in different regions, but is well developed throughout and contains a considerable amount of fat. Over the front of the thigh, especially in the upper medial region, one or more deeper membranous layers may usually be separated from the superficial adipose layer. Between the former and the latter are situated the inguinal lymphatic nodes and the saphenous vein. The deepest layer near the inguinal (Poupart's) ligament is fused with the fascia lata (see below). Medially it is attached to the pubic arch. Thus fluids beneath the tela subcutanea of the abdomen and perineum do not readily pass into the region of the thigh.

Over the lower half of the patella a subcutaneous bursa (**b. præpatellaris subcutanea**) is found. Another is usually found over the upper end of the patellar ligament (**b. infrapatellaris subcutanea**).

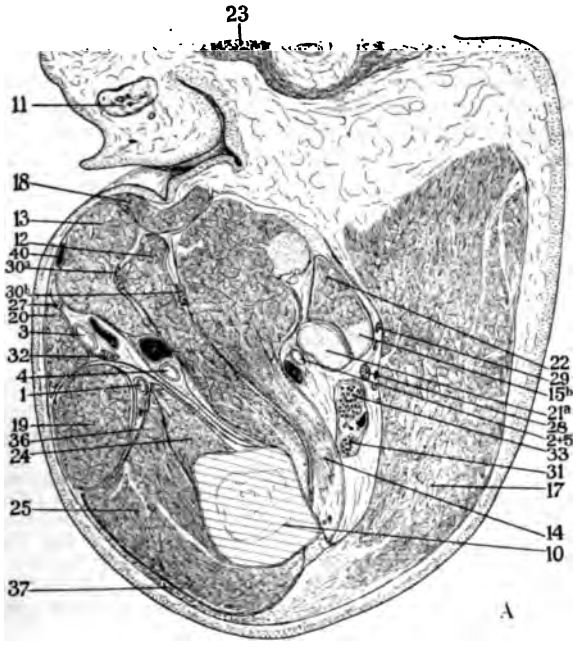
The muscles of the thigh are enclosed in a dense fascial sheet, the **fascia lata** (figs. 418, 441). The gluteal portion of this and the iliotibial band have already been described (p. 491). The ventral portion of the fascia, composed chiefly of transverse fibers, is a dense, fibrous membrane. Above it is attached to the inguinal ligament from the anterior superior spine to the pubic tubercle. Below it extends over the knee, where it is united to the capsule of the joint and is strengthened by expansions from the vastus lateralis and medialis. Between the front of the patella and the fascia is a bursa (**b. prepatellaris subfascialis**). Above the knee the fascia is strengthened by an *arciform process* which extends obliquely distally across the fascia from the iliotibial band to the capsule of the knee. This gives rise to a fold in the skin when the leg is extended and the muscles are not tense. Over the medial and posterior regions of the thigh the fascia is less dense. It extends from the body and inferior ramus of the pubis, the inferior ramus and tuber of the ischium, and the sacrotuberous ligament into the fascia of the back of the leg. Above the popliteal space it is strengthened by a transverse band of fibers. Near the knee the tendons of the quadriceps, sartorius, gracilis, and semitendinosus become bound to the fascia by membranous laminæ.

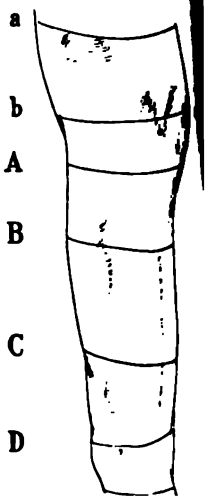
The relations of the fascia lata to the inguinal ligament and the iliac fascia are somewhat complex. The fascia of the iliopsoas muscle extends over the muscle to its femoral insertion. Above the inguinal ligament this fascia is called the **fascia iliaca**; below the ligament, the **fascia iliopectinea**. This fascia is firmly united to the lateral extremity of the inguinal ligament. The pectineus muscle is likewise invested with a fascial membrane which extends over the muscle from the pubis to the femur and is fused laterally with that of the iliopsoas. This combined fascia is firmly bound between the muscles to the iliopectineal eminence. The iliopectineal fascia divides the space beneath the inguinal ligament into a lateral **lacuna musculorum**, which contains the iliopsoas muscle and the femoral (anterior crural) nerve, and a medial **lacuna vasorum**, which contains the femoral artery and vein. Medial to the vein is the **femoral ring**, bounded medially by the **lacunar (Gimbernat's) ligament**. This is closed off from the abdominal cavity by a septum derived from the transversalis fascia, the **femoral septum**, but offers passage for lymph-vessels.

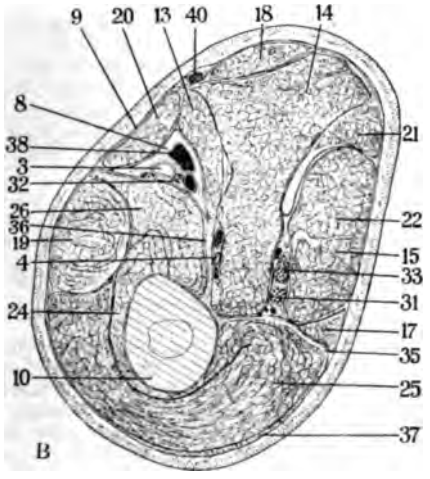
Beyond the inguinal ligament the fasciæ of the iliopsoas and pectineal muscles line a triangular space, **Scarpa's triangle** [trigonum femorale], a space bounded by the inguinal (Poupart's) ligament and the sartorius and long adductor muscles. Within this triangle is a depression, the **iliopectineal fossa**, through which run the femoral vessels (fig. 438). The sartorius muscle partly overlies the distal lateral margin of this fossa. The fascia lata is here reflected from the surface of the sartorius to the iliopsoas fascia, and becomes fused with it. From the medial margin of the sartorius a process of the fascia is continued over the lateral and upper part of the fossa, and is attached to the inguinal and lacunar (Gimbernat's) ligaments (fig. 420). Over the lower extremity of the fossa a process is continued medially into the pectineal fascia. On the medial margin of the fossa the fascia lata is continued directly into the pectineal fascia. The lateral concave margin of the fascia overlying the fossa is called the **falciform margin**; the upper extremity of this, the **superior cornu**; the distal extremity, the **inferior cornu**. The oval space bounded by the margo falciformis is called the **fossa ovalis** (saphenous opening).

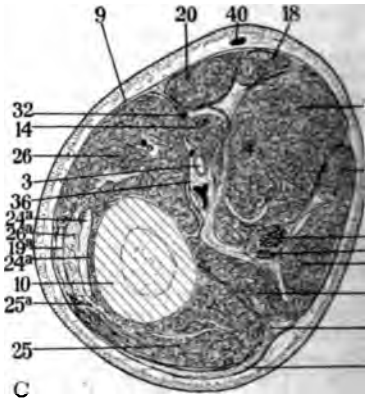
FIG. 441, A–D.—TRANSVERSE SECTIONS THROUGH THE LEFT THIGH IN THE REGIONS INDICATED IN THE DIAGRAM.

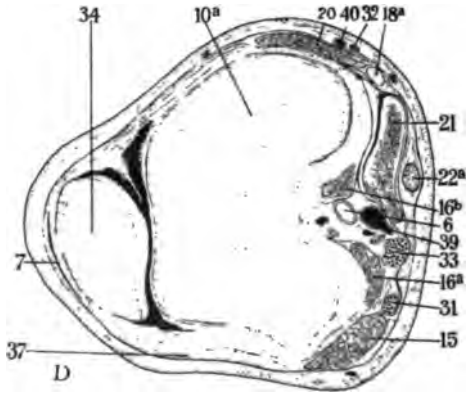
a and *b* in the diagram indicate the regions through which pass sections A and B, fig.











This is covered by the **fascia cribrosa** [illegible] and others a portion of the fascia lata [illegible] passage of blood-vessels and lymphatics [illegible] between the femoral ring and the [illegible]

From the fascia internus [illegible] these, the medial and lateral [illegible]

The **lateral intermuscular septum** [illegible] group. It extends from the [illegible] composed chiefly of longitudinal fibers and [illegible] to its ventrolateral surface [illegible]

It will be noted that this septum [illegible] musculature, with the exception of the [illegible] occupies a position, perhaps [illegible]

The **medial intermuscular septum** [illegible] adductor musculature. It is perhaps simplest in the [illegible] pectineal fossa (fig. 441B). [illegible] between the sartorius and [illegible] the other. The septum here [illegible] tween the two laminæ there is a [illegible] membrane extends between the [illegible]

More distally the same [illegible] sartorius on the lateral margin [illegible] the medial margin to a [illegible] magnus. Beneath the sartorius and between the [illegible] triangular space bounded by the sheaths of these muscles [illegible] in which run the chief blood-vessels of the thigh. This space [illegible] is known as **Hunter's canal**, or the **adductor canal**. [illegible] surrounding fibrous tissue pass through the [illegible] adductor magnus and the femur, to the back of the thigh [illegible] posterior surface of the vast[illegible] to the femur.

MUSCLES

1. The Anterior Group

Figs. 442, 443

This group, which forms a semiconical mass [illegible] the quadriceps femoris and the sartorius muscles [illegible] nerve.

The **sartorius** is a long, ribbon-like muscle [illegible] superior spine of the ilium and extends along the [illegible] passing obliquely across the upper part of the thigh [illegible] dorsomedial side of the knee, whence its tendon [illegible] into the ventromedial surface of the superior extremity of the tibia.

The **quadriceps femoris** is composed of four muscles differentiated from a common embryonic origin. Of these, the **rectus femoris**, which arises from the ventrolateral margin of the ilium by two tendons, is the most superficial and the most completely differentiated. The **vastus lateralis**, which arises from the superior extremity of the ventral surface of the shaft of the femur and from the lateral lip of the linea aspera; the **vastus medialis**, which arises from the medial lip of the linea aspera and from the intertrochanteric line; and the **vastus intermedius** (crureus), which arises between these two and beneath the rectus from the surface of the femur, are less distinctly differentiated from one another. The vastus intermedius and vastus lateralis are partly fused at the insertion. The

1. Arteria circumflexa femoris lateralis. 2. A. circumflexa femoris medialis. 3. A. femoralis. 4. A. femoralis profunda. 5. A. glutea inferior (sciatic). 6. A. poplitea. 7. Bursa præpatellaris subfascialis. 8. Adductor (Hunter's) canal. 9. Fascia lata. 10. Femur—a, distal extremity. 11. Funiculus spermaticus (spermatic cord). 12. Musculus adductor brevis. 13. M. adductor longus. 14. M. adductor magnus. 15. M. biceps femoris—a, long head; b, tendon of origin; c, short head. 16. M. gastrocnemius—a, lateral head; b, medial head. 17. M. gluteus maximus. 18. M. gracilis—a, tendon. 19. M. rectus femoris—a, tendon. 20. M. sartorius. 21. M. semimembranosus—a, tendon. 22. M. semitendinosus—a, tendon. 23. M. sphincter ani. 24. M. vastus intermedius (crureus)—a, tendon. 25. M. vastus lateralis—a, tendon. 26. M. vastus medialis—a, tendon. 27. Nervus cutaneous femoris anterior. 28. N. cutaneous femoris posterior (small sciatic). 29. N. gluteus inferior. 30. N. obturatorius—a, superficial branch; b, deep branch. 31. N. peroneus communis (external popliteal). 32. N. saphenus (great saphenous). 33. N. tibialis (internal popliteal). 34. Patella. 35. Septum intermusculare laterale. 36. Septum intermusculare mediale. 37. Tractus iliotibialis (iliotibial band). 38. Vena femoralis. 39. Vena poplitea. 40. V. saphena magna (great saphenous vein).

intermedius and medialis at their origins. From the four muscles arises a ten which is inserted into the tuberosity of the tibia. In this tendon, which closely applied to the capsule of the knee-joint, lies a sesamoid bone, the pate

The sartorius and the rectus flex the thigh; the quadriceps extends the the sartorius flexes the leg and rotates the thigh lateralward and the medialward.

FIG. 442.—MUSCLES OF THE FRONT OF THE THIGH.

In the embryo the sartorius has an origin distinct from that of the quadriceps. anthropoid apes it is much more developed than in man.

In addition to supplying the muscles of this group, the femoral nerve also gives br to the iliacus muscle (p. 487) and the pectineus muscle (p. 503).

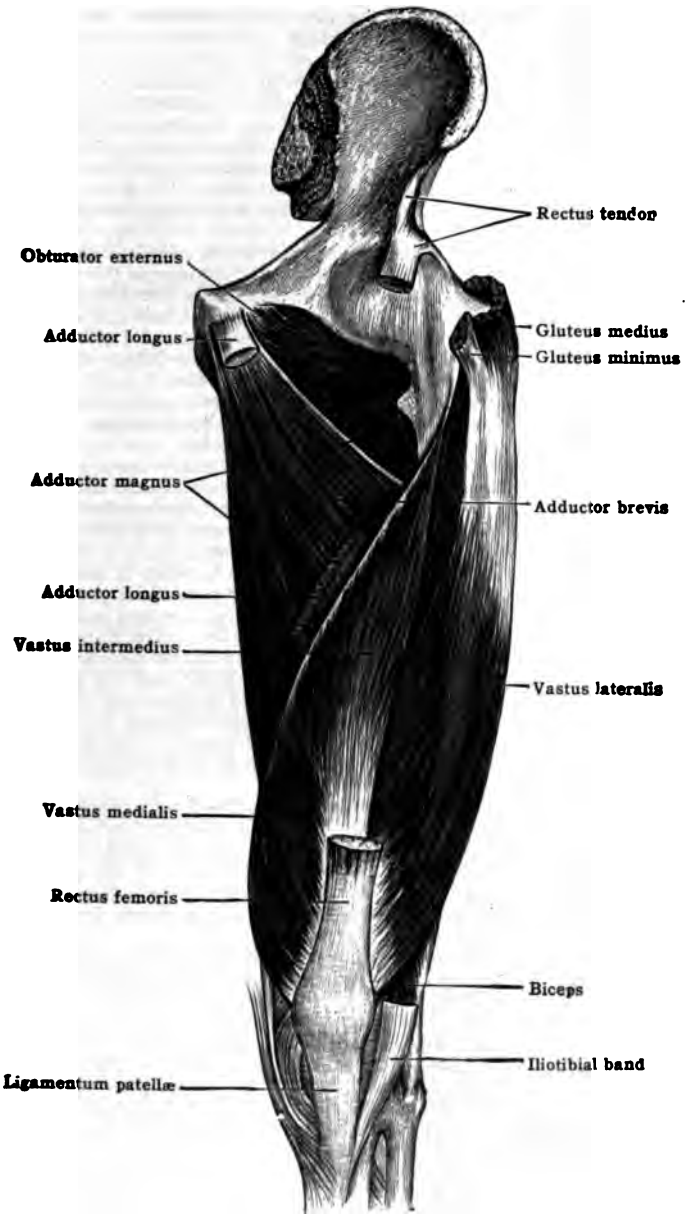
The sartorius (fig. 442).—*Origin.*—From the anterior superior spine of the ilium a area immediately below this.

Insertion.—Into the medial surface of the tibia near the tuberosity and into the neigh fascia of the leg.

ire.—The muscle arises by short tendinous strands. The fiber-bundles take a nearly ırse. The component muscle-fibers are said to be the longest in the body. Near the icondyle of the femur the tendon of insertion makes its appearance on the deep as- ıe muscle. On the superficial surface of the tendon the muscle-fibers are inserted the distal margin of the knee-joint. From there the tendon turns forward to its

supply.—Usually two branches enter the deep surface of the proximal third of the One or both of them may be bound up with an anterior cutaneous nerve passing

FIG. 443.—THE DEEP MUSCLES OF THE FRONT OF THE THIGH.



ıe muscle. The first of the branches is distributed chiefly to the lateral and proximal, i to the medial and distal, portions of the muscle. Within the muscle is a complex

.—(1) To flex the thigh at the hip, abduct and rotate it lateralward; (2) to flex the leg ı it slightly medialward; (3) to make tense the medial part of the fascia lata.
ns.—The sartorius lies in a fascial canal bounded by the fascia lata and by inter- septa which descend from this. It crosses the rectus femoris, iliopsoas, the adductor d magnus, and the vastus medialis muscles, the femoral vessels and nerve, and the . At its insertion its tendon covers the gracilis and semitendinosus.

Variations.—It may arise from the inguinal ligament or be inserted into the fascia lata, the medial epicondyle, or the capsule of the knee-joint. It may be longitudinally divided into two parts. The tendon of the secondary slip is in such instances usually attached to the capsule of the knee-joint, but sometimes is attached to the fascia over the vastus medialis or to the anterior wall of the adductor canal. More frequently the muscle is partly divided proximally or distally. The secondary tendon of origin may arise from the anterior inferior spine, the iliopectineal eminence, etc. The muscle is very rarely absent. It may be crossed by a tendinous inscription, or more rarely it is rendered digastric by an intervening tendon.

The quadriceps femoris (figs. 442, 443).—This, as pointed out above, is composed of the rectus femoris and the vastus lateralis, intermedius, and medialis.

The rectus femoris (fig. 442).—*Origin.*—By two tendons. The anterior 'straight' tendon is attached to the anterior inferior spine of the ilium; the posterior 'reflected' tendon to the posterosuperior surface of the rim of the acetabulum. The two tendons unite so as to form a small arch above the capsule of the joint.

Structure and insertion.—From this arch an aponeurotic expansion descends upon the front of the muscle nearly to the middle of the thigh. This expansion is broad above, becomes narrower as it descends, and is continued a short distance as a narrow intramuscular tendon after it disappears from the surface. The tendon of insertion begins on the back of the muscle above the middle of the thigh, expands into a broad aponeurosis, and finally becomes a strong band which is inserted into the proximal border of the patella. The fiber-bundles pass in a bipenniform manner from the back and sides of the tendon of origin to the front and sides of the tendon of insertion.

Nerve-supply.—As a rule, two branches enter the muscle. One of these enters the deep surface of the muscle in its upper fourth, and is distributed mainly to the proximal part of the lateral half. The other enters the medial margin of the muscle near the junction of the proximal and middle thirds, and is distributed chiefly to the medial half and distal portion of the muscle.

The vastus lateralis (vastus externus) (fig. 443).—*Origin.*—From—(1) the shaft of the femur along the anteroinferior margin of the great trochanter and in front of the gluteal tuberosity; and (2) the lateral intermuscular septum along the upper half of the linea aspera.

Insertion.—By a flat tendon into—(1) the proximolateral border of the patella; and (2) the front of the lateral condyle of the tibia and the fascia of the leg.

Structure.—The fiber-bundles arise partly from the bone, partly from an aponeurosis which covers the proximal two-thirds of the muscle, and from the lateral intermuscular septum. They take a parallel course distally in a ventromedial direction, and are inserted into an aponeurosis which lies on the deep surface of the muscle and receives fibers until within a few centimeters of the patella. Ventrally this aponeurosis fuses with the rectus tendon, laterally with that of the vastus medialis, and dorsally it receives some of the fiber-bundles of the vastus intermedius. Commonly the muscle is distinctly divisible for the greater part of its course into two sheets, a superficial and a deep. The deep sheet is often subdivided into two laminæ.

Nerve-supply.—Usually there are three nerves, one of which, accompanied by blood-vessels, runs on the inner surface of the superficial sheet midway between the tendons of origin and insertion, the second between the two laminæ of the deep layer, and the third passes through the innermost lamina to be distributed in part to the vastus intermedius (crureus) muscle.

The vastus medialis (vastus internus) (fig. 443).—*Origin.*—From the whole extent of the medial lip of the linea aspera and from the distal half of the intertrochanteric line. The origin takes place by means of an aponeurosis which is adherent to the tendons of insertion of the adductor muscles.

Structure and insertion.—The fiber-bundles arise from the deep surface of this aponeurosis and are inserted on the medial surface and margin of a tendon which begins on the deep surface of the muscle about its middle near the lateral margin. On the distal lateral border of the muscle it is inserted into the medial half of the proximal margin of the patella and into the medial condyle of the tibia and the fascia of the leg. For some distance near the knee the lateral margin of the tendon is united to the tendons of the vastus intermedius (crureus), lateralis (externus) and the rectus.

Nerve-supply.—The nerve to this muscle descends on its medial surface, often bound up with the saphenous nerve for a part of its course. It gives off successive branches and finally sinks into the muscle substance. These branches enter about midway between the origin and insertion of the fiber-bundles of the muscle.

The vastus intermedius (crureus) (figs. 441, 443).—*Origin.*—From (1) the distal half of the lateral margin of the linea aspera and its lateral bifurcation; (2) the anterolateral surface of the shaft of the femur. Between the origin of the vastus intermedius (crureus) and that of the vastus medialis the shaft of the femur is free from muscle attachment.

Structure and insertion.—On the ventral surface of the muscle lies an aponeurosis which extends from its proximal fourth to the proximal margin of the patella. The fiber-bundles of the muscle are inserted into the deep surface of this and into the deep surface of the aponeurosis of insertion of the vastus lateralis. The proximal fiber-bundles descend vertically, the medial and lateral, especially the latter, obliquely to their insertion. Medially the tendon is more or less fused with that of the vastus medialis, and laterally with that of the vastus lateralis. The muscle is composed of muscle lamellæ superimposed concentrically about the shaft of the femur. The deepest, most distal of these is called the **articularis genu** (**suberureus**). The fiber-bundles of this layer are inserted into the capsule of the joint or into the superior margin of the patella.

Nerve-supply.—Several branches are usually distributed to this muscle. To the lateral region a branch from the nerve to the vastus lateralis is usually given; to the middle of the muscle another branch descends from the femoral (anterior crural) nerve; to the medial portion there extend several twigs from the nerve to the vastus medialis.

Tendon of the quadriceps.—The quadriceps tendon may be more or less distinctly divided into layers, of which the superficial layer belongs to the rectus, the deep to the vastus

...rmedius, and the intermediate to the vastus lateralis and medialis. Some of the more **...rficial fibers of the tendons of the two vasti, however, cross in front of the rectus ten-** The combined tendon of the quadriceps is in part attached to the superior and lateral **...rgins of the patella, and in part extends over the patella into the patellar ligament. A ...rt of the tendon fibers of the vastus lateralis and medialis run on each side of the patella to ...e ventral surface of the condyles of the tibia. These form the retinacula patellæ mediale and ...erale.** The medial is the broader and better developed. With the retinacula are included **...ndles of fibers which run from the epicondyles to the patella and into which some muscle ...er-bundles are inserted. From the apex of the patella to the tuberosity of the tibia the ...adriceps tendon is continued as the patellar ligament** (fig. 446).

Nerve-supply.—The relations of the branches of distribution to the various parts of the **...uscle** have been pointed out above in connection with each head. The general relations of **...ese** branches of the femoral nerve are as follows:—From the femoral nerve near the proximal **...d** of the vastus medialis the branches for the vastus lateralis, vastus intermedius (crureus), and **...ctus** pass distally and laterally between the rectus and vastus intermedius (crureus) to be **distributed** to the muscles named, while the chief nerve for the vastus medialis descends on the **...edial** side of this muscle in company with the saphenous nerve. The branches to the vastus **...teralis** and intermedius are commonly bound up in a single nerve-trunk for some distance. **The** branches to the rectus are usually bound up with this trunk for a shorter distance. The **...erve** to the vastus medialis may be united to this trunk for a slight distance, but more **frequently** it is more or less bound up with the saphenous nerve.

Action.—The quadriceps is the extensor of the leg. The rectus femoris also flexes the thigh **at** the hip and is a weak abductor of the thigh. The articularis genu makes tense the capsule **of** the knee-joint.

Relations.—The quadriceps is covered ventrally immediately by the fascia lata. The **...rtorius** runs along its medial margin; the tensor fasciæ latæ lies over the proximal quarter **of** its lateral surface. Dorsal to the vastus lateralis lie the gluteus maximus and biceps; dorso-**...edial** to the vastus medialis, the three adductor muscles and the semimembranous. Next **to** vastus medialis lies the adductor canal with the femoral vessels and the saphenous nerve.

Variations.—The variations of this muscle, aside from a greater or less fusion of its parts, **are** not marked. The attachment of the rectus femoris to the anterior inferior spine, which **takes** place in the embryo later than its insertion above the acetabulum, may be wanting. On **the** other hand, this tendon may extend to the anterior superior spine. Occasionally the deep **reflected** tendon may be wanting. The **rectus accessorius** is a fasciculus rarely found, which **arises** by a tendon from the rim of the acetabulum and is inserted into the ventral edge of the **vastus** lateralis. It is innervated by a twig from the branch to the rectus.

Bursæ

B. m. recti femoris (superior).—A small bursa between the deep tendon of the rectus femoris **and the edge of the acetabulum. Rare. B. m. recti femoris (inferior).**—Between the tendon **of the rectus and combined tendon of the vastus lateralis and medialis. Occasional. B. præpatellaris subtendinea.**—A bursa between the tendon of the quadriceps and the periosteum **of the patella. Of the three præpatellar bursæ—the subcutaneous, subfascial, and subten-dinous—as a rule only one occurs. When two or three exist, they usually communicate freely with one another. B. suprapatellaris.**—A bursa between the anterior surface of the lower end **of the femur and the tendon of the quadriceps. It usually communicates with the joint cavity. B. infrapatellaris profunda.**—A bursa between the patellar ligament and the tibia. It seldom **communicates with the joint cavity. B. m. sartorii propria.**—A bursa, fairly large, between the **tendon of the sartorius and the tendons of the semitendinosus and gracilis muscles. This usually communicates with the bursa anserina** (see p. 506).

2. The Medial (Adductor) Group
(Figs. 440, 442, 443)

To this group of muscles belong the gracilis, the pectineus, the adductors brevis, longus, and magnus, and the obturator externus. The most superficial of the group is the **gracilis** (figs. 439, 442). This ribbon-shaped muscle arises from the inferior pubic and ischial rami, extends along the medial side of the thigh, and gives rise to a tendon which curves forward from behind the medial condyle of the femur to be inserted under the tendon of the sartorius into the medial side of the upper extremity of the tibia. The quadrilateral **pectineus** arises from the body and superior ramus of the pubis; the triangular **adductor longus** from the superior ramus medial to this (fig. 442). The pectineus is inserted into the pectineal line of the femur; the adductor longus into the middle third of the linea aspera. The triangular **adductor brevis** (fig. 443) arises from the inferior pubic ramus below the adductor longus. It is inserted into the pectineal line and the upper third of the linea aspera. The large, triangular **adductor magnus** (figs. 440, 443) arises from the inferior ramus and the tuber of the ischium and is inserted behind the short and long adductors into the whole length of the linea aspera, and by a special tendon into the adductor tubercle of the femur. The deepest muscle of the group, the **obturator externus,** which arises from the outer

surface of the bones bounding the ventral two-thirds of the obturator foramen and is inserted by a tendon into the trochanteric (digital) fossa, has been described in connection with the ischio-pubo-femoral muscles of the hip.

All the muscles of this group adduct the thigh. The gracilis, obturator externus, adductor brevis and the lower part of the adductor magnus (when the thigh is extended) rotate it lateralward. The pectineus, adductor longus, and the adductor magnus rotate it medialward. Those attached to the pubis flex the thigh. The gracilis flexes the leg and rotates it medialward. The inferior part of the adductor magnus extends the thigh.

The muscles of this group are supplied by the obturator nerve, except the pectineus, which usually gets its whole supply from the femoral (anterior crural) nerve, and the adductor magnus, which gets a part of its supply from the sciatic nerve.

In embryonic development the pectineus arises in close conjunction with the obturator group, and in the adult it may get the whole or a part of its nerve-supply from the obturator nerve or from the accessory obturator nerve. In the lower mammals the nerve-supply may come from the femoral (anterior crural) or the obturator nerve or from both. It is not certain whether the innervation from the femoral nerve indicates that the muscle belongs phylogenetically, if not ontogenetically, with the primitive dorsal musculature of the limb. By some it is considered to be derived in part from the primitive dorsal, in part from the primitive ventral, musculature. The adductor magnus arises in the embryo as two distinct portions, one connected with the flexor group of muscles, the other with the adductor group. These two portions later become fused. Primitively the sciatic portion of the adductor magnus and the semimembranosus constitute a single medial flexor muscle.

The gracilis (figs. 439, 442).—*Origin.*—By a flat tendon from the medial margin of the inferior ramus of the pubis and the pubic extremity of the inferior ramus of the ischium.

Structure and insertion.—The nearly parallel fiber-bundles which arise between two laminæ of the tendon form a thin band of muscle which is narrower and thicker distally than proximally. They are inserted on a tendon which begins as an aponeurosis on the posterior border and medial surface of the muscle in the distal third of the thigh, becomes free as a rounded cord a little proximal to the medial condyle of the femur, runs behind the condyle, and then turns forward to be inserted by an expanded process into the tibia below the medial condyle.

Nerve-supply.—The nerve enters the deep surface of the muscle near the junction of the superior and middle thirds.

Action.—To adduct, flex and (slightly) rotate the thigh lateralward, and flex the leg. With the knee flexed, it acts as a medial rotator of the leg.

Relations.—It occupies a position beneath the fascia lata and superficial to the adductor brevis, longus, and magnus muscles. Distally the sartorius lies in front, the semimembranosus behind. Its tendon crosses the tibial collateral ligament of the knee-joint and the tendons of the semitendinosus and the semimembranosus, and is overlapped by that of the sartorius.

Variations.—The pubic origin of the muscle may be much reduced or may be double. Its tendon of insertion may give rise to an accessory fasciculus which extends distally in the leg. In some of the apes the tendon descends normally much farther down the leg than in man.

The pectineus (fig. 442).—*Origin.*—(1) From the pecten (crest) of the os pubis, the bone in front of this, and the pectineal fascia near this origin; and (2) from the anterior margin of the obturator sulcus and from the pubocapsular ligament. Laterally the two areas of origin are usually separated by most of the superior surface of the body of the pubis. Medially they come together.

Structure and insertion.—From each area of origin a separate lamina arises. The fiber-bundles of each layer take a nearly parallel course and terminate between two tendinous lamellæ which fuse to be inserted into the upper half of the pectineal line behind the small trochanter. The fiber-bundles of the superficial layer cross those of the deep slightly obliquely. The muscle faces ventrally at its origin, laterally at its insertion.

Nerve-supply.—From a branch of the femoral (anterior crural) nerve, which passes behind the femoral artery and vein and through the pectineal fascia to enter the ventral surface of the muscle. It may also be supplied by the accessory obturator nerve, when present, or by a branch from the obturator. When both the femoral (anterior crural) and obturator nerves supply this muscle, the femoral supplies the superficial, the obturator, the deep lamina (Paterson).

Action.—To flex and adduct the thigh (as in crossing the legs).

Relations.—It is covered by the pectineal fascia, lies between the iliopsoas and the adductor longus muscles, and crosses the obturator externus and adductor brevis muscles. The medial circumflex artery runs between it and the iliopsoas, the deep femoral artery between it and the adductor longus.

Variations.—The extent of the division of the pectineus into superficial and deep portions varies considerably. It may also be divided into a lateral and a medial division. Often the pectineus is fused with the adductor longus. It may receive an accessory fasciculus from the capsule of the hip-joint, the iliacus muscle, the obturator externus, or the adductor brevis muscles, or the small trochanter. It may send a fasciculus to the sartorius.

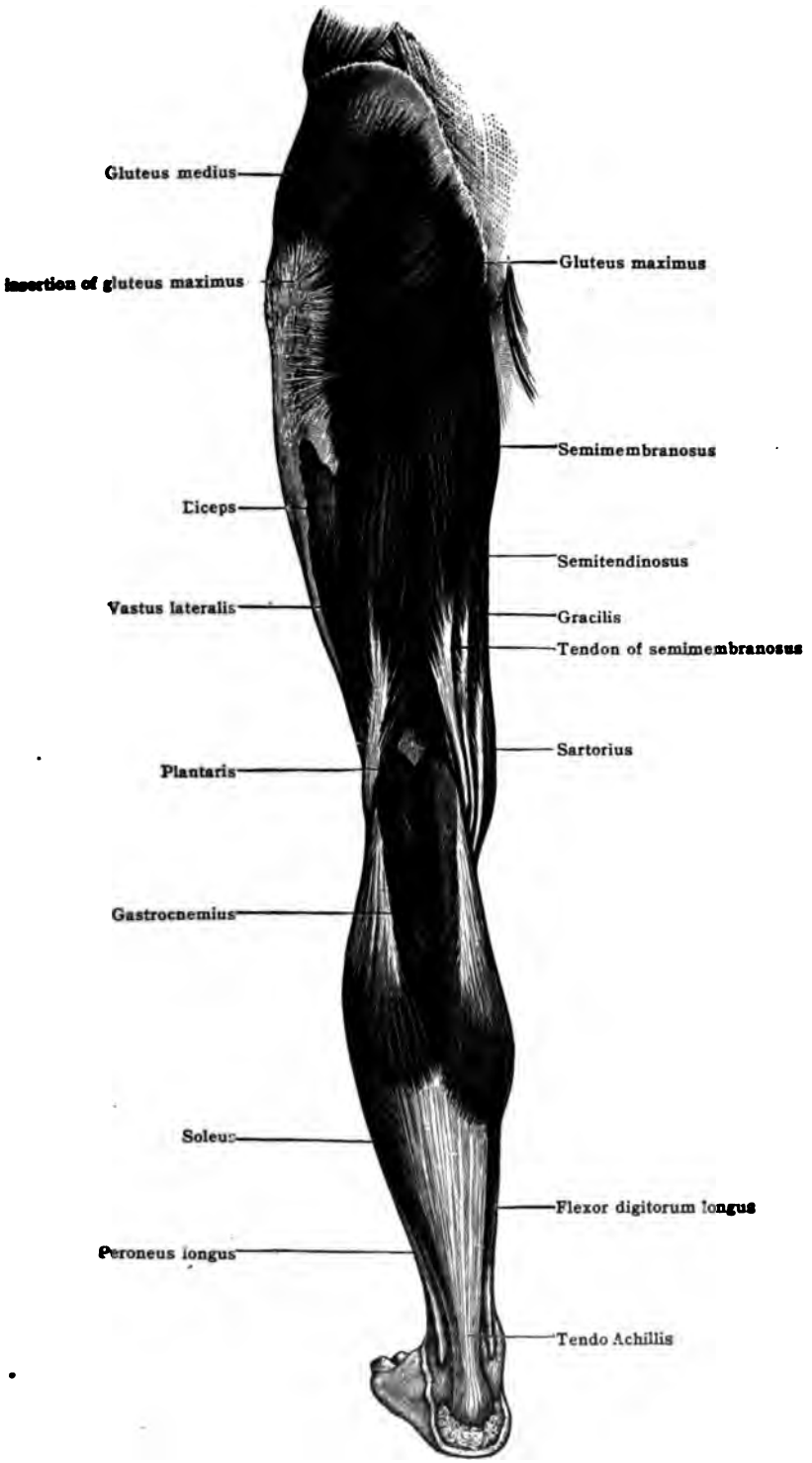
The adductor longus (fig. 442).—*Origin.*—From the medial corner of the superior ramus of the pubis by a strong tendon which extends for some distance on the medial border of the muscle.

Structure and insertion.—From this tendon the fiber-bundles diverge toward their insertion. This takes place between two lamellæ of a short tendon attached to the middle third of the linea

The tendon is usually fused to the medial intermuscular septum and sends an expan- the long tendon of the adductor magnus.

ve-supply.—A branch from the anterior division of the main obturator trunk gives off

FIG. 444.—SUPERFICIAL MUSCLES OF THE BACK OF THE THIGH AND LEG.



twigs which enter the middle third of the deep surface of the muscle. Occasionallya ranch from the femoral (anterior crural) nerve enters the muscle. This is probably in nature.

Action.—To adduct and flex the thigh, and rotate it medialward.

Relations.—The sartorius, the vastus medialis, and the femoral vessels lie anterolat to it. Behind it lie the adductor brevis and adductor magnus muscles. Between these the longus run the profunda vessels. Its lateral border touches the pectineus above, bu separated from it toward the insertion.

Variations.—It may be fused with the other adductors, including the pectineus. It m be doubled. The femoral insertion may extend to the medial epicondyle.

The adductor brevis (fig. 443).—*Origin.*—From the medial part of the outer surface of t inferior ramus of the pubis directly, and by means of short tendinous processes or a short f tendon.

Structure and insertion.—From their origin the fiber-bundles diverge into a sheet which inserted by short tendinous bands into the distal two-thirds of the pectineal line and the up third of the linea aspera. The muscle is more or less completely divided into two fasciculi alo its insertion. The place of division is near where the intertrochanteric line curves away fro the linea aspera.

Nerve-supply.—Usually from the anterior but also sometimes from the posterior branch of the main obturator trunk. The rami enter the middle third of the muscle near the proximal border.

Action.—It is chiefly an adductor and to a less extent a flexor and a lateral rotator of the thigh.

Relations.—In front lie the pectineus and adductor longus; behind, the obturator externus quadratus femoris and adductor magnus. It is crossed by the profunda artery. The first perforating artery passes usually between the two fasciculi of the insertion.

Variations.—It may be fused with other members of the group. It may be divided completely into two fasciculi, rarely into three.

The adductor magnus (figs. 440, 443).—The *origin* of this muscle begins on the inferior ramus of the pubis posterior to the origins of the adductor brevis and gracilis muscles. From here it extends backward along the inferior margin of the ventrolateral surface of the ischium to the tuberosity. The muscle in passing from this curved origin to its extensive femoral insertion presents posteriorly a longitudinal groove in which rest the hamstring muscles. The adductor magnus is composed of three superimposed fasciculi, of which the first is frequently fairly distinct and is called the **adductor minimus**, while the other two are normally fused, but are occasionally distinct.

The **superior fasciculus** (**adductor minimis**) *arises* directly from the inferior rami of the pubis and ischium. From here the fibers diverge to form a thin sheet *inserted* by tendinous bands to the medial side of the gluteal ridge and the superior part of the linea aspera. The **middle fasciculus** *arises* directly from the inferior margin of the ventrolateral surface of the inferior ramus and the tuber of the ischium, and from a tendon which descends along the dorsomedial margin of the muscle from the tuber ischii. The fiber-bundles diverge to be inserted between the lamellæ of a narrow flat tendon attached to the distal three-fourths of the linea aspera. This tendon is pierced by the perforating vessels. The **inferior fasciculus** arises dorsal to and in common with the middle fasciculus. The fiber-bundles converge toward a strong tendon which begins in the distal third of the thigh and is *inserted* into a tubercle at the distal end of the medial supracondylar ridge.

Nerve-supply.—The chief nerve-supply is from the posterior ramus of the obturator. This enters by one or more branches the proximal portion of the ventral surface of the muscle about midway between its pubic and femoral attachments. It also receives a branch from the sciatic which enters the dorsal surface of the muscle in the middle third of the thigh. To the adductor minimus a branch may be sent from the nerve to the quadratus femoris.

Action.—It is the strongest of the adductors. The superior and middle fasciculi rotate the thigh medialward and flex it; the inferior rotate it lateralward when the thigh is extended, but medialward when the thigh is flexed. The latter also extend the thigh.

Relations.—In front are the pectineus, the short and long adductor and the vastus medialis muscles, and the profunda artery. Behind lie the hamstring muscles and the gluteus maximus. Medially lies the gracilis muscle. The femoral and perforating arteries pass through its attachment to the shaft of the femur.

Variations.—The divisions of the muscle may be more or less distinct. It may be partly fused or exchange fasciculi with neighboring muscles—the semimembranosus, quadratus femoris, adductor brevis, and adductor longus.

Bursæ

B. m. pectinei.—A small bursa frequently present between this muscle and the iliopsoas and small trochanter. **B. anserina.**—A fairly large bursa which lies between the tendons of the sartorius, gracilis, and semitendinosus muscles and the tibial collateral ligament of the knee-joint. (See also B. M. Sartorii Propria, p. 503.)

3. The Posterior (Hamstring) Group

(Figs. 439, 444)

The muscles of this group are the semitendinosus, semimembranosus, and biceps. They flex the leg and extend and adduct the thigh. The semitendinosus and semimembranosus rotate the thigh and the leg medialward; the biceps, lateralward. The semitendinosus and the long head of the biceps constitute a superficial layer; the semimembranosus and the short head of the biceps a deep

er. The **semitendinosus** and the **long head of the biceps** arise by a common don from the tuber of the ischium. The somewhat fusiform semitendinosus es rise to a tendon in the lower half of the thigh. The tendon curves forward ind the knee to be inserted under that of the sartorius into the medial side of e tibia. The penniform **short head of the biceps** arises from the linea aspera the lower part of the thigh, and is inserted, together with the fusiform long ad, into a tendon that passes over the lateral side of the knee and is attached the head of the fibula. The **semimembranosus** arises from the tuber ischii rough a long, flat, triangular tendon. The belly of the muscle incresaes in ckness toward the knee. It is inserted by a strong tendon on the back of the edial condyle of the tibia. From the tendons of all the hamstring muscles pansions are sent into the crural fascia.

The muscles of this group are all supplied by the tibial portion of the sciatic, cept the short head of the biceps, which is supplied from the peroneal portion.

The femoral head of the biceps is characteristic of the anthropoid apes and man. In many mmals its place is taken by a slender muscle, the **tenuissimus**, which extends from the caudal rtebræ, the sacrotuberous (great sacrosciatic) ligament, or the gluteal fascia to the fascia the back of the leg. In some forms this muscle is broad instead of slender. According to stut, the long head of the biceps may be looked upon as arising by two fasciculi, one primirely attached to the posterior part of the ilium, the other to the caudal vertebræ or coccyx. e sacrotuberous (great sacrosciatic) ligament represents the reduced upper portion of this scle. In the fetus the origin of the muscle extends higher on the sacrotuberous ligament an in the adult. In many of the lower mammals the origins of the semimembranosus and nitendinosus take place in part from the sacrocaudal vertebræ.

In the mammals below man the insertion of the biceps, gracilis, and semitendinosus takes ce chiefly into the fascia of the back of the leg, and extends more distally than in man. is insertion of these flexor muscle is associated with a permanent position of flexion the leg at the knee. In the human embryo likewise these muscles are inserted more tally than in the adult. In the lower primates the semimembranosus is chiefly a medial ator of the leg.

Biceps femoris (figs. 439, 444).—**Long head.**—*Origin.*—From a tendon common to it and semitendinosus. This tendon arises from the more medial of the two facets on the back of tuber of the ischium and from the sacrotuberous (great sacrosciatic) ligament. It is tinued for a third of the distance to the knee as a septum between the biceps and the semidinosus, and for a short distance as an aponeurotic sheath on the deep surface of the biceps.

Structure and insertion.—The fiber-bundles begin to arise from the tendon some distance m the ischium. They form a thick fusiform belly which is inserted into the deep surface of endon that begins laterally on the back of the muscle about the middle of the thigh. The ertion of the fiber-bundles of the long head continues on the medial margin of the deep surface the tendon nearly as far as the lateral condyle of the femur.

Short head.—*Origin.*—By short tendinous fibers from the lateral lip of the linea aspera of femur from the middle of the shaft to the bifurcation of this line, the proximal two-thirds the supracondylar ridge, and the lateral intermuscular septum.

Structure and insertion.—The fiber-bundles take a nearly parallel course, to be inserted on deep surface of the common tendon of insertion. The most distal fibers are inserted nearly the skeletal attachment of the tendon. The tendon is inserted into the superior extremity the head of the fibula, into the lateral condyle of the tibia, and into the fascia of the leg.

Nerve-supply.—Commonly two branches are given to the long head of the biceps. One these branches is given off proximal to the ischium, and enters the proximal third of the deep face of the muscle. The other is given off more distally and usually enters the middle third. ther or both branches may be doubled or the two may be combined for some distance in a mmon trunk. The nerve-fibers arise usually from the first, second, and third sacral nerves. e branch to the short head arises from the peroneal (external popliteal) portion of the sciatic rve about the middle of the thigh. It enters the posterior surface near the lateral margin of gin and insertion. The nerve-fibers come chiefly from the fifth lumbar, first and second ral nerves.

Action.—To extend and adduct the thigh and flex the leg. The short head acts only on the . The long head acts as a lateral rotator of the thigh, and of the leg when flexed.

Relations.—The upper extremity of the muscle is covered by the gluteus maximus. Below is the long head and tendon of insertion lie beneath the fascia lata and overlie the short head. ntral to the muscle lie the tendon of origin of the semimembranosus, the adductor magnus d vastus lateralis muscles, and the lateral head of the gastrocnemius. The medial border is contact with the semitendinosus and semimembranosus. Distally it forms the upper lateral rder of the popliteal space. The sciatic nerve runs between it and the adductor magnus.

Variations.—The short head is rarely absent. It may be more isolated from the long ad than usual, and at times has a separate tendon of insertion. It may itself be divided into o distinct laminæ. Its origin may take place higher up on the femur than usual or from the cia lata. Variations of this sort suggest the tenuissimus muscle of some of the lower mamals (see above). The long head of the biceps may receive accessory fasciculi from the coccyx, rum, sacrotuberous (great sacrosciatic) ligament, tuber of the ischium, or the deep surface the gluteus maximus. These fasciculi suggest the iliac and sacrococcygeal origin of the scle found in lower vertebrates (see above). Inferiorly, a muscle fasciculus may take place of the fibrous prolongations from the tendon of the biceps into the sural fascia (the

tensores fasciæ suralis). This may extend to the tendon of Achilles. The long head may have a tendinous inscription similar to that of the semitendinosus.

The **semitendinosus** (figs. 439, 444).—*Origin.*—Partly from a mediodorsal facet on the distal margin of the tuber of the ischium by direct implantation of the fiber-bundles, partly from the medial surface of the tendon common to it and the long head of the biceps.

Structure and insertion.—The fiber-bundles spread out to form a flat, fusiform belly which about the middle of the thigh, again contracts toward the tendon of insertion. This begins on the medial margin and dorsal surface of the muscle, becomes free from the muscle slightly above the medial condyle of the femur, passes behind this and curves forward to be inserted by a triangular expansion into the proximal part of the medial surface of the tibia behind and distal to the insertion of the gracilis. An aponeurotic expansion is continued into the fascia of the leg. About the middle of the muscle a narrow irregular tendinous inscription more or less complete divides the belly into proximal and distal divisions.

Nerve-supply.—To the muscle two nerves are commonly given. One arises from the sciatic nerve or directly from the plexus, proximal to the tuber of the ischium, sometimes in company with a branch to the long head of the biceps. It enters the middle third of the deep surface of the proximal portion of the muscle. The other branch arises from the sciatic nerve, usually distal to the ischial tuber, sometimes in common with a nerve to the biceps or the semimembranosus. It enters about the middle of the deep surface of the distal half of the muscle. Either or both branches may be represented by two nerves. The nerve fibers of the first branch arise chiefly from the first and second sacral nerves, those of the second from the lumbar and first sacral nerves.

Action.—To extend and adduct the thigh and rotate it medialward and to flex the leg and with knee flexed, to rotate the leg medialward.

Relations.—It is covered by the gluteus maximus and fascia lata; on the lateral side by the biceps; and in front, the semimembranosus and adductor magnus.

Variations.—It may be completely separated from the biceps at its origin. It may be fused with neighboring muscles. There may be two tendinous inscriptions. It may have a femoral head (a condition characteristic of many birds). A muscle fasciculus may extend from the body of the muscle to the fascia of the back of the leg.

The **semimembranosus** (figs. 439, 444).—*Origin.*—By a long, flat tendon which lies beneath the proximal half of the semitendinosus, and which arises from the more lateral of the two facets on the back of the tuber of the ischium, between the tendons of the biceps and the quadratus femoris. The tendon is at first adherent to the tendon of the adductor magnus in front and to that of the biceps and semitendinosus behind. It descends to the middle of the muscle.

Structure and insertion.—From both surfaces of the medial side and distal extremity of the tendon of origin fiber-bundles arise which take an oblique course to their insertion on the aponeurosis of the tendon of insertion. This appears on the deep surface and medial margin of the muscle opposite the end of the tendon of origin and descends on the medial side and deep surface of the muscle. Near the back of the medial condyle of the femur the insertion of muscle-fibers ceases and the tendon is inserted directly on the back of the medial condyle of the tibia, and by aponeurotic expansions into the capsule of the joint, into the lateral condyle of the femur, into the tibial collateral ligament, and into the fascia of the popliteus muscle.

Nerve-supply.—By several branches from the sciatic nerve, which usually arise from a common trunk in company with the branches to the adductor magnus. These branches enter the deep surface of the muscle about midway between the origin and insertion of the constituent fiber-bundles.

Action.—To flex the leg and rotate it medialward and to extend and adduct the thigh and rotate it medialward.

Relations.—It is covered by the gluteus maximus, the long head of the biceps, the semitendinosus, and the fascia lata. It lies dorsal to the quadratus femoris, the adductor magnus, and the knee-joint.

Variations.—It may be fused with the semitendinosus or the adductor magnus. It may be doubled. Its tendons may have a more extensive attachment than usual. The extent of the belly of the muscle varies considerably. A muscle fasciculus may be sent into the popliteal space. An extra head may arise from the ischial spine.

Bursæ

B. m. bicipitis femoris superior.—A fair-sized bursa which frequently lies between the tendon of origin of the long head of the biceps and semitendinosus and the tendon of the semimembranosus and the ischial tuber. **B. m. bicipitis femoris inferior.**—A small bursa which separates the tendon of insertion from the fibular collateral ligament of the knee-joint. **B. m. bicipitis gastrocnemialis.**—A bursa infrequently found between the tendon of the biceps and the tendons of origin of the lateral head of the gastrocnemius and the plantaris muscles. **B. m. semimembranosi.**—This is a large double bursa constantly present. One part extends between the semimembranosus, the medial head of the gastrocnemius, and the knee-joint. With the cavity of the joint it frequently communicates. The other part extends between the tendon of the semimembranosus and the medial condyle of the tibia.

C. MUSCULATURE OF THE LEG

(Figs. 444, 446 447)

The musculature of the leg arises in part from the distal end of the femur, but in the main from the tibia and fibula. The muscle-bellies are best developed in the proximal half of the leg, where they give rise to the 'calf' behind and to less

narked ventral and lateral protrusions. Toward the ankle the muscle- give way to tendons which attach the muscles of the leg to the skeleton of ot.

he musculature is divisible into **anterior, a lateral** and a **posterior group** of es. The anterior and lateral groups are separated from one another by an uscular septum. The anterolateral groups are separated from the pos- group by the tibia and fibula, the interosseous membrane, and by an **muscular** septum which extends from the lateral margin of the shaft of the to the fascia enveloping the leg. Medially the separation is well marked e broad medial surface of the tibia. Laterally the line of division is not so y marked externally. In the proximal part of the leg the dorsal musculature udes somewhat ventrally; in the distal part of the lateral musculature passes l to the lower end of the fibula. The posterior group is divided by a trans- septum into superficial and deep divisions.

he anterior group of muscles flexes the ankle dorsally, everts the foot and nds the toes. The lateral group extends the ankle (plantar flexion) and rts the foot. The posterior group flexes the knee, extends the ankle, inverts foot and flexes the toes.

While in the forearm the extensor-supinator muscles extend proximally on the radial side he arm to the humerus, and the flexor-pronator muscles on the ulnar side, in the leg both he corresponding sets of muscles extend primitively on the fibular side of the leg to the femur. he higher vertebrates the superficial layer of the flexor musculature of the leg takes origin n both sides of the distal extremity of the femur, and the origin of the extensor musculature s to extend to the femur. The crural musculature is primitively inserted into the bones of leg, the tarsus, and the aponeuroses of the foot. On the extensor side of the leg the muscula- ultimately becomes attached wholly to the foot by means of tendons differentiated, in part ast, from the dorsal aponeurosis. The lateral portion of the extensor musculature, which itively extends from the femur to the fibula, in the higher vertebrates extends from the a to the tarsus and metatarsus (peroneal musculature). On the flexor side of the leg the superficial musculature maintains a tarsal attachment through the tendon of Achilles. deeper musculature in part extends from the femur to the tibia, and in part arises from fibula and tibia, and is inserted into the metatarsus and the digits through tendons differ- ated from the plantar aponeuroses. The musculature of the sole of the foot is highly devel- l in five-toed vertebrates, but in those which walk on the toes, and especially in hoofed mals, it is very greatly reduced.

FASCIÆ OF THE LEG

(Fig. 445)

he **tela subcutanea** of the leg contains a considerable amount of fat where it overlies the les, but less where it overlies the bones and joints. Subcutaneous bursæ are found over tuberosity of the tibia (**b. subcutanea tuberositatis tibiæ**) and over each of the malleoli **subcutanea malleoli medialis et lateralis**). Over the dorsum of the foot the tela contains paratively little fat, but on the sole of the foot and plantar surface of the toes it contains h fat interposed between dense fibrous tissue. The **b. subcutanea calcanea** lies beneath uber calcanei.

he **crural fascia**, or external layer of fascia of the leg, extends from the knee to the ankle. rms an enveloping cone-like sheath for the muscles and is adherent to the periosteum of medial surface of the tibia. It is formed of transverse, oblique, and longitudinal fibers is thickest in front.

entrally the fascia of the thigh, to which the tendons of the quadriceps, sartorius, gracilis, tendinosus, and biceps muscles and the iliotibial band are closely united, becomes attached these tendons to the tibia and fibula. From these attachments, therefore, the fascia of front of the leg may be said to arise. Into it extend processes from the tendons men- d. Dorsally the fascia of the thigh is continued uninterruptedly into that of the leg. ally the crural fascia is attached to the two malleoli and to the posterior surface of the neus.

n the proximal part of the leg in front the underlying muscles in part take origin from the a; in other places the fascia is separated from the underlylng muscles by loose tissue.

rom the fascia two main intermuscular septa arise. One, the **anterior intermuscular um**, extends between the extensor digitorum longus and peroneal muscles to the anterior of the fibula; the other, the **posterior intermuscular septum**, between the peroneal muscles the soleus to the lateral crest of the fibula. These septa separate compartments for the rior, lateral, and posterior groups of muscles.

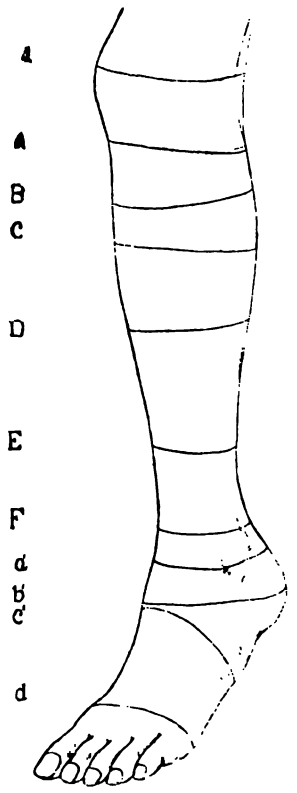
s the heads of the gastrocnemius pass over the back of the knee they are held in place by a ial deep lamina of the fascia lata, which distally becomes fused with the crural fascia (fig. A).

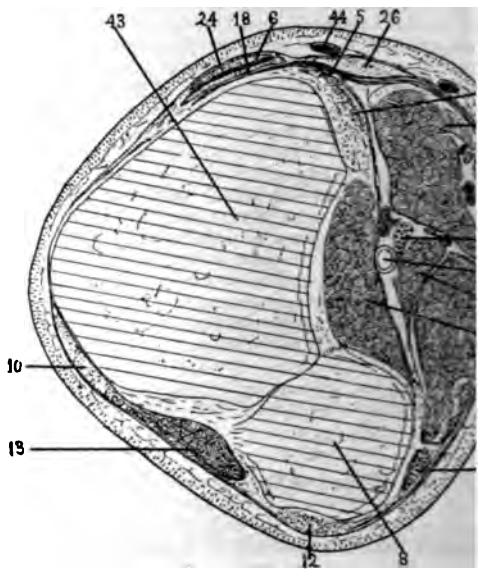
he semimembranosus has a special fascial investment which, on the back of the knee mes bound on each side of the muscle and its tendon to the capsule of the joint. This a extends into a transverse septal membrane which is continued over the deep muscles of ack of the leg to the ankle. It is united on one side to the tibia, on the other to the fibula.

FIG. 445, A–F.—TRANSVERSE SECTIONS THROUGH THE LEFT LEG IN THE REGIONS OF THE DIAGRAM.

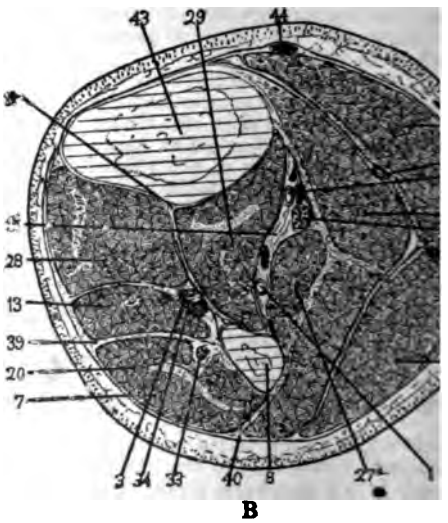
d In the diagram indicates the region through which passes section D, fig. 441; *a'*, *b'*, regions through which pass sections A, B, C, D, fig. 448.

1. Arteria peronea. 2. A. poplitea. 3. A. tibialis anterior. 4. A. tibialis po
Bursa anserina. 6. Bursa m. sartorii propria. 7. Fascia cruralis. 8. F
Ligamentum crurale transversum. 10. Lig. patellæ. 11. Membrana intero
Musculus biceps femoris—tendon. 13. M. extensor digitorum longus—a, ten
M. extensor hallucis longus. 15. M. flexor digitorum longus. 16. M. flexor hal
gus. 17. M. gastrocnemius—a, lateral head; b, medial head. 18. M. gracilis
19. M. peroneus brevis. 20. M. peroneus longus—a, tendon. 21. M. peroneu
22. M. plantaris—a, tendon. 23. M. popliteus. 24. M. sartorius, tendon
semimembranosus, tendon. 26. M. semitendinosus, tendon. 27. M. soleus—a
accessorius. 28. M. tibialis anterior—a, tendon. 29. M. tibialis posterior—a
30. N. cutaneus suræ lateralis. 31. N. cutaneus suræ medialis. 32. N. perone
munis (external popliteal). 33. N. peroneus profundus (anterior tibial). 34.
neus superficiales (musculocutaneus). 35. N. plantaris lateralis (external plant
N. plantaris medialis (internal plantar). 37. N. suralis (external saphenous).
tibialis (posterior tibial). 39. Septum intermusculare (anterior). 40. S. interm
(posterior). 41. S. suræ transversum. 42. Tendo Achillis (calcanei). 4
44. Vena saphena magna. 45. V. saphena parva.





A



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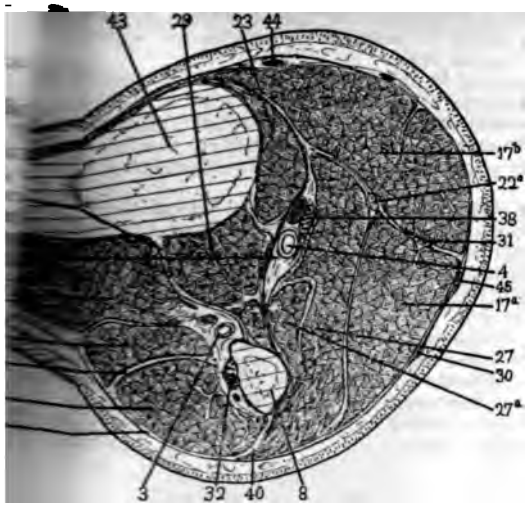
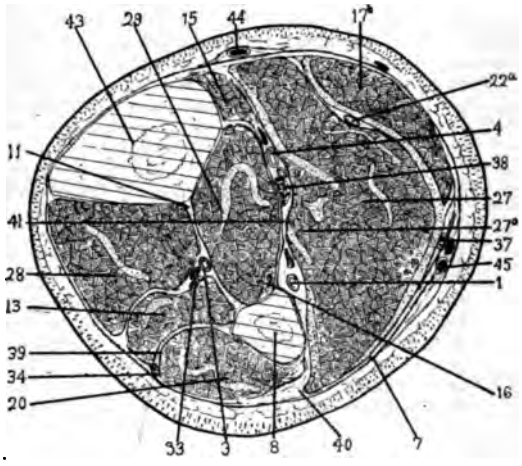
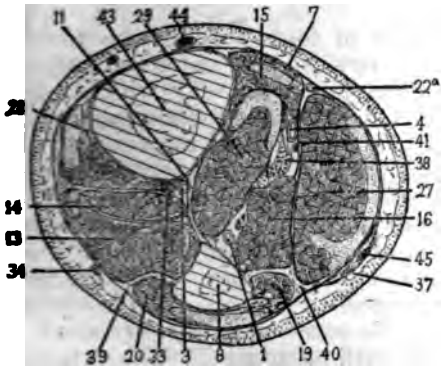


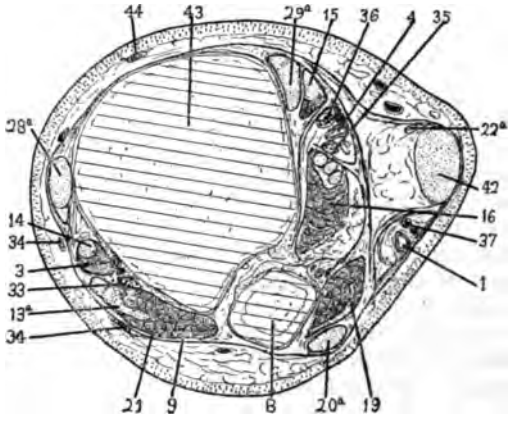
C



D



E



F

Proximally the fibers are continued into it from the tendon of the semimembranosus. Over the back of the tibia the septum is interrupted by the attachment of the soleus to the popliteal line. Beyond the tibial origin of the soleus it is fused on the medial side of the flexor digitorum longus to the crural fascia.

In addition to the two intermuscular septa and the longitudinal transverse septum, other septa serve to separate the individual muscles of the different groups.

Above the ankle the fascia is enforced by bands of tissue so that ligaments are formed which serve to retain in position the various tendons which pass from the leg into the foot.

The transverse crural ligament (upper part of anterior annular ligament) (fig. 446) lies on the front of the lower part of the leg above the ankle. It is composed of fascia strengthened by transverse bundles which pass from the medial side of the tibia to the ventral margin of the fibula. From its deep surface a strong, broad septum descends to the tibia and divides the underlying space into two osteofibrous canals, a medial for the tibialis anterior and a lateral for the long extensor muscles. The lateral compartment is further subdivided by a slightly marked septum into a medial division for the extensor hallucis longus and a lateral for the extensor digitorum longus and the peroneus tertius.

The cruciate ligament (lower part of anterior annular ligament) (fig. 446) serves to hold the tendons of the anterior muscle group in place as they pass to the dorsum of the foot. In part it is formed by a dense fibrous band lying in the fascia over the ankle, in part of a ligament which passes from the bones of the ankle to the deep surface of this band. The superficial band is V-shaped. It arises from the lateral surface of the body of the calcaneus and passes across the dorsum of the foot, one arm of the V going to the medial malleolus, the other to the side of the foot, where it terminates in the fascia over the first cuneiform bone. The apex of the V lies over the tendons of the extensor digitorum longus and peroneus tertius muscles. The distal arm extends over the tendons of the extensor hallucis longus and tibialis anterior muscles. The proximal arm passes over the tendon of the extensor hallucis longus and then divides into two layers, between which the tendon of the tibialis anterior passes. The deeper ligament mentioned above arises from deep within the tarsal sinus, some of its fibers even from the sustentaculum tali. It then passes forward and medially beneath the long extensor

tendons, and divides into two parts, one of which curves about the medial margin of the don of the extensor digitorum longus, the other about the extensor hallucis longus tend the under surface of the proximal arm of the V-shaped band.

The **peroneal retincula** are strengthened regions in the fascia which serve to hold tendons of the peroneal muscles in place. The **superior** extends from the lateral malleolus the fascia on the back of the leg, and to the lateral surface of the calcaneus. The in overlies the tendons on the lateral surface of the calcaneus, and is attached to this bone each side of them. Between the tendons it sends a septum to the bone. It is connected w the superficial layer of the cruciate ligament.

The **laciniate ligament** (internal annular) (fig. 447) is found on the medial side of the ank Here the fascia is strengthened by fiber-bands which form a well-marked ligament that ho in place the tendons of the deep dorsal cruropedal muscles. This ligament extends from dorsal and distal margins of the medial malleolus to the calcaneus. It is closely bound to tibia and the talotibial (tibioastragaloid) ligament until the tendon of the tibialis posterior reached. It passes over this and becomes bound to the bony structures on the poste margin of the tendon. From this attachment two layers, a deep and a superficial, ext backward. The superficial layer extends to the tuber calcanei, and is connected superio with the crural fascia. The deep layer, which represents a continuation distally of the tra verse septum, extends over the tendons of the flexor digitorum longus and flexor hallucis lon to the medial surface of the calcaneus, and is closely united to the underlying bone on ea side of these tendons, thus giving rise to osteofibrous canals.

MUSCLES

1. Muscles of the Front of the Leg
(Figs. 446, 449)

The anterior musculature of the leg consists of four muscles, the tibialis anterior, extensor digitorum longus, peroneus tertius, and extensor hallucis longus. The **tibialis anterior** has a quadrangular prismatic belly which arises from the lateral side of the tibia and adjacent interosseous membrane in the proximal half of the leg. The tendon passes over the front of the tibia to the first metatarsal. The **extensor digitorum longus** is a transversely flattened, fusiform muscle, which arises from the superior extremity of the tibia, the anterior crest of the fibula, and the adjacent interosseous membrane, and gives rise to a tendon which passes over the front of the distal extremity of the tibia and sends tendons to the terminal phalanges of the four more lateral toes. The **peroneus tertius** represents a more or less completely differentiated portion of the preceding muscle. Its tendon passes laterally through the same osteofibrous canal in the same synovial sheath and terminates on the fifth metatarsal. The **extensor hallucis longus** is a narrow muscle which arises from the distal half of the medial surface of the fibula and the interosseous membrane. Its tendon extends over the ankle to the great toe. The tendons of these muscles are held in place by the transverse and cruciate ligaments described above.

All the muscles of this group flex the foot. The extensors extend the toes; the peroneus tertius and the extensor digitorum longus evert the foot. The nerve supply is from the deep peroneal (anterior tibial) nerve.

The tibialis anterior is represented in the arm probably by the **brachioradialis** and the two radial extensors; the extensor digitorum longus by the extensor **digitorum communis** and extensor digiti quinti proprius; and the extensor hallucis longus by the extensor **pollicis longus**. Two abnormal muscles not infrequently found, the abductor **hallucis longus** and extensor **primi** internodii hallucis, represent probably the corresponding normal muscles of the hand.

The tibialis anterior (fig. 446). *Origin.*—From the distal surface of the lateral condyle of the tibia, and the lateral surface of the proximal half of the shaft of the tibia, the adjacent interosseous membrane, the overlying fascia near the condyle (tuberosity) of the tibia, and the intermuscular septum between it and the extensor digitorum longus.

Structure.—Bipenniform. The fiber-bundles converge upon a flat tendon which begins high in the muscle and emerges on the anterior margin of the muscle about the middle of the leg. On the deep surface the implantation of fiber-bundles continues to the transverse crural (anterior annular) ligament.

Insertion.—The tendon passes over the front of the tibia to the medial side of the foot, where it is inserted into the medial surface of the first cuneiform and the base of the first metatarsal.

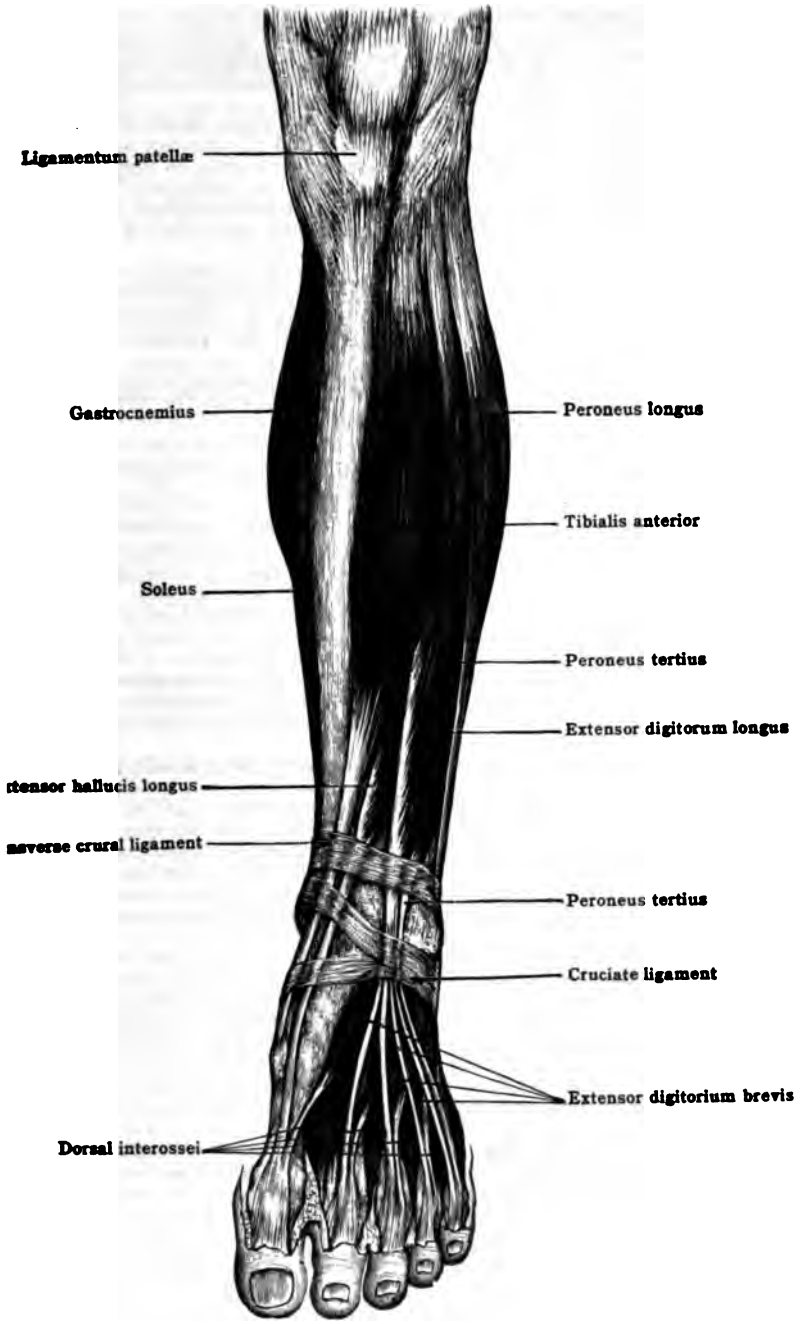
Nerve-supply.—As a rule, a branch from the common peroneal (external popliteal) nerve enters the proximal portion of the muscle by several twigs, and another from the deep peroneal (anterior tibial) enters near the middle of the belly on the lateral edge.

Relations.—In the proximal half of the leg the extensor digitorum longus lies lateral to it; and between the two muscles, the anterior tibial artery and vein. It is covered by the crural fascia and rests on the interosseous membrane. Distally it lies over the extensor hallucis

he tendon passes in special compartments beneath the transverse and the cruciate nnular) ligaments.

tensor digitorum longus (fig. 446).—*Origin.*—From the lateral condyle of the tibia, ›r crest (surface) of the fibula, the intermuscular membrane between it and the erior, the lateral margin of the interosseous membrane, the septum between it and us lungus, and the fascia of the leg near the tibial origin.

FIG. 446.—THE MUSCLES OF THE FRONT OF THE LEG.



ɛ.—Penniform. The fiber-bundles converge upon the posterior surface of a tendon ns at the middle of the leg. The implantation of fibers continues nearly to the ually at the distal margin of the transverse (anterior annular) ligament the tendon o two parts which pass between the two layers of the cruciate (lower part of an- ılar) ligament, and then each divides again into two parts, thus giving rise to four or each of the four lateral toes.

Insertion.—Each tendon on the dorsal surface of the toe to which it goes divides into three fasciculi: an intermediate, which is attached to the dorsum of the base of the second phalanx, and two lateral, which converge to the dorsum of the base of the third phalanx. The margins of the tendon are also bound by fibrous tissue to the sides of the back of the first phalanx.

Nerve-supply.—Most frequently two branches of the deep peroneal (anterior tibial) enter the deep surface of the muscle, one near its tibial origin, one about the center of the belly.

Relations.—In the proximal half of the leg it lies on the interosseous membrane, and beneath the fascia of the leg, and adjoins medially the tibialis anterior, laterally the peroneus longus. Distally it lies over the extensor hallucis longus and adjoins laterally the peroneus brevis. The tendon passes beneath the transverse crural and the superficial layer of the cruciate (anterior annular) ligaments and over the extensor digitorum brevis muscle. The superficial peroneal (musculocutaneous) nerve runs in the septum between it and the peroneal muscles; the anterior tibial artery and deep peroneal nerve pass beneath the head of the muscle, and then between it and the tibialis anterior.

The peroneus tertius (fig. 446).—*Origin.*—From the distal third of the medial surface of the fibula, the neighboring interosseous membrane, and the anterior intermuscular septum.

Structure.—It is essentially a fasciculus of the extensor digitorum longus, from which it is seldom completely differentiated. The fiber-bundles descend obliquely forward to be inserted in a penniform manner on a tendon which runs along the lateral margin of the tendons of the extensor digitorum. The attachment of fiber-bundles continues to the cruciate ligament (lower part of anterior annular ligament).

Insertion.—On the base of the fifth metatarsal and often also on the base of the fourth.

Nerve-supply.—The more distal nerve to the extensor digitorum continues into this muscle.

Relations.—It lies lateral to the extensor digitorum longus. Its tendon passes into the foot beneath the transverse crural and the superficial layer of the cruciate ligament in the same compartments with those of the extensor longus.

The extensor hallucis longus (fig. 446).—*Origin.*—From the middle two-fourths of the medial surface of the fibula near the interosseous crest, and from the distal half of the interosseous membrane.

Structure.—Penniform. The fiber-bundles are attached as far as the cruciate ligament to the back and sides of a tendon which begins on the anteromedial margin of the distal third of the muscle.

Insertion.—On the base of the second phalanx of the big toe. On the back of the first phalanx the margins of the tendon are attached to the bone by bands of fibers.

Nerve-supply.—As a rule, a branch from the deep peroneal (anterior tibial) nerve enters the deep surface of the muscle near the junction of the upper and middle thirds, and passes distally across the middle of the obliquely running muscle fiber-bundles.

Relations.—It lies on the distal half of the interosseous membrane, partly covered by the extensor digitorum longus and the tibialis anterior muscles. Its tendon passes over the front of the distal extremity of the tibia and the medial side of the dorsum of the foot and is held in place by the transverse and cruciate ligaments and by a strengthening band in the fascia over the base of the first metatrsal. In the distal part of the leg the anterior tibial artery and the deep peroneal (anterior tibial) nerve pass beneath the muscle to enter the foot of the lateral side of its tendon.

Actions of the muscles of this group.—All flex the ankle. The tibialis anterior and extensor hallucis longus evert the foot at the talocalcaneonavicular joint, and invert it at the talonavicular and calcaneocuboid joints. In certain positions the tibialis anterior may, however, invert the foot at the latter joint. The peroneus tertius and the long extensor of the toes evert the foot. The force of the extensor hallucis longus is exerted powerfully on the first phalanx and weakly on the second. The short muscles of the big toe aid in extending the second phalanx. The extensor digitorum longus extends the first phalanx of each toe powerfully, but exerts less force on the second and third. The lumbrical muscles assist in extending the last two phalanges.

Variations.—The origin of the tibialis anterior may extend to the femur. Its tendon of insertion may give accessory slips to the cuneiforms, metatarsals, and phalanges. More rarely its belly is divided into two portions, one of which sends a tendon to the first cuneiform and one to the first metatarsal. A slip, the **tensor fasciæ dorsalis pedis** (Wood), may pass to the dorsal fascia of the foot. Another, the **tibioastragalus anticus** (Gruber), to the talus (astragalus) or calcaneus. The bellies or the tendons of the extensor hallucis and extensor digitorum may be more or less completely fused, or tendon slips may pass from the tendon of one muscle to that of the other. Tendon slips may pass to the metatarsal bones or from the tendon of one toe to that of a neighboring toe. The tendon to each toe may be doubled. The belly of the extensor digitorum longus may be more or less completely subdivided to correspond with the tendons to individual toes. The peroneus tertius is frequently fused with the long extensor. It may be doubled. More often its tendon may bifurcate or trifurcate and be inserted into the extensor tendons of the fifth toe or into the fourth or third metatarsal. It is absent in about 8.5 per cent. of bodies (Le Double).

Abnormal Muscles.—The **abductor hallucis longus** is rarely found as a completely independent muscle. It usually arises as a fasciculus of the extensor digitorum longus, extensor hallucis longus, or the tibialis anterior. It is inserted into the base of the first metatarsal. The **extensor primi internodii hallucis** (extensor hallucis brevis) has an origin similar to that of the long abductor above described. It is inserted into the dorsum of the base of the first phalanx of the big toe. It is not to be confounded with that portion of the extensor digitorum brevis connected with the great toe and also sometimes called the extensor **hallucis brevis.**

B. subtendinea m. tibialis anterioris.—A small bursa between the medial surface of the first cuneiform bone and the tendon of the tibialis anterior. **B. subtendinea m. extensoris hallucis longi.**—A small bursa beneath the tendon near the tarsometatarsal articulation. It may communicate with the synovial sheath of the tendon. **B. sinus tarsi.—A large bursa in**

the sinus tarsi and on the lateral surface of the neck of the talus (astragalus) beneath the tendons of the extensor digitorum longus and the fibrous bands between the talocalcaneal and the cruciate ligaments. It extends back to the talocrural, forward to the talonavicular joint, and may communicate with the joint cavity of the latter.

Synovial Tendon-sheaths

Vagina tendinis m. tibialis anterioris.—This sheath surrounds the tendon from above the transverse crural ligament to the talonavicular joint. **Vagina tendinis m. extensoris hallucis longi.**—The sheath begins above the proximal arm of the cruciate ligament, and ends near the tarsometatarsal joint beneath a band-like thickening of the dorsal fascia of the foot. **Vagina tendinum m. extensoris digitorum longi.**—This sheath surrounds the tendons of the long digital extensor and the peroneus tertius from above the cruciate ligament to the middle of the third cuneiform bone.

2. Lateral Musculature of the Leg
(Figs. 446, 447, 453)

The lateral muscles consist of the peroneus longus and the peroneus brevis. They extend and evert the foot. The thick prismatic belly of the **peroneus longus** arises from the proximal half of the lateral surface of the fibula and from neighboring structures, while the smaller belly of the **peroneus brevis** arises from the middle third of the lateral surface of this bone. The peroneus longus partly covers the peroneus brevis. The tendons of the two muscles pass behind the lateral malleolus, held in place by special retinacula (p. 512). There the tendon of the peroneus longus lies at first lateral to and then crosses behind that of the peroneus brevis and curves about the lateral side of the calcaneus and across the sole of the foot closely applied to the cuboid and to the tarsometatarsal articulations, and terminates on the base of the first metatarsal. The tendon of the peroneus brevis terminates on the lateral side of the foot at the base of the fifth metatarsal. The nerve supply is from the superficial peroneal (musculocutaneous) nerve.

The two muscles are probably represented in the arm by the extensor carpi ulnaris. In some of the lower animals the head of the peroneus longus extends to the femur. The fibular collateral ligament of the knee-joint probably represents in man the femoral head of the peroneus longus.

The peroneus longus (figs. 447, 453).—*Origin.*—Anterior head: tendinous from the anterior tibiofibular ligament, the neighboring part of the lateral condyle of the tibia, and the head of the fibula; fleshy from the proximal third of the anterior intermuscular septum and the crural fascia near the tibia. Posterior head: fleshy from the proximal half of the lateral surface of the shaft of the fibula and from the posterior intermuscular septum.

Structure.—Bipenniform. The fiber-bundles converge upon a tendon which begins high in the muscle. The constituent fiber-bundles of the anterior head are long and take a nearly vertical course. The fiber-bundles of the posterior head take a more oblique course and their attachment extends more distally on the tendon. The tendon emerges on the surface of the muscle in the distal half of the leg. The fiber-bundles of the posterior head extend to within a few centimeters of the lateral malleolus. The tendon passes through the retromalleolar groove, passes across the lateral face of the calcaneus, to and through the peroneal groove of the cuboid, and crosses the second and third tarsometatarsal joints. Where the tendon enters the groove in the cuboid it contains a fibrocartilaginous nodule which may become a sesamoid bone.

Insertion.—On the inferior surface of the first cuneiform and on the superolateral border and base of the first metatarsal. From the region of the fibrocartilaginous nodule above mentioned a fibrous slip is usually sent to the base of the fifth metatarsal.

Nerve-supply.—Most commonly the peroneal (external popliteal) nerve before dividing gives off two branches. One of these enters the deep surface of the middle third of the anterior head, the other passes across the middle third of the constituent bundles of the posterior head. The latter branch may arise from the superficial peroneal (musculocutaneous) nerve, and it may extend to supply the peroneus brevis.

The peroneus brevis (fig. 447).—*Origin.*—From the middle third of the lateral surface of the fibula; (2) from the septa which separate it from the anterior and posterior groups of muscles.

Structure.—Penniform. The fiber-bundles converge upon a tendon which begins high in the muscle and becomes visible on the lateral surface of the distal half of the belly. Behind the lateral malleolus the tendon becomes free, then passes forward below the malleolus and across the calcaneus and cuboid.

Insertion.—Into the tip of the tuberosity of the fifth metatarsal.

Nerve-supply.—The nerve arises from the superficial peroneal (musculocutaneous) nerve, or from a branch to the peroneus longus. It enters the proximal margin of the muscle and passes distally across its constituent fiber-bundles.

Relations.—The peroneal muscles in the leg are contained in a compartment bounded by the anterior and posterior intermuscular septa, by the fibula, and by the fascia of the leg. The peroneus longus to a considerable degree overlies the peroneus brevis. Beneath the upper part of the peroneus longus the peroneal (external popliteal) nerve bifurcates into its two chief branches. The deep peroneal (anterior tibial) nerve passes medially beneath the anterior head of the muscle. The superficial peroneal (musculocutaneous) nerve extends in the interval between the areas of the attachment of the two heads of the peroneus longus, and along the anterior margin of the peroneus brevis to the anterior intermuscular septum, through which it passes to its superficial distribution. The tendon of the peroneus longus at first lies lateral to and slightly overlaps that of the peroneus brevis. Toward the tip of the malleolus it lies almost directly posterior to this tendon. On the lateral surface of the calcaneus the tendon of the brevis lies superior to that of the longus, from which it is separated by bony spine, the processus trochlearis of the calcaneus. The tendon of the longus is separated from the deep surface of the abductor of the little toe, and is held in place in the groove in the cuboid by the long plantar ligament.

Action.—The peroneus brevis everts the foot. The peroneus longus extends, abducts, and everts the foot, and supports the arch of the foot. The peroneus brevis also extends the foot when this is flexed.

Variations.—The two peroneal muscles may be more or less fused. The origin of the peroneus longus may extend to the femur. The two heads of origin may be fused. Its tendon of insertion may send slips to the second, third, and rarely to the fourth and fifth metatarsals. The tendon may be united to that of the tibialis posterior (12 out of 45 bodies—Picou). Sesamoid cartilages or bones are occasionally found in the retromalleolar and calcaneal portions of the tendon. The tendon of the peroneus brevis may send a slip to the second or third phalanx or to the head of the metatarsal of the fifth toe, to its extensor tendon, or to the cuboid. It may also send a fasciculus to the fourth metatarsal or the extensor tendon of the fourth toe.

Accessory peroneals.—Poirier considers these all varieties of a muscle which in its simplest form arises from the distal fourth of the fibula and is inserted by a tendon into the fifth toe. A corresponding muscle is normally found in many of the monkeys (**peroneus digiti quinti**). In man in one form or another it is a frequent anomaly. It may be so fused with the peroneus brevis that only its tendon of insertion is apparent. It may appear as a special muscle fasciculus of the peroneus longus or brevis. It may be merely a tendinous band, or it may be tendinous at origin and insertion, with an intermediate belly. Instead of being attached to the fifth toe, it may be inserted into the fifth metatarsal, the cuboid, the tendon of the peroneus longus, the calcaneus, lateral malleolus, or posterior talofibular ligament.

Synovial Tendon-sheaths

Vagina tendinum peroneorum communis.—There is a double sheath for the tendons of the peroneal muscles as they pass back of the lateral malleolus. From this region of union the sheath sends processes along each tendon proximally above the malleolus and distally over the lateral surface of the calcaneus. This process on the tendon of the peroneus longus often communicates with the following sheath. **Vagina tendinis m. peronæi longi plantaris.**—This sheath begins in the peroneal groove of the cuboid and ends near the medial border of the long plantar ligament.

3. Musculature of the Back of the Leg

a. Superficial Group (fig. 444)

To this group belong the **gastrocnemius, soleus, and plantaris muscles.** They extend the foot and flex the leg. The two ovoid heads of the **gastrocnemius** arise one on each side from above the condyles of the femur, extend about to the middle of the back of the leg, and are inserted into the posterior surface of the tendon of Achilles, and through this into the back of the calcaneus. The broad, flat, ovoid **soleus** arises beneath the gastrocnemius from the tibia and fibula, and is inserted into the deep surface of the tendon of Achilles as far as the ankle. The two heads of the gastrocnemius and the soleus constitute the **triceps suræ.** The **plantaris** is a slender muscle which passes along the medial margin of the lateral head of the gastrocnemius and beneath the medial head, where it gives rise to a slender tendon that runs between the gastrocnemius and soleus and along the medial margin of the tendon of Achilles to the fatty fibrous tissue of the heel. The nerve-supply is from the tibial nerve.

The muscles of this group have a common embryonic origin, and are first differentiated on the fibular side of the leg, whence they extend over the posterior tibial vessels and nerve to their medial attachments. The gastrocnemius corresponds with the flexor carpi radialis and ulnaris, the plantaris with the palmaris longus, the soleus with a portion of the flexor digitorum sublimis of the forearm. In many of the monkeys and in the prosimians the plantaris is much more developed than in man.

The gastrocnemius (fig. 444).—**Medial head.**—*Origin.*—From a facet on the back of the medial condyle of the femur above the articular surface, from an area on the back of the femur superior and lateral to this, and from the femoral margin of the capsule of the knee-joint.

head.—*Origin.*—From a facet on the proximal portion of the posterolateral surface teral condyle of the femur and from a rough area situated more medially and at a istance from the joint.

ture and insertion.—The heads of the gastrocnemius are similar in structure. From the facets there descend aponeurotic bands, one on the medial margin and the medial side sterior surface of the medial head, the other on the lateral margin and the lateral side sterior surface of the lateral head. These bands descend about two-thirds of the way muscle. In the tendon of the lateral head a sesamoid bone is frequently found. The idles of the muscle pass obliquely from the supracondylar areas of origin and from the face of the aponeurosis on each side to the tendon of insertion. This tendon begins as between the two heads, and as a lamina on the deep surface of each head. The septum ns soon fuse with the broad aponeurosis which covers the dorsal surface of the soleus. achment of fiber-bundles continues to about the middle of the back of the leg. The ent of the medial head extends more distally than that of the lateral head. As a rule, al head is also the broader and thicker of the two.

soleus (fig. 583).—*Origin.*—(1) By a fibular head from the back of the head and the third of the posterior surface of the shaft of the fibula, and from the intermuscular between it and the peroneus longus; and (2) by a tibial head from the transverse septum distal margin of the popliteus, from the popliteal line, and from the middle third of the order of the tibia.

ture and insertion.—From the fibular and tibial origins arise broad aponeuroses which ximally on the deep surface of the muscle so as to form a fibrous arch over the pos- ial vessels and nerves. Distally they diverge and become more narrow, but the fibular sis is continued on the fibular side and the tibial aponeurosis on the tibial side of les as far as the distal quarter of the leg. The main portion of the belly of the muscle l by fiber-bundles which arise from the posterior surface of these aponeuroses and quely to be inserted in a bipenniform manner on the deep surface of the tendon of This tendon begins as a broad aponeurosis which covers the greater part of the surface of the muscle, and gradually converges into a heavy fibrous band that is in- to the calcaneus. The bundles of fibers of the tendon take a slightly spiral course. the posterior surface run from the medial margin toward the lateral surface of the ; those on the anterior surface in a reverse direction. The attachment of the fiber- continues to within a short distance of the heel. A few of the fiber-bundles arise rom the fibula and the posterior intermuscular septum. On the deep surface of the he muscle there is an **accessory fasciculus** which is formed by fiber-bundles that sprir g ide from the anterior surface of the aponeuroses of origin of the muscle and have a rm insertion on each side of a thin, oblique tendinous lamina which inferiorly becomes the deep surface of the tendon of Achilles.

plantaris (fig. 444).—This muscle *arises* from the distal part of the lateral line of bi- of the linea aspera, in close association with the lateral head of the gastrocnemius. -bundles give rise to a flat, short, fusiform belly, and are united to a narrow tendon tends along the medial edge of the tendon of Achilles to the lateral part of the dorsal f the calcaneus, where it *terminates* in the neighboring fibrous tissue.

-supply.—From the tibial (internal popliteal) part of the sciatic nerve in the popliteal ves arise for each head of the gastrocnemius. Each nerve enters the middle third of the ace of the head near the proximal margin. The nerve-supply for the soleus is from two One nerve arises in the popliteal space, often in company with the nerve to the lateral he gastrocnemius. It enters the posterior surface of the muscle near the proximal id divides into two branches, one for each head of the muscle. The tibial (posterior rve gives rise to a branch which, about half-way down the leg, enters the deep surface uscle and furnishes branches for the deep portion of the muscle on each side The pply of the plantaris is by a branch from the tibial (internal popliteal) portion of c. This arses in the popliteal space and enters the deep surface of the muscle.

ons.—The semimembranosus winds about the medial margin of the medial head of cnemius to its deep surface. The biceps passes to the lateral side of the lateral head strocnemius, and the plantaris along its medial margin. The semimembranosus and ove, the medial head of the gastrocnemius and the plantaris below, bound the popliteal he peroneal (external popliteal) nerve passes from the popliteal space obliquely across aris and the lateral head of the gastrocnemius. The medial sural (short saphenous) l the small saphenous vein pass between the heads of the gastrocnemius to the surface e to the lateral side of the ankle. From the peroneal (external popliteal) nerve in the space the lateral sural (communicans peronei) nerve extends distally over the calf. erior) tibial nerve and posterior tibial artery and vein run between the two heads of the mius, and then beneath the soleus to the medal side of the ankle. In the region of the f Achilles a considerable space filled with fatty tissue intervenes between the tendon ransverse septum.

.—The contraction of the triceps suræ produces extension, adduction, and inversion t. The gastrocnemius is also a flexor of the leg. The plantaris has no known function In some animals it is an extensor of the plantar fascia.

tions.—There is considerable variation in the extent of the separation of the different he triceps suræ. The tendons of the three heads may be separate nearly to the heel. both heads of the gastrocnemius or the soleus may be doubled. A slip from the biceps embranosus, from the linea aspera, or popliteal space may join the triceps and give quadriceps suræ. On the other hand, one of the heads of the gastrocnemius or the d of the soleus may be missing. A supernumerary fasciculus may extend from the ace of the soleus to the calcaneus. The plantaris is exceedingly variable in origin, , and insertion. The origin may be from the capsule of the knee-joint, the fascia of the

leg, or from the tibia. Its tendon may terminate at almost any part of its course in neighboring structures. It may be represened by a fibrous band. It is absent in about 7 per cent. of instances (Le Double).

Bursæ

B. m. gastrocnemii lateralis.—A bursa is often found between the tendon of the lateral head of the gastrocnemius and the capsule of the joint. It may communicate with the joint cavity. **B. m. gastrocnemii medialis.**—A bursa usually lies between the tendon of origin of the medial head of the gastrocnemius, the condyle of the femur, and the capsule of the joint. Another bursa (**b. m. semimembranosi**) extends between the semimembranosus and the medial head of the gastrocnemius muscle. The two bursæ frequently communicate with one another and with the joint. **B. tendinis calcanei.**—This lies between the tendon of Achilles and the upper part of the back of the calcaneus. Between the back of the tendon and the crural fascia another bursa is frequently present.

b. Deep Group

The deep posterior musculature is separated from the superficial by the transverse septum described above (p. 509). The muscles covered by this septal fascia are the **popliteus**, the **flexor digitorum longus**, the **flexor hallucis longus**, and the **tibialis posterior.** An intermuscular septum between the popliteus and the tibialis posterior, and the attachment of the soleus to the popliteal line on the back of the tibia serve to separate the popliteus from the other deep posterior muscles which lie distal to this region and send tendons into the sole of the foot. The deep posterior musculature may thus be considered as divided into a proximal femorotibial and a distal cruropedal group. Both sets of muscles are supplied by branches of the tibial nerve.

Femorotibial Muscle

The popliteus (fig. 447).—A triangular muscle which *arises* from an ovoid facet at the inferior extremity of the groove on the outer side of the lateral condyle of the femur and is *inserted* into the proximal lip of the popliteal line of the tibia and the surface of the shaft of the tibia proximal to this. It rotates the leg medialward and flexes it.

Structure.—From the origin a broad tendon glides over the condyle within the capsule of the joint, then over the lateral fibrocartilage and through a groove on the back of the tibiofibular articulation. From both surfaces of this tendon, fiber-bundles diverge toward the area of insertion. The tendon is more or less intimately united to several structures with which it comes in contact about the joint. Rarely it contains a sesamoid bone. The fibers of insertion terminate in part in the fascia covering the muscle. The popliteus is homologous with the pronator teres of the arm, or, according to some investigators, with the deep portion of that muscle.

Nerve-supply.—A nerve which arises either independently or in conjunction with that to the posterior tibial muscle enters the popliteus near the middle of its distal edge. Sometimes a branch from the chief nerve to the knee-joint enters the proximal edge of the muscle.

Action.—To flex and rotate the leg medially.

Relations.—The popliteus lies within a compartment bounded by the transverse septum, the capsules of the knee and superior tibiofibular joints, the back of the tibia, and a septum extending to the popliteal line (see above). On the transverse septum run the popliteal vessels and the tibial nerve. The proximal margin of the soleus overlaps the distal margin of the popliteus. The synovial membrane of the knee-joint sends a prolongation between its tendon and the back of the lateral condyle of the tibia.

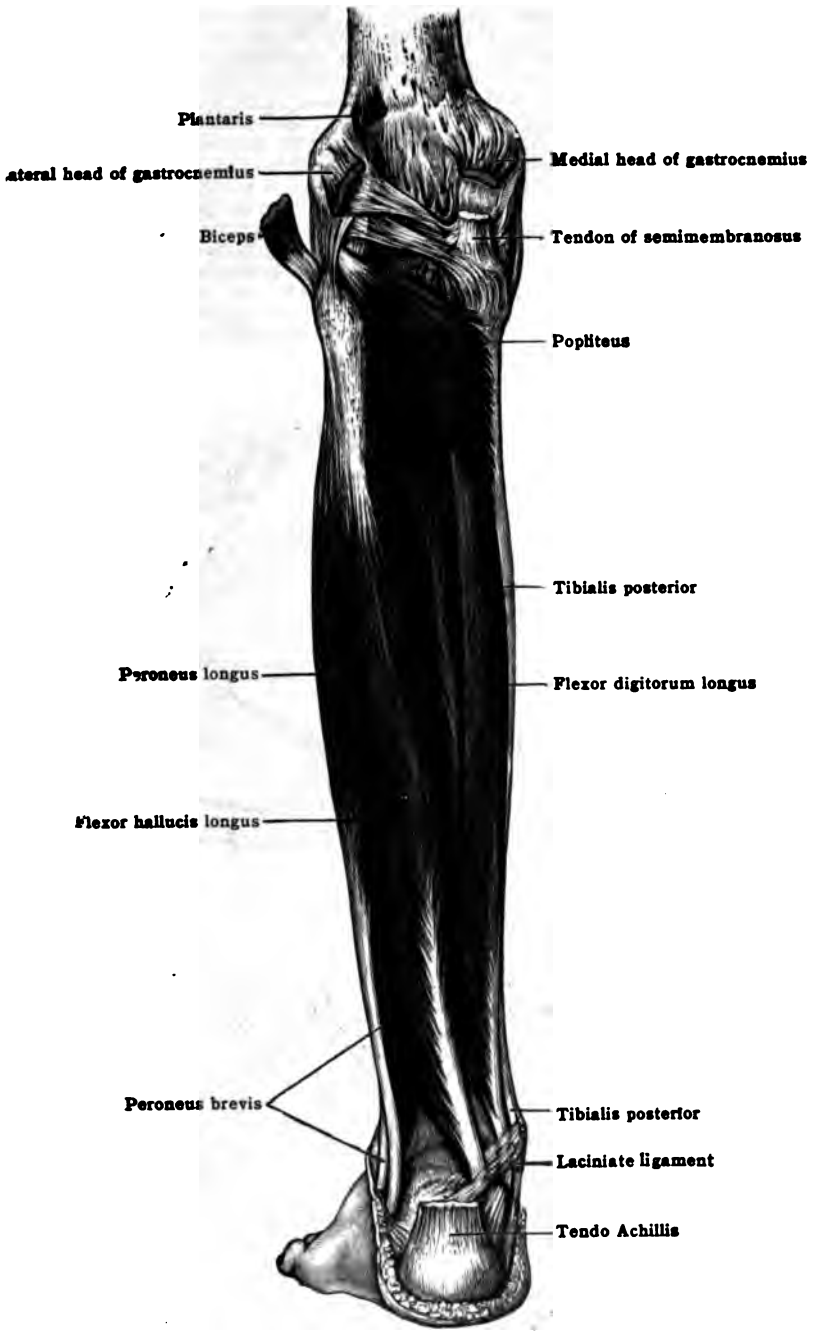
Variations.—It is rarely absent. An accessory head may arise from the medial side of the lateral condyle or from some neighboring structure. The **fibulotibialis (peroneotibialis)** is a small muscle found by Gruber in one body in seven. It arises from the medial side of the head of the fibula and is inserted into the posterior surface of the tibia beneath the popliteus.

Cruropedal Muscles (figs. 447, 451)

Of the three muscles of this group, the **flexor digitorum longus** lies on the tibial side of the leg, the **flexor hallucis longus** on the fibular side, and the **tibialis posterior** upon the interosseous membrane, partly covered by the other two muscles, beneath the former of which it crosses, distally, to the tibial side of the leg. Septa separate the flexor muscles from the tibialis. The tendons of the three muscles pass behind the medial malleolus, held in place by the transverse septum and the deep layer of the laciniate (internal annular) ligament. They lie in compartments divided by septa which descend to the tibia. The compartment for the tibialis posterior is the most medial. It is partly overlapped by that for the flexor digitorum. At the ankle the tendon of the tibialis passes

the tendon of the flexor digitorum medial to, and that of the flexor hallucis the sustentaculum tall, each in a separate osteofibrous canal bounded lly by the laciniate (internal annular) ligament. In the sole the tendon of ; flexor of the big toe passes deeper than the tendon of the flexor digitorum,

FIG. 447.—THE DEEP MUSCLES OF THE BACK OF THE LEG.

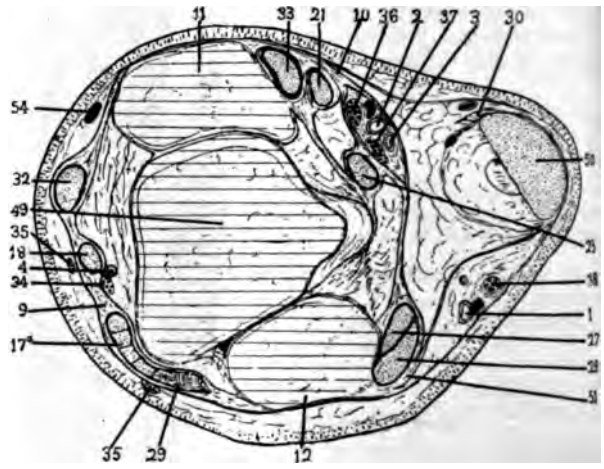


h it gives a slip, and is inserted into the terminal phalanx of the big toe. don of the long flexor of the toes passes obliquely across the sole, is joined quadratus plantæ (flexor accessorius), and gives rise to a tendon for the l phalanx of each of the four lateral toes. From these tendons the lum- nuscles arise. The tibialis posterior has an extensive insertion on the surface of the *tarsus.*

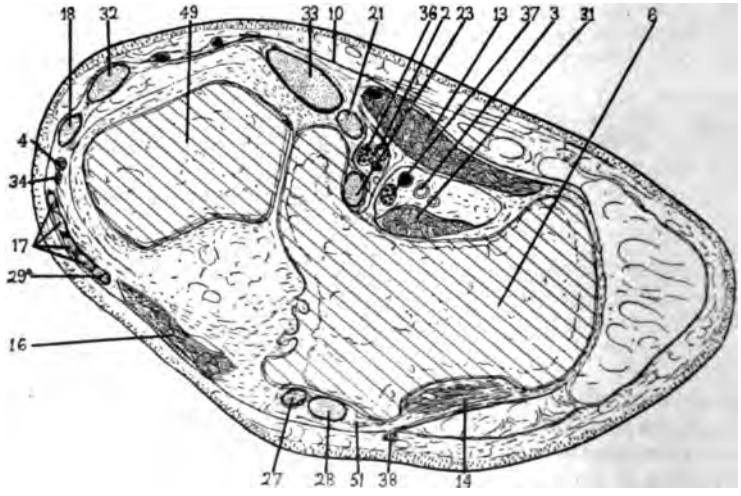
FIG. 448. A–D.—TRANSVERSE SECTIONS THROUGH THE FOOT IN THE REGIONS SHOWN IN THE DIAGRAM.

f in the diagram indicates the region through which passes section F, fig. 445.

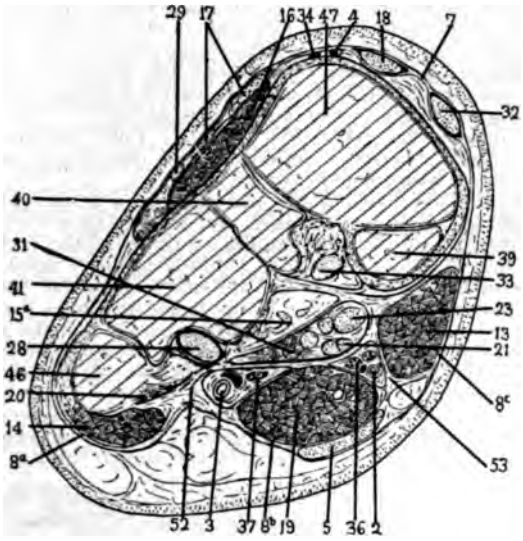
1. Arteria peronea. 2. A. plantaris medialis (internal). 3. A. plantaris lateralis (external). 4. A. tibialis anterior. 5. Aponeurosis plantaris. 6. Calcaneus. 7. Fascia pedis dorsalis. 8. F. plantaris—a, lateral; b, intermediate; c, medial. 9. Ligamentum cruciatum (anterior annular). 10. L. laciniatum (internal annular). 11. Malleolus lateralis (external). 12. Malleolus medialis (internal). 13. Musculus abductor hallucis—a, tendon. 14. M. abductor quinti digiti—a, insertion. 15. M. adductor hallucis—a, oblique head, origin; b, transverse head. 16. M. extensor digitorum brevis—a, tendons. 17. M. extensor digitorum longus, tendons. 18. M. extensor hallucis longus, tendon. 19. M. flexor digitorum brevis—a, tendon. 20. M. flexor digiti quinti brevis—a, tendon. 21. M. flexor digitorum longus, tendon. 22. M. flexor hallucis brevis tendon. 23. M. flexor hallucis longus. 24. M. interossei dorsales. 25. M. interossei plantares. 26. M. lumbricales. 27. M. peroneus brevis. 28. M. peroneus longus. 29. M. peroneus tertius—a, tendon. 30. M. planaris, tendon. 31. M. quadratus plantæ. 32. M. tibialis anterior, tendon. 33. M. tibialis posterior, tendon. 34. Nervus peroneus profundus. 35. N. peronæus superficialis (musculocutaneous). 36. N. plantaris medialis (internal). 37. N. plantaris lateralis (external). 38. N. suralis (external saphenous). 39. Os cuneiforme I. 40. Os cuneiforme III. 41. Os cuboid. 42. Os metacarpale I. 43. Os metacarpale II. 44. Os metacarpale III. 45. Os metacarpale IV. 46. Os metacarpale V. 47. Os naviculare. 48. Ossa sesamoidea. 49. Os talus (astragalus). 50. Tendo Achillis. 51. Retinacula mm. peroneorum. 52. Septum intermusculare laterale. 53. S. intermusculare mediale. 54. Vena saphena magna.



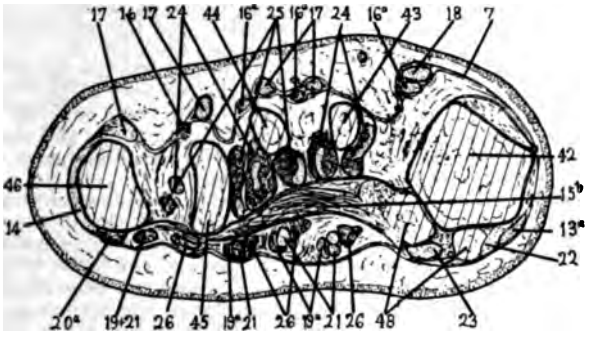
A



B



C



D

long flexors act chiefly on the toes. Together with the tibialis posterior ert and extend the foot.

ng flexors of the toes probably represent the flexor profundus and the flexor pollicis the forearm. The tendons of the deep flexors of the forearm do not, however, cross of the long flexors of the toes. In the lower mammals there is much variation in the hich the tibial and fibular flexors are distributed. The tibialis posterior has no cer- sentative in the forearm. The rare ulnocarpeus may represent it.

exor digitorum longus (figs. 447, 451).—*Origin.*—From the popliteal line, the medial e second quarter of the dorsal surface of the tibia, the fibrous septum between the id the tibialis posterior, and the fascia covering its proximal extremity.

ure and insertion.—From these areas of origin the fiber-bundles run obliquely to be n a penniform manner on a tendon which begins in the proximal quarter of the muscle ow septum, and more distally becomes a strong band on the medial margin. The of the fiber-bundles continues nearly to the medial malleous. From here the tendon hind the medial malleolus, dorsolateral to the tendon of the tibialis posterior, crosses rior talotibial ligament, and passes along the medial margin of the sustentaculum tali sole of the foot. Here it crosses the tendon of the flexor hallucis longus, from which s a tendinous slip, and divides into four parts, which pass to the second to the fifth ch tendon is bound to the phalanges of the toe to which it passes by a fibrous sheath. d to it in the sheath lies a tendon of the flexor digitorum brevis, which the flexor lon- on perforates as it passes to the base of the terminal phalanx. The tendon is connect- ose of the fingers, by vincula tendinum, to the phalanges of the toes.

supply.—From the tibial (posterior tibial) nerve a branch arises, often in company es to some other or others of the muscles of this group. The nerve divides into two one of which passes to the lateral side of the muscle, where it extends along near the the fiber-bundles of that side, while the other branch passes along near the middle er-bundles of the medial side of the muscle.

ns.—In the proximal half of the leg it lies on the tibia, in the distal half on the pos- ial muscle. Between it and the flexor hallucis lie the posterior tibial vessels and ear the ankle the plantar vessels and nerves cross the tendon of the muscle, separated the deep layer of the laciniate (internal annular) ligament. In the upper two-thirds

of its extent it is covered by the triceps suræ. In the lower third of the leg it emerges medial to the soleus and the tendon of Achilles. The relations of its tendon at the ankle have been described above. The tendon lies beneath the origin of the abductor hallucis muscle and in the sole is covered by the flexor digitorum brevis, crosses the tendon of the long flexor and the oblique adductor of the big toe and the interosseous muscles, is joined by the quadratus plantæ (flexor accessorius), and gives origin to the lumbrical muscles.

The flexor hallucis longus (figs. 447, 451).—*Origin.*—From the distal two-thirds of the posterior surface of the fibula, the septa between it and the tibialis posterior and peroneal muscles, and the fascia above its proximal extremity.

Structure and insertion.—The fiber-bundles converge upon a tendon which begins in the second quarter of the muscle, within its substance, and emerges upon the posteromedial margin in its distal half. The insertion of the fiber-bundles continues to the end of the tibia. From here the tendon passes over the dorsal talotibial (tibioastragaloid) ligament, and through the groove on the posterior surface of the talus and the under surface of the sustentaculum tali, where it lies on the fibular side of the tendon of the flexor digitorum longus. It then crosses the deep surface of this tendon, to which it gives a slip, passes over the plantar surface of the medial head of the flexor hallucis brevis, and between the sesamoid bones of this muscle into the osteofibrous canal on the plantar surface of the big toe. It is inserted into the base of the terminal phalanx of the big toe.

Nerve-supply.—The nerve arises from the tibial (posterior tibial) nerve, often in company with the nerve to the flexor digitorum longus or the other muscles of the group. It runs along the deep surface of the muscle and sends twigs into the middle third of its constituent fiber-bundles. Sometimes two nerves are furnished to the muscle.

Relations.—It lies on the fibular side of the distal two-thirds of the leg. Proximally it diverges from the preceding muscle so as to disclose the tibialis posterior, which is more deeply situated. Between it and the tibialis posterior lie the peroneal vessels. Distally its tibial margin approaches the flexor digitorum longus, but between them lie the posterior tibial vessels and nerve. Lateral to it lie the peroneal muscles. It is covered in the leg by the soleus. In the distal part of the leg its tendon lies medial to the tendon of Achilles. On entering the foot the tendon crosses beneath the abductor hallucis muscle and the lateral plantar vessels and nerve. The other relations of the tendon have been described above.

The tibialis posterior (figs. 447, 453).—*Origin.*—From—(1) the lateral half of the distal margin of the popliteal line and the middle third of the posterior surface of the tibia; (2) the medial side of the head and of that part of the body of the fibula next the interosseous membrane in the proximal two-thirds; (3) from the whole of the proximal and the lateral portion of the distal part of the posterior surface of the interosseous membrane; and (4) from the septa between its proximal portion and the long flexor muscles.

Structure.—From this extensive area of origin the fiber-bundles converge upon a tendon, which is at first deep seated within the muscle-belly, but about the middle of the leg emerges on the medial margin of the muscle. The fibular portion of the muscle is much more extensive than the tibial. The proximal fibers take a nearly perpendicular, the most distal (from the fibula) a nearly transverse, course. The insertion of fibers stops a little proximal to the medial malleolus. The tendon then extends to the medial side of the tendon of the long flexor of the toes, passes through the groove on the back of the malleolus, across the medial talotibial (tibioastragaloid) ligament, and above the sustentaculum tali to the sole.

Insertion.—The tendon divides into two chief divisions, a deep and a superficial. (1) The deep portion becomes attached chiefly to the tubercle of the navicular bone, and usually in part also to the first cuneiform. (2) The superficial spreads out to be attached chiefly to the third cuneiform and the base of the fourth metatarsal, but also in part to the second cuneiform, to the capsule of the naviculocuneiform joint, to the sulcus of the cuboid, and usually also to the origin of the short flexor of the big toe and the base of the second metatarsal. Slips may, however, also be given to other structures. A sesamoid bone is usually found in the tendon either near the calcaneonavicular ligament or the navicular bone.

Nerve-supply.—The nerve arises from the tibial (posterior tibial) in company often with branches to the other muscles of the group. It enters the posterior surface of the muscle in its proximal third, and gives off one or two branches for the tibial fasciculus. The main trunk descends across the middle third of the fasciculi arising from the fibula.

Relations.—The muscle covers the posterior surface of the interosseous membrane, and extends distally over the posterior surface of the tibia beneath the flexor digitorum longus. It is covered proximally by the soleus, distally by the two long digital flexors. The posterior tibial and peroneal arteries and the tibial (posterior tibial) nerve run upon its posterior surface. The tendon in the sole is under cover of the origin of the plantar muscles of the big toe.

Action.—The tibialis posterior adducts the foot and slightly inverts it. The flexor digitorum longus flexes the terminal phalanx on the second and the second on the first, and at the height of its contraction the first on the metatarsals. It also rotates medially to some extent the ends of the fourth and fifth toes, and inverts the foot. The flexor hallucis longus flexes the second phalanx of the big toe on the first, and, less energetically, the first on the metatarsal. It also inverts the foot. All three muscles extend the foot. The flexor hallucis is the strongest of the three in this respect.

Variations.—The muscles of the group may be more or less fused with one another or be united by fasciculi. This is especially common between the two flexors of the toes. The individual muscles vary in development. The flexor digitorum longus may be more or less divided into separate fasciculi for the individual toes. The slip from the flexor hallucis longus to the flexor digitorum longus varies greatly in extent, but usually passes mainly to the second and third toes, more rarely to the second, third, and fourth, and very rarely to the fifth. In most of the apes the tibial flexor (flexor digitorum) sends tendons to the second and fifth, the fibular flexor (flexor hallucis) to the first, third, and fourth toes. This condition is also some-

times found in man. A slip may pass from the tendon of the flexor digitorum to that of the flexor hallucis longus. There may be a sesamoid bone in the tendon of the flexor hallucis longus as it passes over the talus (astragalus) and calcaneus. The tibialis posterior may be doubled. Aberrant fasciculi may arise from various regions on the back of the leg and join any one of the three muscles of the group.

Abnormal muscles.—**The soleus accessorius.**—Arises by a tendon from the head of the fibula beneath the soleus. It is usually a slender muscle inserted into the medial surface of calcaneus. **The tibialis secundus** (tensor of capsule of ankle-joint).—A small muscle which arises from the tibia beneath the flexor digitorum and is inserted into the capsule of the ankle-joint. **The fibulocalcaneus medialis** (peroneocalcaneus internus of MacAlister, flexor accessorius long. dig. long., etc).—A fasciculus which arises from the lower third of the body of the fibula and gives rise to a tendon which passes beneath the laciniate ligament to the quadratus plantæ or to the tendon of the flexor digitorum longus.

Bursæ

B. subtendinea m. tibialis posterioris.—A small bursa between the navicular fibrocartilage and the tendon.

Synovial Tendon-sheaths

Vagina m. flexoris digitorum longi.—The tendon is surrounded by a synovial sheath from the back of the medial malleolus to where it crosses the tendon of the flexor hallucis longus below the navicular bone. It may communicate with the sheath of the tibialis anterior or with that of the flexor hallucis longus. **Vaginæ tendinum digitales.**—The tendons of the long flexor, together with those of the short flexor, are surrounded by synovial sheaths from the heads of the metatarsals to the insertions of the tendons. In structure these resemble those of the fingers. **Vagina m. flexoris hallucis longi.**—The tendon is surrounded by a sheath from the back of the medial malleolus to the crossing of the tendon of the flexor digitorum longus. Another sheath surrounds the tendon from the middle of the first metatarsal to its insertion. **Vagina m. tibialis posterioris.**—The tendon is surrounded by a synovial sheath extending from a region proximal to the medial malleolus to the insertion of the tendon.

D. MUSCULATURE OF THE FOOT
(Figs. 449–453)

On the dorsum of the foot there is a muscle not represented in the hand, the extensor digitorum brevis. In the sole of the foot there is a highly developed musculature which may be subdivided into the flexor digitorum brevis; the muscles connected with the long extensor of the toes, quadratus plantæ and lumbricales; the intrinsic muscles of the great toe; the intrinsic muscles of the little toe; and the interosseous muscles. These muscles abduct and adduct the toes, flex them at the metacarpophalangeal joints and flex and extend them at the first row of interphalangeal joints. On the second row of interphalangeal joints they seem to exert relatively little action. All the movements, excepting flexion, are weak in most individuals. The extensor digitorum brevis is innervated by the deep peroneal (anterior tibial) nerve. The muscles of the sole of the foot are all innervated by the lateral (external) plantar, except the flexor digitorum brevis, the most medial of the lumbrical muscles, and the abductor and flexor brevis of the great toe, which are innervated by the medial (internal) plantar.

FASCIÆ
(Fig. 448)

Tela subcutanea.—Over the dorsum of the foot the tela subcutanea contains little fat. On the sole of the foot and the plantar surface of the toes it contains much fat embedded in dense fibrous tissue.

Muscle fasciæ.—Over the dorsum of the foot a fascial membrane extends from the cruciate ligament mentioned above to the toes, where it is continued as fibrous sheaths for the extensor tendons. Laterally and medially it is continued into the plantar fascia. Where it overlies skeletal structures it becomes adherent to them. In the main this fascial sheet is thin. Over the base of the first metatarsal it is strengthened by a band which runs from the medial side of this bone over the extensor tendons of the big toe to the base of the second metatarsal. The extensor digitorum brevis is covered by an adherent fascial sheet. The dorsal surface of each dorsal interosseous muscle is likewise covered by an adherent membrane.

The **plantar surface** of the foot is invested by a fascia in which three distinct regions may be observed, a central, a lateral, and a medial. The central region is greatly thickened by bands of fibrous tissue, the **plantar aponeurosis,** which diverge toward the toes from the medial half of the tuber calcanei. These bands become distinct from one another as the toes are

approached, and each finally terminates partly in the skin over the head of the [illegible] metatarsal and in the digital sheath of the flexor tendons. Some of the fibers are [illegible] into the transverse capitular ligaments, the others extend through near the metatarso[illegible] articulation to the dorsum of the foot. Broader, thicker bands go to the three [illegible] than to the big and little toes. At the margins of this central area some fibers [illegible] the fascia of the lateral and medial area, some extend laterally into the skin, and [illegible] into the intermuscular septa described below. Near the toes well-marked transverse [illegible] of fibers may be seen between the digital bands. The central area of the plantar fas[illegible] densely adherent to the skin.

The digital sheaths of the flexor tendons of the toes correspond essentially with [illegible] previously described (p. 433) for the fingers.

The medial plantar fascia is thin and adherent to the skin. It extends between the [illegible] plantar and the dorsal fascia over the intrinsic muscles of the big toe. The lateral plantar fascia is thick and well-developed near the heel, thin as the little toe is approached. A band, the calcaneometatarsal ligament, strengthens it between the calcaneus and the tube[illegible] of the fifth metatarsal.

At the junction of the medial with the central region of the plantar fascia the medial intermuscular septum sinks in to be attached to the first cuniform, the navicular and the [illegible] of the posterior tibial. A similar lateral intermuscular septum sinks in between the latera[illegible] central regions of the plantar fascia and is attached to the long plantar ligament, the [illegible] sheath of the peroneus longus and the base of the fifth metatarsal. The fascia of each of [illegible] regions in considerable part extends into these septa instead of becoming continuous [illegible] them.

The sole is thus divided into three great fascial compartments by these septa, a latera[illegible] central, and a medial. In the lateral lie the intrinsic pedal muscles of the little toe; in the medial, the abductor and the flexor brevis of the big toe and the distal end of the tendon of the flexor hallucis longus. The central compartment is subdivided by transverse septa into several subcompartments. In the most superficial compartment lies the flexor digitorum brevis; in the second, the tendons of the flexor digitorum longus and its associated muscles, the quadratus plantæ (flexor accessorius) and the lumbrical muscles; in the third, the adductor muscles of the big toe; and in the fourth, the interosseous muscles.

The first two subcompartments are most clearly marked in the region of the tarsus. Distally they become merged by the disappearance of the intervening transverse septum, and longtiudinally subdivided by fibrous septa which serve to make a complete sheath over each digit for the flexor tendons. The sheath over the adductor muscle of the big toe is a thin membrane continued laterally from the medial intermuscular septum. Where the two heads of the adductor muscle advance upon their tendon of insertion, the medial septum has no skeletal attachment, so that the adductor subcompartment of the middle fascial compartment communicates freely with the medial compartment. Over the cuneiform bones the tendon of the flexor hallucis longus passes from the long flexor region of the middle compartment into the medial compartment. Here the medial intermuscular septum divides into two layers, which form a sheath for the tendon as it passes to the plantar surface of the flexor hallucis brevis.

MUSCLES

1. Muscle of the Dorsum of the Foot

The **extensor digitorum brevis** (fig. 449).—This muscle is broad and thin, lies beneath the tendons of the long extensor muscle on the tarsus, lateral to the navicular and the head of the talus, and sends tendons to the four more medial toes. It arises from the calcaneus. Its nerve-supply is from the deep peroneal.

Origin.—From the lateral and superior surfaces of the body of the calcaneus and from the apex of the cruciate ligament.

Structure and insertion.—The fiber-bundles arise directly from the ligament, and by short tendinous bands from the bone. As they extend distally they become grouped into four bellies. Those of the most medial and largest belly, the **extensor hallucis brevis**, become inserted in a bipenniform manner on the lateral and medial margins of a tendon which begins opposite the cuboid. The insertion of fiber-bundles continues to the base of the first metatarsal. The insertion of the fiber-bundles of the other bellies, which are seldom so distinctly isolated as the first, takes place in a penniform manner into their respective tendons, but the exact mode of attachment is subject to great individual variations. The tendon of the first digit is inserted mainly into the middle of the back of the base of the first phalanx, but it is often also united to the tendon of the long extensor. The other three tendons are fused with the lateral margins of the corresponding tendons of the long extensor near the bases of the three middle digits. They also usually give slips to the bases of the first phalanges of the corresponding toes.

Nerve-supply.—The deep peroneal (anterior tibial) nerve, which, accompanied by the anterior tibial artery, passes beneath the medial belly of the muscle, gives off a branch which passes transversely across the middle of the deep surface of the muscle and sends twigs into it.

Relations.—It lies on the lateral side of the tarsus, beneath the long extensor tendons of the toes. The relations of its tendons have been described above.

Action.—It aids the long extensors in extending the first phalanx of each of the four medial digits. It has but a limited action on the second and third phalanges. It serves also to pull the ends of the toes to which its tendons go toward the little toe.

Variations.—The muscle shows great variation in development. Rarely the whole muscle, more frequently one or more of its digital divisions, may be missing. On the other hand, it may

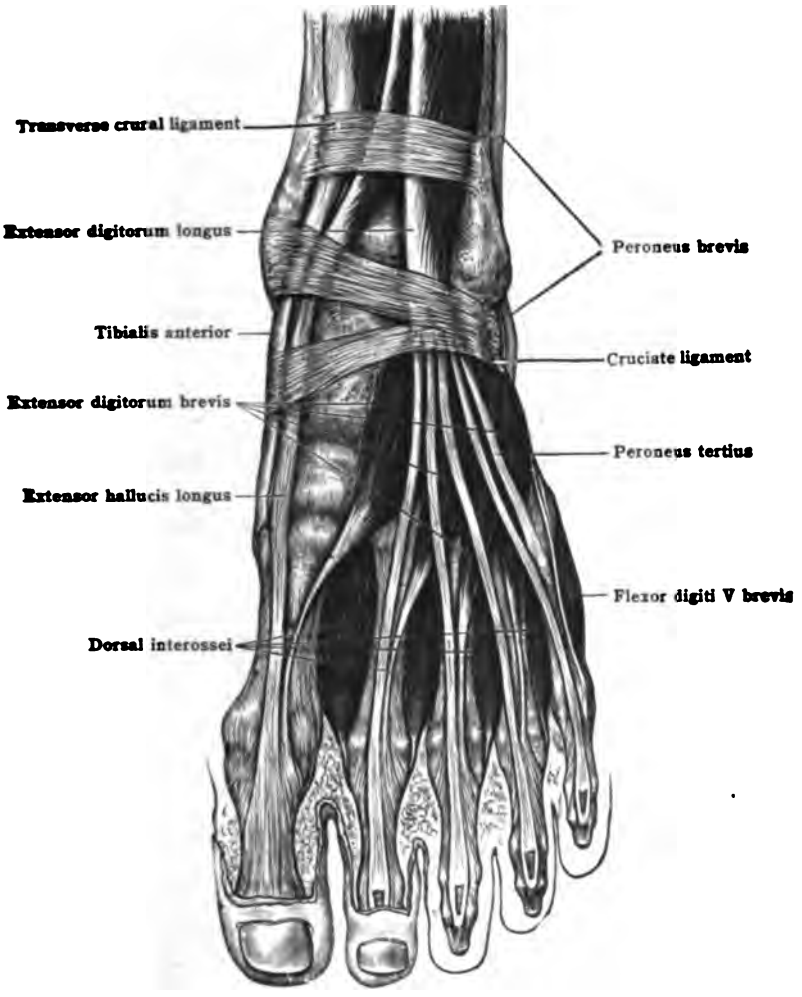
are highly developed than usual. Accessory fasciculi vary greatly in origin and termination. Most frequently their tendons go to a metacarpophalangeal articulation or to the ed or the fifth toe.

2. Muscles of the Sole of the Foot

a. Flexor Digitorum Brevis (fig. 450)

The flexor digitorum brevis, the most superficially placed of the plantar muscles, lies in the **plantar** region beneath the plantar fascia and over the tendons of the long flexor of the toes **and its** associated muscles. It arises from the calcaneus, and has a flat, elongated belly, which **ward** the middle of the sole is prolonged into four processes, each of which has a special ten**on that** is inserted into the second phalanx of one of the four lateral toes. The tendons of

Fig. 449.—The Muscle of the Dorsum of the Foot.



the muscle correspond to those of the flexor sublimis in the palm. The belly of the flexor sublimis is supposed to be represented by the soleus. The nerve supply is from the medial (internal) plantar.

Origin.—From (1) the medial process of the tuber calcanei; (2) the posterior third of the plantar aponeurosis; and (3) the medial and lateral intermuscular septa.

Structure.—The constituent fiber-bundles pass distally in a compact mass. The tendons of insertion begin within the muscle substance, and as the fiber-bundles become inserted on them, the separate fasciculi become more and more distinct. The fasciculi for the second and third toes are larger and arise more superficially than those for the fourth and fifth toes. The fasciculus for the fifth toe is often very small, and its tendon takes an oblique course to the insertion.

Insertion.—The tendons of the short flexor pass superficial to those of the long flexor into the osteofibrous canals on the flexor surface of the digits. Upon the first phalanx of each toe the tendon of the short flexor divides and forms an opening (chiasma tendinis) through which

the tendon of the long flexor passes, while the tendon of the short flexor becomes attached to the base of the second phalanx. The arrangement is essentially like that described at length for the flexors of the fingers (p. 433).

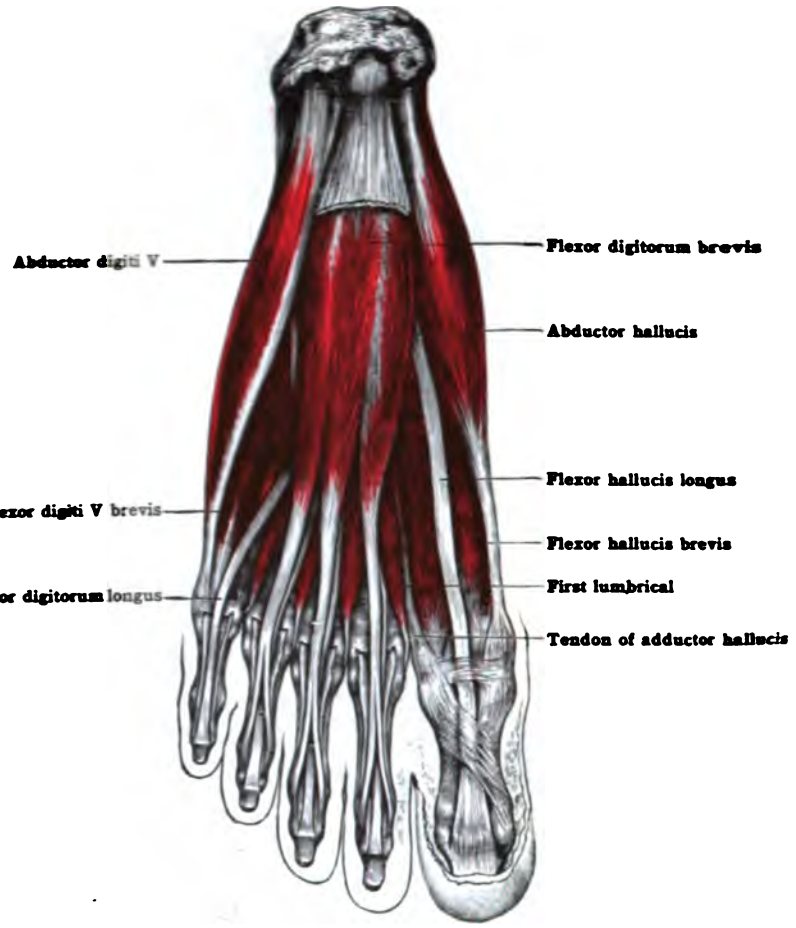
Nerve-supply.—From the medial plantar nerve by a branch which enters the middle third of the deep surface near the medial margin of the muscle.

Action.—It is a strong flexor of the second row of phalanges.

Relations.—The short flexor is separated from the abductors of the big toe and little toe by strong intermuscular septa (p. 524), and from the long flexor tendons and the quadratus plantæ (flexor accessorius) by a transverse septum in which the lateral plantar vessels and nerve cross the foot. In its distal two-thirds it is separated from the plantar fascia by loose tissue.

Variations.—The muscle shows a tendency toward reduction, one or more of its fasciculi being frequently absent, and occasionally the whole muscle. The fasciculus for the fifth toe is absent in about 20 per cent. of bodies (Le Double). When a fasciculus is absent, its tendon is usually replaced by an accessory tendon from the long flexor. The muscle or its tendons may be more or less fused to the tendons of the flexor digitorum longus.

FIG. 450.—FIRST LAYER OF THE MUSCLES OF THE SOLE.



b. MUSCLES ATTACHED TO THE TENDONS OF THE FLEXOR DIGITORUM LONGUS (fig. 451)

The muscles belonging in this group are the **quadratus plantæ** (flexor accessorius), a flat, quadrangular, bicipital muscle which runs from the medial and plantar surface of the body of the calcaneus to the dorsolateral margin and deep surface of the long flexor tendon; and the **lumbricales**, four slender bipinnate muscles which run from the medial sides of the digital slips of the tendon to the medial sides of the four more lateral toes. The quadratus aids the long flexor muscle; the lumbricales extend the last two phalanges and flex the first phalanx of each of the digits to which they pass. The lumbrical muscles correspond to

those of the hand. The quadratus is not there represented. The nerve-supply is from the lateral (external) plantar nerve except that for the first lumbrical muscle which gets its supply from the medial (internal) plantar.

The quadratus plantæ (flexor accessorius) (fig. 451).—This muscle *arises* by two heads. The *lateral head* springs by an elongated tendon from the calcaneus in front of the lateral process of the tuber, and from the lateral margin of the long plantar ligament. The *medial head* arises directly from the medial surface of the body of the calcaneus as far back as the medial process of the tuber calcanei, and from neighboring ligaments.

Structure and insertion.—The two heads are separated at their origin by a short triangular space. They soon fuse to form a single belly, but the fiber-bundles of each head in the main are separately inserted. Those from the lateral head diverge to be attached to the lateral margin of the flexor tendon. Those from the medial head are inserted on a tendon that begins on the medial margin and deep surface of this head, becomes broader, and is inserted as a flat aponeurosis on the deep surface of the flexor tendon. There are great individual variations in the structure of this muscle. The fibers of either part may be inserted with those of the other part.

Nerve-supply.—From a branch of the lateral plantar nerve which passes obliquely across the superficial surface of the muscle parallel with the tendon of the flexor digitorum longus.

Relations.—The muscle lies in a fascial compartment with the long flexor tendons. This compartment is bounded on each side by intermuscular septa, deeply by the tarsus, and plantarward by a septum which intervenes between it and the flexor digitorum brevis, and in which the lateral plantar nerve and vessels cross to the lateral side of the foot.

Action.—It assists the long flexor tendon in flexing the toes. It makes the direction of traction on the toes parallel with the long axis of the foot.

Variations.—It is frequently reduced in size. The lateral head is not infrequently missing, the medial head or the whole muscle much more rarely. The mode of attachment to the tendon varies. It may be inserted in part or wholly into the long flexor of the great toe. It may receive, in about one body in twenty (Wood), an accessory slip of origin from the fibula, one of the muscles of the leg, the fascia of the leg or foot, or the medial surface of the calcaneus, etc.

The lumbricales.—The three lateral muscles *arise* from the contiguous sides of the digital tendon-slips of the flexor digitorum longus in the angles of division. The first lumbrical arises on the medial margin of the tendon to the second toe. The fiber-bundles of each muscle converge on both sides of a tendon which becomes free near the metatarsophalangeal joint and is *attached* to the medial side of the first phalanx of the toe to which the muscle belongs. A tendinous expansion is sent into the aponeurosis of the extensor muscle.

Nerve-supply.—The three lateral lumbrical muscles are most frequently supplied by branches of the deep ramus of the lateral plantar nerve, the medial by the first common plantar digital branch of the medial plantar nerve. The latter nerve may supply the two more medial muscles or the more medial muscles may receive a double supply. The branches of the lateral plantar nerve enter the deep surfaces of the muscles in the middle third. The branches of the medial plantar enter the medial borders of the muscles near the junction of the proximal and middle thirds.

Relations.—The lumbrical muscles lie in a plane with the long flexor tendons deeper than the flexor brevis tendons and superficial to the adductor hallucis. The deep branches of the lateral plantar nerve and vessels pass across their deep surface; superficial branches of both plantar nerves across the superficial surface.

Action.—To extend the last two phalanges of the toes and to flex the first.

Variations.—One or more of the muscles may be absent. Sometimes a muscle is doubled. This is more frequently the case with the third and fourth muscles. The first may arise wholly from the tendon of the posterior tibial muscle or from this and the long flexor of the big toe. The third lumbrical may arise from the flexor digitorum brevis. The second and fourth lumbricals may be inserted into the tendons of the flexor digitorum brevis.

c. Intrinsic Muscles of the Great Toe (figs. 450–452)

These muscles are the abductor, flexor brevis, and adductor. Of the three muscles, the first two lie in the medial fascial compartment, while the last lies in the middle compartment covered by the flexor digitorum longus and its associated muscles.

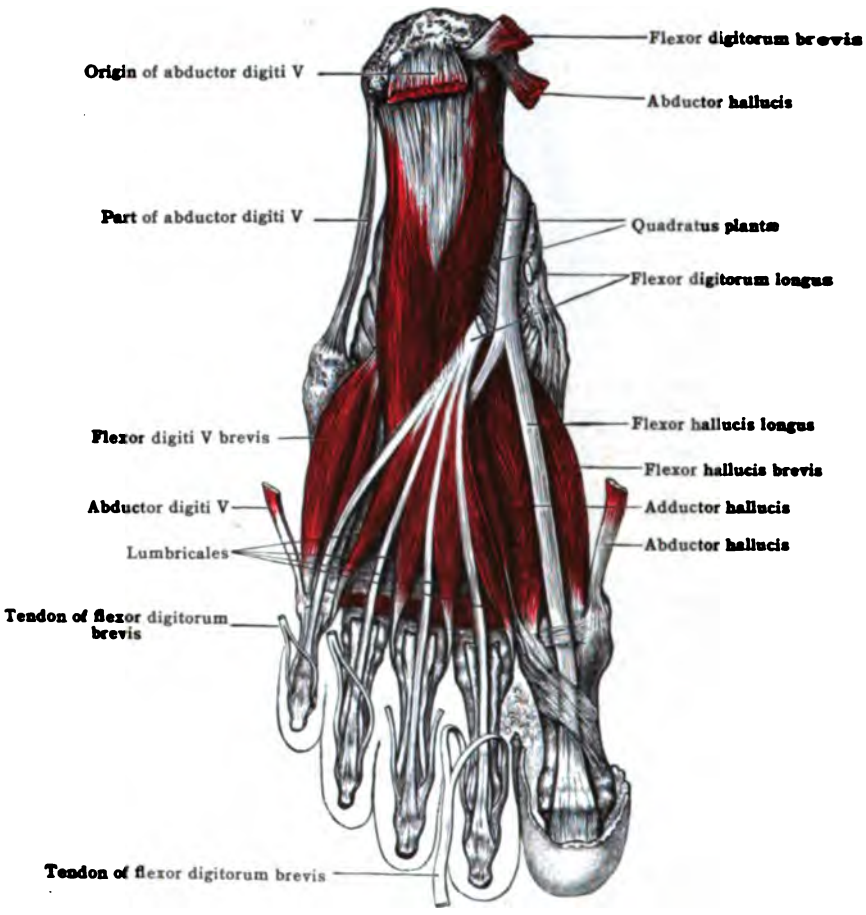
The **abductor hallucis** (fig. 450), the largest and most superficial of these muscles, lies on the border of the sole medial to the short flexor muscle. It passes from the calcaneus across the tendons of the long flexor muscles, and is inserted into the medial side of the base of the first phalanx of the great toe and into the medial side of the long extensor tendon. The **flexor hallucis brevis** (fig. 452) is a bicaudal muscle which arises in the region of the cuneiform bones and is inserted on each side of the base of the first phalanx. Its tendons are fused with those of the abductor and the oblique head of the adductor. The **adductor hallucis** (fig. 452) is composed of two distinct heads, an oblique and a transverse. The oblique head extends from the long plantar ligament to the lateral side of the base of the first phalanx of the great toe. Its tendon of insertion is joined by the transverse head, which arises from the capsules of the third to the fifth metatarsophalangeal joints.

These muscles perform not only the functions indicated by their names, but also extend the second phalanx. They correspond fairly well with those of the thumb. The opponens is not normally present in the foot. The nerve supply for the adductor is from the lateral (external) plantar nerve; that for the other muscles is from the medial (internal) plantar.

The abductor hallucis (fig. 450).—*Origin.*—From (1) the medial process of the tuber calcanei; (2) the deep surface of the neighboring plantar fascia; (3) the laciniate (internal annular) ligament; (4) the septum between the muscle and the flexor digitorum brevis; and (5) a fibrous arch which extends on the deep surface of the muscle over the plantar vessels and nerves and the long flexor tendons from the calcaneus to the navicular bone.

Structure.—From the medial process of the tuber calcanei a tendinous band passes to the deep, lateral side of the muscle. Numerous tendinous bands arise from the other areas of

FIG. 451.—SECOND LAYER OF THE MUSCLES OF THE SOLE.



origin. The fiber-bundles arise from these tendons and directly from the fibrous arch. They are attached in a penniform manner to numerous tendinous slips which extend far up in the muscle. These slips become gradually fused into a tendon which appears on the superficial plantar aspect of the muscle. Opposite the distal half of the first metatarsal bone the tendon leaves the belly of the muscle and becomes closely bound to the medial belly of the flexor hallucis brevis.

Insertion.—In conjunction with the tendon of the medial belly of the flexor brevis into the base of the first phalanx. It usually sends an expansion to the extensor tendon.

Nerve-supply.—A branch from the medial plantar nerve usually enters near the middle of the lateral border of the muscle.

Relations.—It is covered by the plantar fascia and is separated from the muscles of the medial compartment by the medial intermuscular septum. It crosses the tendons of the tibialis anterior, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles and the plantar vessels and nerves.

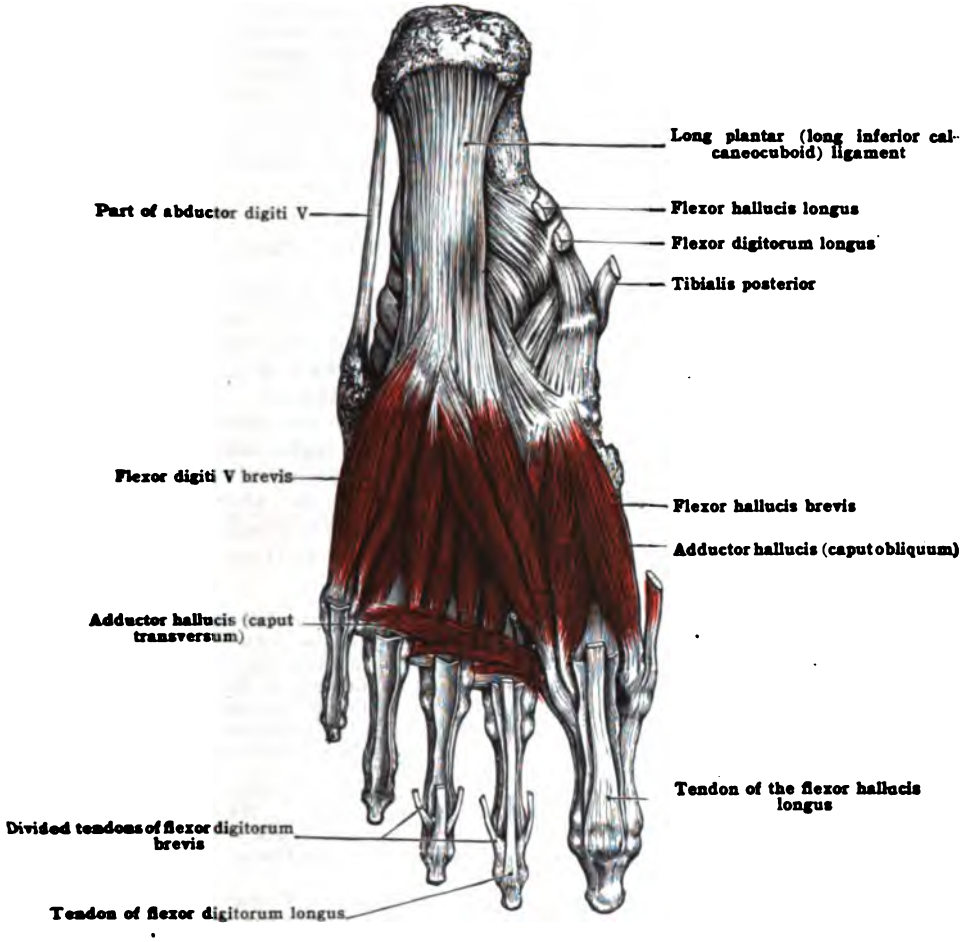
The flexor hallucis brevis (fig. 452).—*Origin.*—From a tendon attached to the first (internal), second and third cuneiform bones. The more lateral of its fibers are continued into the plantar calcaneocuboid ligament and the more medial into the expansion of the tendon of the posterior tibial muscle.

Structure and insertion.—The fiber-bundles give rise to two bellies, a medial and a lateral. Those of the medial belly pass obliquely medially to be inserted into the tendon of the abductor hallucis, and by a short tendon fused with this into the medial side of the plantar surface of the base of the first phalanx. This tendon contains a sesamoid bone. Those of the lateral converge upon the tendon of the oblique head of the adductor, and the two muscles are inserted by a common tendon, which contains a sesamoid bone, into the lateral side of the plantar surface of the base of the first phalanx.

Nerve-supply.—A branch from the medial plantar (or first plantar digital) nerve divides over the plantar surface of the muscle and gives a twig to each belly near the middle third. Rarely the lateral belly may receive a branch from the lateral plantar nerve.

Relations.—The abductor hallucis covers it medially; the tendon of the flexor hallucis longus passes between its two heads. Branches of the medial plantar vessels and nerve lie on its superficial surface.

FIG. 452.—THIRD LAYER OF THE MUSCLES OF THE SOLE.


Long plantar (long inferior calcaneocuboid) ligament
Part of abductor digiti V
Flexor hallucis longus
Flexor digitorum longus
Tibialis posterior
Flexor digiti V brevis
Flexor hallucis brevis
Adductor hallucis (caput obliquum)
Adductor hallucis (caput transversum)
Tendon of the flexor hallucis longus
Divided tendons of flexor digitorum brevis
Tendon of flexor digitorum longus

The adductor hallucis (fig. 452).—The **oblique head.**—*Origin.*—From (1) the tuberosity of the cuboid and the sheath over the tendon of the peroneus longus muscle; (2) the plantar calcaneocuboid ligament; (3) the third cuneiform; (4) the bases of the second and third metatarsals and (5) a fibrous arch which extends from the plantar calcaneocuboid ligament to the interosseous fascia.

Structure and insertion.—From short tendon-slips the fiber-bundles pass forward to form a thick, fusiform belly which is attached in a bipenniform manner to a flat tendon. The tendon begins about the middle of the plantar surface of the muscle and is inserted in common with that of the flexor brevis into the lateral side of the plantar surface of the base of the first phalanx, and by a slip into the aponeurosis of the long extensor muscle on the back of the big toe.

Nerve-supply.—A branch from the deep ramus of the lateral plantar nerve enters the middle third of the lateral border of the muscle on its deep surface.

The transverse head *arises* from the joint-capsules of the third, fourth, and fifth metatarsophalangeal joints and from the transverse capitular ligaments.

Structure and insertion.—Of the three fasciculi, that to the little toe lies nearest the heel, that to the middle toe the most distally. The fiber-bundles take a nearly parallel course to be attached to tendon-slips which are fused into a common tendon that splits and passes on each

of its extent it is covered by the triceps suræ. In the lower third of the leg it emerges medial to the soleus and the tendon of Achilles. The relations of its tendon at the ankle have been described above. The tendon lies beneath the origin of the abductor hallucis muscle and in the sole is covered by the flexor digitorum brevis, crosses the tendon of the long flexor and the oblique adductor of the big toe and the interosseous muscles, is joined by the quadratus plantæ (flexor accessorius), and gives origin to the lumbrical muscles.

The flexor hallucis longus (figs. 447, 451).—*Origin.*—From the distal two-thirds of the posterior surface of the fibula, the septa between it and the tibialis posterior and peroneal muscles, and the fascia above its proximal extremity.

Structure and insertion.—The fiber-bundles converge upon a tendon which begins in the second quarter of the muscle, within its substance, and emerges upon the posteromedial margin in its distal half. The insertion of the fiber-bundles continues to the end of the tibia. From here the tendon passes over the dorsal talotibial (tibioastragaloid) ligament, and through the groove on the posterior surface of the talus and the under surface of the sustentaculum tali, where it lies on the fibular side of the tendon of the flexor digitorum longus. It then crosses the deep surface of this tendon, to which it gives a slip, passes over the plantar surface of the medial head of the flexor hallucis brevis, and between the sesamoid bones of this muscle into the osteofibrous canal on the plantar surface of the big toe. It is inserted into the base of the terminal phalanx of the big toe.

Nerve-supply.—The nerve arises from the tibial (posterior tibial) nerve, often in company with the nerve to the flexor digitorum longus or the other muscles of the group. It runs along the deep surface of the muscle and sends twigs into the middle third of its constituent fiber-bundles. Sometimes two nerves are furnished to the muscle.

Relations.—It lies on the fibular side of the distal two-thirds of the leg. Proximally it diverges from the preceding muscle so as to disclose the tibialis posterior, which is more deeply situated. Between it and the tibialis posterior lie the peroneal vessels. Distally its tibial margin approaches the flexor digitorum longus, but between them lie the posterior tibial vessels and nerve. Lateral to it lie the peroneal muscles. It is covered in the leg by the soleus. In the distal part of the leg its tendon lies medial to the tendon of Achilles. On entering the foot the tendon crosses beneath the abductor hallucis muscle and the lateral plantar vessels and nerve. The other relations of the tendon have been described above.

The tibialis posterior (figs. 447, 453).—*Origin.*—From—(1) the lateral half of the distal margin of the popliteal line and the middle third of the posterior surface of the tibia; (2) the medial side of the head and of that part of the body of the fibula next the interosseous membrane in the proximal two-thirds; (3) from the whole of the proximal and the lateral portion of the distal part of the posterior surface of the interosseous membrane; and (4) from the septa between its proximal portion and the long flexor muscles.

Structure.—From this extensive area of origin the fiber-bundles converge upon a tendon, which is at first deep seated within the muscle-belly, but about the middle of the leg emerges on the medial margin of the muscle. The fibular portion of the muscle is much more extensive than the tibial. The proximal fibers take a nearly perpendicular, the most distal (from the fibula) a nearly transverse, course. The insertion of fibers stops a little proximal to the medial malleolus. The tendon then extends to the medial side of the tendon of the long flexor of the toes, passes through the groove on the back of the malleolus, across the medial talotibial (tibioastragaloid) ligament, and above the sustentaculum tali to the sole.

Insertion.—The tendon divides into two chief divisions, a deep and a superficial. (1) The deep portion becomes attached chiefly to the tubercle of the navicular bone, and usually in part also to the first cuneiform. (2) The superficial spreads out to be attached chiefly to the third cuneiform and the base of the fourth metatarsal, but also in part to the second cuneiform, to the capsule of the naviculocuneiform joint, to the sulcus of the cuboid, and usually also to the origin of the short flexor of the big toe and the base of the second metatarsal. Slips may, however, also be given to other structures. A sesamoid bone is usually found in the tendon either near the calcaneonavicular ligament or the navicular bone.

Nerve-supply.—The nerve arises from the tibial (posterior tibial) in company often with branches to the other muscles of the group. It enters the posterior surface of the muscle in its proximal third, and gives off one or two branches for the tibial fasciculus. The main trunk descends across the middle third of the fasciculi arising from the fibula.

Relations.—The muscle covers the posterior surface of the interosseous membrane, and extends distally over the posterior surface of the tibia beneath the flexor digitorum longus. It is covered proximally by the soleus, distally by the two long digital flexors. The posterior tibial and peroneal arteries and the tibial (posterior tibial) nerve run upon its posterior surface. The tendon in the sole is under cover of the origin of the plantar muscles of the big toe.

Action.—The tibialis posterior adducts the foot and slightly inverts it. The flexor digitorum longus flexes the terminal phalanx on the second and the second on the first, and at the height of its contraction the first on the metatarsals. It also rotates medially to some extent the ends of the fourth and fifth toes, and inverts the foot. The flexor hallucis longus flexes the second phalanx of the big toe on the first, and, less energetically, the first on the metatarsal. It also inverts the foot. All three muscles extend the foot. The flexor hallucis is the strongest of the three in this respect.

Variations.—The muscles of the group may be more or less fused with one another or be united by fasciculi. This is especially common between the two flexors of the toes. The individual muscles vary in development. The flexor digitorum longus may be more or less divided into separate fasciculi for the individual toes. The slip from the flexor hallucis longus to the flexor digitorum longus varies greatly in extent, but usually passes mainly to the second and third toes, more rarely to the second, third, and fourth, and very rarely to the fifth. In most of the apes the tibial flexor (flexor digitorum) sends tendons to the second and fifth, the fibular flexor (flexor hallucis) to the first, third, and fourth toes. This condition is also some-

d in man. A slip may pass from the tendon of the flexor digitorum to that of the ucis longus. There may be a sesamoid bone in the tendon of the flexor hallucis it passes over the talus (astragalus) and calcaneus. The tibialis posterior may be Aberrant fasciculi may arise from various regions on the back of the leg and join the three muscles of the group.

al muscles.—**The soleus accessorius.**—Arises by a tendon from the head of the fibula ıe soleus. It is usually a slender muscle inserted into the medial surface of cal- **The tibialis secundus** (tensor of capsule of ankle-joint).—A small muscle which ı the tibia beneath the flexor digitorum and is inserted into the capsule of the ankle- **e fibulocalcaneus medialis** (peroneocalcaneus internus of MacAlister, flexor acces- ;. dig. long., etc).—A fasciculus which arises from the lower third of the body of the gives rise to a tendon which passes beneath the laciniate ligament to the quadratus to the tendon of the flexor digitorum longus.

Bursæ

ndinea m. tibialis posterioris.—A small bursa between the navicular fibrocartilage ndon.

Synovial Tendon-sheaths

m. flexoris digitorum longi.—The tendon is surrounded by a synovial sheath from f the medial malleolus to where it crosses the tendon of the flexor hallucis longus navicular bone. It may communicate with the sheath of the tibialis anterior or with ıe flexor hallucis longus. **Vaginæ tendinum digitales.**—The tendons of the long ether with those of the short flexor, are surrounded by synovial sheaths from the he metatarsals to the insertions of the tendons. In structure these resemble those gers. **Vagina m. flexoris hallucis longi.**—The tendon is surrounded by a sheath ack of the medial malleolus to the crossing of the tendon of the flexor digitorum nother sheath surrounds the tendon from the middle of the first metatarsal to its **Vagina m. tibialis posterioris.**—The tendon is surrounded by a synovial sheath ex- ım a region proximal to the medial malleolus to the insertion of the tendon.

D. MUSCULATURE OF THE FOOT
(Figs. 449–453)

ıe dorsum of the foot there is a muscle not represented in the hand, the digitorum brevis. In the sole of the foot there is a highly developed ure which may be subdivided into the flexor digitorum brevis; the connected with the long extensor of the toes, quadratus plantæ and les; the intrinsic muscles of the great toe; the intrinsic muscles of the ; and the interosseous muscles. These muscles abduct and adduct the : them at the metacarpophalangeal joints and flex and extend them st row of interphalangeal joints. On the second row of interphalangeal ey seem to exert relatively little action. All the movements, excepting ıre weak in most individuals. The extensor digitorum brevis is in- by the deep peroneal (anterior tibial) nerve. The muscles of the sole ot are all innervated by the lateral (external) plantar, except the flexor ı brevis, the most medial of the lumbrical muscles, and the abductor r brevis of the great toe, which are innervated by the medial (internal)

FASCIÆ
(Fig. 448)

cutanea.—Over the dorsum of the foot the tela subcutanea contains little fat. On the foot and the plantar surface of the toes it contains much fat embedded in dense ıue.

fasciæ.—Over the **dorsum** of the foot a fascial membrane extends from the cru- ıent mentioned above to the toes, where it is continued as fibrous sheaths for the endons. Laterally and medially it is continued into the plantar fascia. Where skeletal structures it becomes adherent to them. In the main this fascial sheet is ır the base of the first metatarsal it is strengthened by a band which runs from the e of this bone over the extensor tendons of the big toe to the base of the second . The extensor digitorum brevis is covered by an adherent fascial sheet. The ace of each dorsal interosseous muscle is likewise covered by an adherent membrane. **ntar surface** of the foot is invested by a fascia in which three distinct regions may d, a central, a lateral, and a medial. The central region is greatly thickened by brous tissue, the **plantar aponeurosis,** which diverge toward the toes from the medial ı tuber calcanei. These bands become distinct from one another as the toes are

approached, and each finally terminates partly in the skin over the head of the corresponding metatarsal and in the digital sheath of the flexor tendons. Some of the fibers are continued into the transverse capitular ligaments, the others extend through near the metatarsophalangeal articulation to the dorsum of the foot. Broader, thicker bands go to the three middle toes than to the big and little toes. At the margins of this central area some fibers radiate into the fascia of the lateral and medial area, some extend laterally into the skin, and some sink into the intermuscular septa described below. Near the toes well-marked transverse bundles of fibers may be seen between the digital bands. The central area of the plantar fascia is not densely adherent to the skin.

The digital sheaths of the flexor tendons of the toes correspond essentially with those previously described (p. 433) for the fingers.

The **medial plantar fascia** is thin and adherent to the skin. It extends between the central plantar and the dorsal fascia over the intrinsic muscles of the big toe. The **lateral plantar fascia** is thick and well-developed near the heel, thin as the little toe is approached. A dense band, the **calcaneometatarsal ligament,** strengthens it between the calcaneus and the tuberosity of the fifth metatarsal.

At the junction of the medial with the central region of the plantar fascia the **medial intermuscular septum** sinks in to be attached to the first cuniform, the navicular and the tendon of the posterior tibial. A similar **lateral intermuscular septum** sinks in between the lateral and central regions of the plantar fascia and is attached to the long plantar ligament, the tendon sheath of the peroneus longus and the base of the fifth metatarsal. The fascia of each of these regions in considerable part extends into these septa instead of becoming continuous across them.

The sole is thus divided into three great fascial compartments by these septa, a lateral, a central, and a medial. In the lateral lie the intrinsic pedal muscles of the little toe; in the medial, the abductor and the flexor brevis of the big toe and the distal end of the tendon of the flexor hallucis longus. The central compartment is subdivided by transverse septa into several subcompartments. In the most superficial compartment lies the flexor digitorum brevis; in the second, the tendons of the flexor digitorum longus and its associated muscles, the quadratus plantæ (flexor accessorius) and the lumbrical muscles; in the third, the adductor muscles of the big toe; and in the fourth, the interosseous muscles.

The first two subcompartments are most clearly marked in the region of the tarsus. Distally they become merged by the disappearance of the intervening transverse septum, and longtiudinally subdivided by fibrous septa which serve to make a complete sheath over each digit for the flexor tendons. The sheath over the adductor muscle of the big toe is a thin membrane continued laterally from the medial intermuscular septum. Where the two heads of the adductor muscle advance upon their tendon of insertion, the medial septum has no skeletal attachment, so that the adductor subcompartment of the middle fascial compartment communicates freely with the medial compartment. Over the cuneiform bones the tendon of the flexor hallucis longus passes from the long flexor region of the middle compartment into the medial compartment. Here the medial intermuscular septum divides into two layers, which form a sheath for the tendon as it passes to the plantar surface of the flexor hallucis brevis.

MUSCLES

1. Muscle of the Dorsum of the Foot

The **extensor digitorum brevis** (fig. 449).—This muscle is broad and thin, lies beneath the tendons of the long extensor muscle on the tarsus, lateral to the navicular and the head of the talus, and sends tendons to the four more medial toes. It arises from the calcaneus. Its nerve-supply is from the deep peroneal.

Origin.—From the lateral and superior surfaces of the body of the calcaneus and from the apex of the cruciate ligament.

Structure and insertion.—The fiber-bundles arise directly from the ligament, and by short tendinous bands from the bone. As they extend distally they become grouped into four bellies. Those of the most medial and largest belly, the **extensor hallucis brevis,** become inserted in a bipenniform manner on the lateral and medial margins of a tendon which begins opposite the cuboid. The insertion of fiber-bundles continues to the base of the first metatarsal. The insertion of the fiber-bundles of the other bellies, which are seldom so distinctly isolated as the first, takes place in a penniform manner into their respective tendons, but the exact mode of attachment is subject to great individual variations. The tendon of the first digit is inserted mainly into the middle of the back of the base of the first phalanx, but it is often also united to the tendon of the long extensor. The other three tendons are fused with the lateral margins of the corresponding tendons of the long extensor near the bases of the three middle digits. They also usually give slips to the bases of the first phalanges of the corresponding toes.

Nerve-supply.—The deep peroneal (anterior tibial) nerve, which, accompanied by the anterior tibial artery, passes beneath the medial belly of the muscle, gives off a branch which passes transversely across the middle of the deep surface of the muscle and sends twigs into it.

Relations.—It lies on the lateral side of the tarsus, beneath the long extensor tendons of the toes. The relations of its tendons have been described above.

Action.—It aids the long extensors in extending the first phalanx of each of the four medial digits. It has but a limited action on the second and third phalanges. It serves also to pull the ends of the toes to which its tendons go toward the little toe.

Variations.—The muscle shows great variation in development. Rarely the whole muscle, more frequently one or more of its digital divisions, may be missing. On the other hand, it may

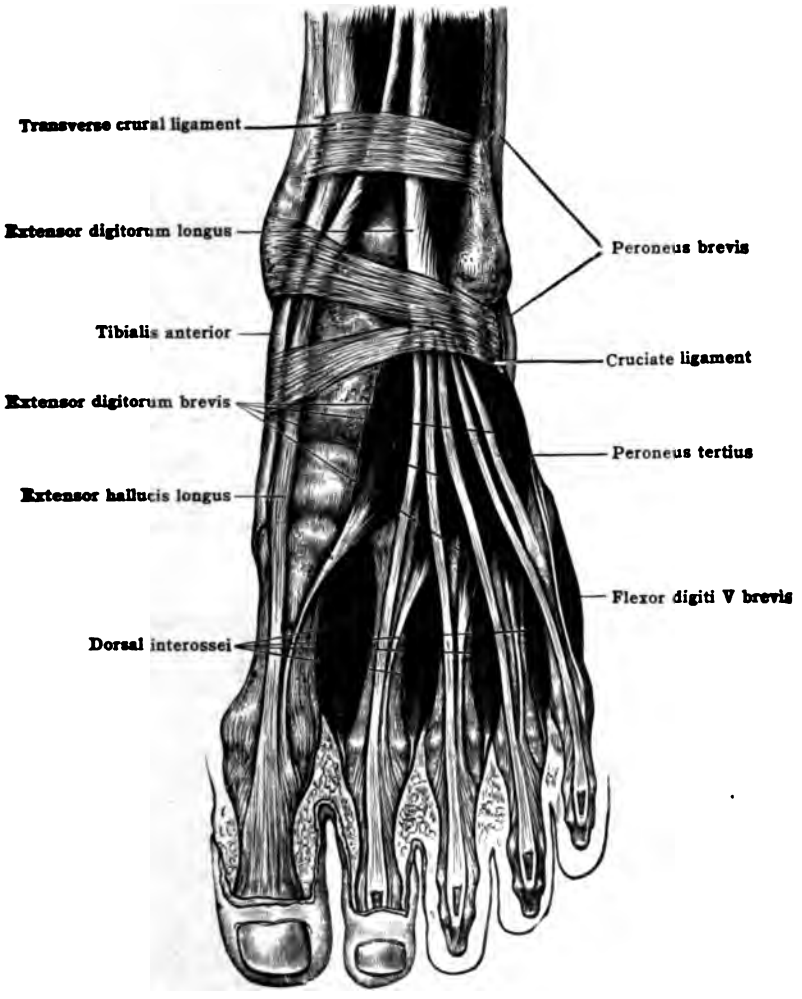
more highly developed than usual. Accessory fasciculi vary greatly in origin and termination. Most frequently their tendons go to a metacarpophalangeal articulation or to the second or the fifth toe.

2. Muscles of the Sole of the Foot

a. Flexor Digitorum Brevis (fig. 450)

The **flexor digitorum brevis,** the most superficially placed of the plantar muscles, lies in the midplantar region beneath the plantar fascia and over the tendons of the long flexor of the toes and its associated muscles. It arises from the calcaneus, and has a flat, elongated belly, which toward the middle of the sole is prolonged into four processes, each of which has a special tendon that is inserted into the second phalanx of one of the four lateral toes. The tendons of

Fig. 449.—The Muscle of the Dorsum of the Foot.



the muscle correspond to those of the flexor sublimis in the palm. The belly of the flexor sublimis is supposed to be represented by the soleus. The nerve supply is from the medial (internal) plantar.

Origin.—From (1) the medial process of the tuber calcanei; (2) the posterior third of the plantar aponeurosis; and (3) the medial and lateral intermuscular septa.

Structure.—The constituent fiber-bundles pass distally in a compact mass. The tendons of insertion begin within the muscle substance, and as the fiber-bundles become inserted on them, the separate fasciculi become more and more distinct. The fasciculi for the second and third toes are larger and arise more superficially than those for the fourth and fifth toes. The fasciculus for the fifth toe is often very small, and its tendon takes an oblique course to the insertion.

Insertion.—The tendons of the short flexor pass superficial to those of the long flexor into the osteofibrous canals on the flexor surface of the digits. Upon the first phalanx of each toe the tendon of the short flexor *divides and forms an opening* (chiasma tendinis) through which

the tendon of the long flexor passes, while the tendon of the short flexor becomes attached base of the second phalanx. The arrangement is essentially like that described at len the flexors of the fingers (p. 433).

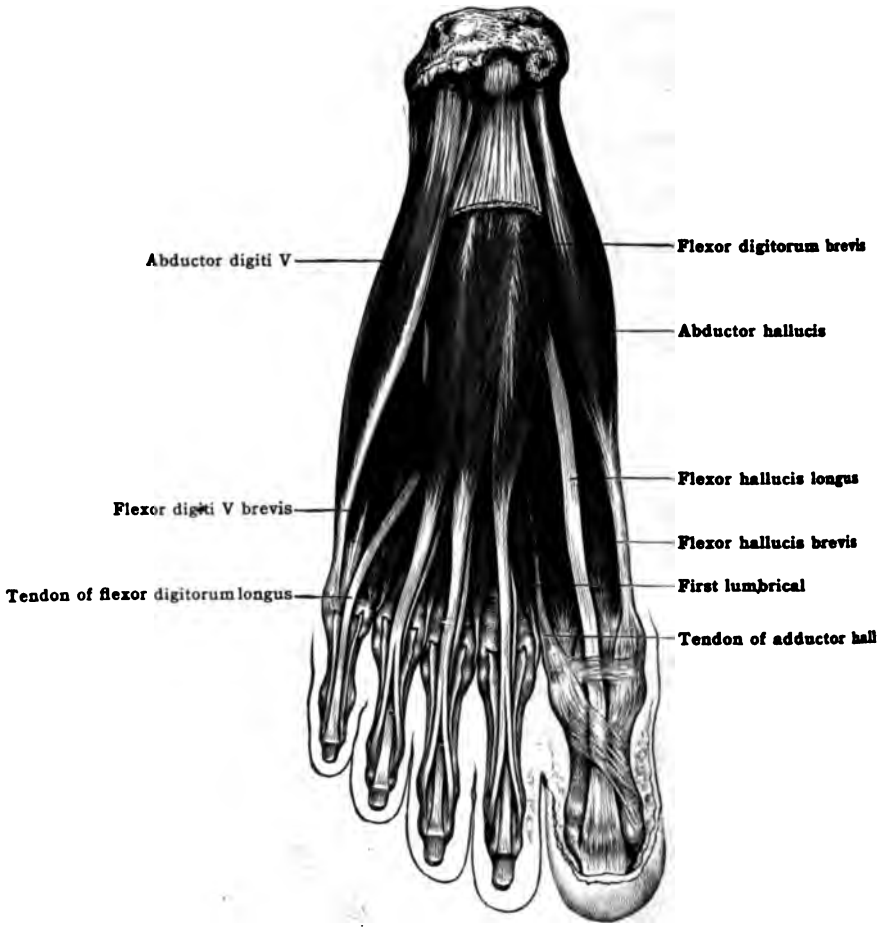
Nerve-supply.—From the medial plantar nerve by a branch which enters the middl of the deep surface near the medial margin of the muscle.

Action.—It is a strong flexor of the second row of phalanges.

Relations.—The short flexor is separated from the abductors of the big toe and lit by strong intermuscular septa (p. 524), and from the long flexor tendons and the qua plantæ (flexor accessorius) by a transverse septum in which the lateral plantar vess nerve cross the foot. In its distal two-thirds it is separated from the plantar fascia b tissue.

Variations.—The muscle shows a tendency toward reduction, one or more of its fa being frequently absent, and occasionally the whole muscle. The fasciculus for the fif

FIG. 450.—FIRST LAYER OF THE MUSCLES OF THE SOLE.



is absent in about 20 per cent. of bodies (Le Double). When a fasciculus is absent, its te usually replaced by an accessory tendon from the long flexor. The muscle or its tend be more or less fused to the tendons of the flexor digitorum longus.

b. MUSCLES ATTACHED TO THE TENDONS OF THE FLEXOR DIGITORU LONGUS (fig. 451)

The muscles belonging in this group are the **quadratus plantæ (fle** cessorius), a flat, quadrangular, bicipital muscle which runs from the med plantar surface of the body of the calcaneus to the dorsolateral margin an surface of the long flexor tendon; and the **lumbricales, four slender bi** muscles which run from the medial sides of the digital slips of the tendon medial sides of the four more lateral toes. The quadratus aids the long muscle; the lumbricales extend the last two phalanges and flex the first p of each of the digits to which they pass. The lumbrical muscles corresp

he hand. The quadratus is not there represented. The nerve-supply ıe lateral (external) plantar nerve except that for the first lumbrical ıich gets its supply from the medial (internal) plantar.

ıdratus plantæ (flexor accessorius) (fig. 451).—This muscle *arises* by two heads. *head* springs by an elongated tendon from the calcaneus in front of the lateral he tuber, and from the lateral margin of the long plantar ligament. The *medial head* tly from the medial surface of the body of the calcaneus as far back as the medial he tuber calcanei, and from neighboring ligaments.

e and insertion.—The two heads are separated at their origin by a short triangular ay soon fuse to form a single belly, but the fiber-bundles of each head in the main ely inserted. Those from the lateral head diverge to be attached to the lateral he flexor tendon. Those from the medial head are inserted on a tendon that begins lial margin and deep surface of this head, becomes broader, and is inserted as a rosis on the deep surface of the flexor tendon. There are great individual varia- structure of this muscle. The fibers of either part may be inserted with those of art.

pply.—From a branch of the lateral plantar nerve which passes obliquely across ial surface of the muscle parallel with the tendon of the flexor digitorum longus.

s.—The muscle lies in a fascial compartment with the long flexor tendons. This it is bounded on each side by intermuscular septa, deeply by the tarsus, and plantar- eptum which intervenes between it and the flexor digitorum brevis, and in which the tar nerve and vessels cross to the lateral side of the foot.

–It assists the long flexor tendon in flexing the toes. It makes the direction of the toes parallel with the long axis of the foot.

ns.—It is frequently reduced in size. The lateral head is not infrequently missing, ıead or the whole muscle much more rarely. The mode of attachment to the tendon may be inserted in part or wholly into the long flexor of the great toe. It may bout one body in twenty (Wood), an accessory slip of origin from the fibula, one of of the leg, the fascia of the leg or foot, or the medial surface of the calcaneus, etc.

ıbricales.—The three lateral muscles *arise* from the contiguous sides of the digital ı of the flexor digitorum longus in the angles of division. The first lumbrical arises ial margin of the tendon to the second toe. The fiber-bundles of each muscle con- th sides of a tendon which becomes free near the metatarsophalangeal joint and is he medial side of the first phalanx of the toe to which the muscle belongs. A tendi- ion is sent into the aponeurosis of the extensor muscle.

pply.—The three lateral lumbrical muscles are most frequently supplied by branches ramus of the lateral plantar nerve, the medial by the first common plantar digital ıe medial plantar nerve. The latter nerve may supply the two more medial muscles medial muscles may receive a double supply. The branches of the lateral plantar the deep surfaces of the muscles in the middle third. The branches of the medial ır the medial borders of the muscles near the junction of the proximal and middle

ı.—The lumbrical muscles lie in a plane with the long flexor tendons deeper than revis tendons and superficial to the adductor hallucis. The deep branches of the tar nerve and vessels pass across their deep surface; superficial branches of both ·es across the superficial surface.

–To extend the last two phalanges of the toes and to flex the first.

ns.—One or more of the muscles may be absent. Sometimes a muscle is doubled. frequently the case with the third and fourth muscles. The first may arise wholly ıdon of the posterior tibial muscle or from this and the long flexor of the big toe. ımbrical may arise from the flexor digitorum brevis. The second and fourth lum- be inserted into the tendons of the flexor digitorum brevis.

c. Intrinsic Muscles of the Great Toe (figs. 450–452)

muscles are the abductor, flexor brevis, and adductor. Of the three he first two lie in the medial fascial compartment, while the last lies in compartment covered by the flexor digitorum longus and its associated

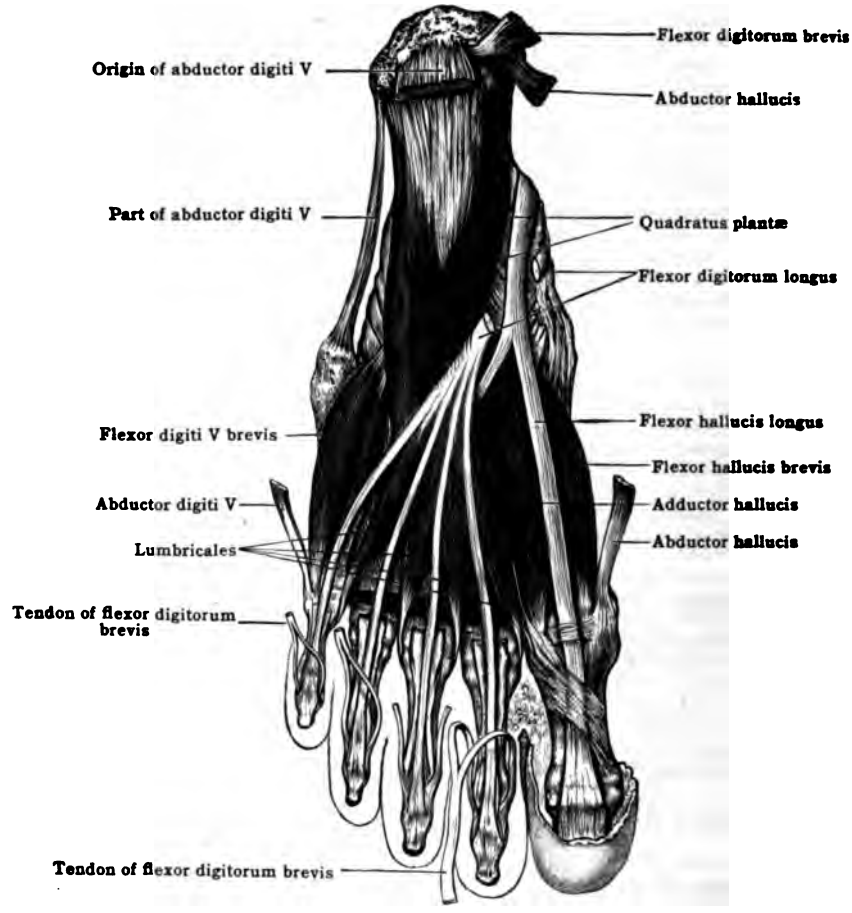
ıductor hallucis (fig. 450), the largest and most superficial of these es on the border of the sole medial to the short flexor muscle. It passes alcaneus across the tendons of the long flexor muscles, and is inserted edial side of the base of the first phalanx of the great toe and into the ɔ of the long extensor tendon. The **flexor hallucis brevis** (fig. 452) is a ıuscle which arises in the region of the cuneiform bones and is inserted le of the base of the first phalanx. Its tendons are fused with those of tor and the oblique head of the adductor. The **adductor hallucis** s composed of two distinct heads, an oblique and a transverse. The ad extends from the long plantar ligament to the lateral side of the base phalanx of the great toe. Its tendon of insertion is joined by the trans- l, which arises from the capsules of the third to the fifth metatarso- joints.

These muscles perform not only the functions indicated by their names, but also extend the second phalanx. They correspond fairly well with those of the thumb. The opponens is not normally present in the foot. The nerve supply for the adductor is from the lateral (external) plantar nerve; that for the other muscles is from the medial (internal) plantar.

The abductor hallucis (fig. 450).—*Origin.*—From (1) the medial process of the tuber calcanei; (2) the deep surface of the neighboring plantar fascia; (3) the laciniate (internal annular) ligament; (4) the septum between the muscle and the flexor digitorum brevis; and (5) a fibrous arch which extends on the deep surface of the muscle over the plantar vessels and nerves and the long flexor tendons from the calcaneus to the navicular bone.

Structure.—From the medial process of the tuber calcanei a tendinous band passes to the deep, lateral side of the muscle. Numerous tendinous bands arise from the other areas of

FIG. 451.—SECOND LAYER OF THE MUSCLES OF THE SOLE.



origin. The fiber-bundles arise from these tendons and directly from the fibrous arch. They are attached in a penniform manner to numerous tendinous slips which extend far up in the muscle. These slips become gradually fused into a tendon which appears on the superficial plantar aspect of the muscle. Opposite the distal half of the first metatarsal bone the tendon leaves the belly of the muscle and becomes closely bound to the medial belly of the flexor hallucis brevis.

Insertion.—In conjunction with the tendon of the medial belly of the flexor brevis into the base of the first phalanx. It usually sends an expansion to the extensor tendon.

Nerve-supply.—A branch from the medial plantar nerve usually enters near the middle of the lateral border of the muscle.

Relations.—It is covered by the plantar fascia and is separated from the muscles of the medial compartment by the medial intermuscular septum. It crosses the tendons of the tibialis anterior, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles and the plantar vessels and nerves.

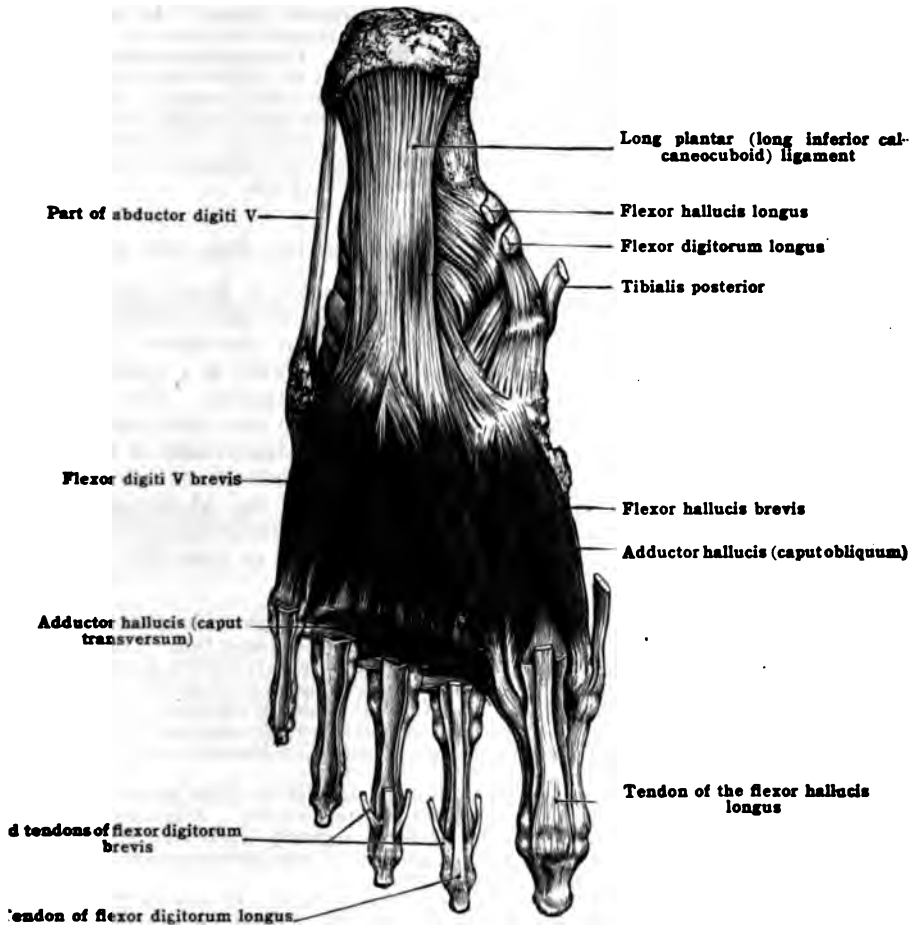
The flexor hallucis brevis (fig. 452).—*Origin.*—From a tendon attached to the first (internal), second and third cuneiform bones. The more lateral of its fibers are continued into the plantar calcaneocuboid ligament and the more medial into the expansion of the tendon of the posterior tibial muscle.

ructure and insertion.—The fiber-bundles give rise to two bellies, a medial and a lateral. s of the medial belly pass obliquely medially to be inserted into the tendon of the abductor is, and by a short tendon fused with this into the medial side of the plantar surface of the of the first phalanx. This tendon contains a sesamoid bone. Those of the lateral converge the tendon of the oblique head of the adductor, and the two muscles are inserted by a mon tendon, which contains a sesamoid bone, into the lateral side of the plantar surface e base of the first phalanx.

erve-supply.—A branch from the medial plantar (or first plantar digital) nerve divides over lantar surface of the muscle and gives a twig to each belly near the middle third. Rarely teral belly may receive a branch from the lateral plantar nerve.

elations.—The abductor hallucis covers it medially; the tendon of the flexor hallucis is passes between its two heads. Branches of the medial plantar vessels and nerve lie superficial surface.

FIG. 452.—THIRD LAYER OF THE MUSCLES OF THE SOLE.


Long plantar (long inferior calcaneocuboid) ligament
Part of abductor digiti V
Flexor hallucis longus
Flexor digitorum longus
Tibialis posterior
Flexor digiti V brevis
Flexor hallucis brevis
Adductor hallucis (caput obliquum)
Adductor hallucis (caput transversum)
Tendon of the flexor hallucis longus
d tendons of flexor digitorum brevis
endon of flexor digitorum longus

ıe adductor hallucis (fig. 452).—The **oblique head.**—*Origin.*—From (1) the tuberosity ı cuboid and the sheath over the tendon of the peroneus longus muscle; (2) the plantar ıeocuboid ligament; (3) the third cuneiform; (4) the bases of the second and third meta- s and (5) a fibrous arch which extends from the plantar calcaneocuboid ligament to the aseous fascia.

ructure and insertion.—From short tendon-slips the fiber-bundles pass forward to form a fusiform belly which is attached in a bipenniform manner to a flat tendon. The tendon s about the middle of the plantar surface of the muscle and is inserted in common with that ı flexor brevis into the lateral side of the plantar surface of the base of the first phalanx, y a slip into the aponeurosis of the long extensor muscle on the back of the big toe.

rve-supply.—A branch from the deep ramus of the lateral plantar nerve enters the middle of the lateral border of the muscle on its deep surface.

ıe transverse head *arises* from the joint-capsules of the third, fourth, and fifth metatarso- ngeal joints and from the transverse capitular ligaments.

ructure and insertion.—Of the three fasciculi, that to the little toe lies nearest the heel, o the middle toe the most distally. The fiber-bundles take a nearly parallel course to be ıed to tendon-slips which are fused into a common tendon that splits and passes on each

side of the tendon of the oblique head and is inserted into the sheath of the tendon of th flexor of the great toe (Leboucq).

Nerve-supply.—A branch from the deep ramus of the lateral plantar nerve enters the third of the deep surface of the muscle.

Relations.—The adductor hallucis is crossed superficially by the tendons of the digitorum longus and by the lumbrical muscles. On its deep surface lie the interosseous cles, and the deep plantar vessels and nerves.

Action.—The actions of the muscles of this group are indicated by the names of the i ual muscles. The abductor and the oblique head of the adductor are also flexors of th phalanx. All the muscles of the group aid in extending the second phalanx. The tra head of the adductor serves to draw together the heads of the metatarsals after they hav separated by the weight of the body during the tread.

Variations.—The extent of fusion of the abductor and adductor with the two heads short flexor varies considerably. The abductor may receive an accessory fasciculus fr medial border of the foot. Either the adductor or the flexor brevis may send a tendon base of the first phalanx or to the short flexor tendon of the second toe. The adductor frequent variations in relation to its metatarsal attachments, owing to the fact that ori a fasciculus from the body of the second (and third) metatarsal was probably normally and the transverse head was more developed (Leboucq). The **opponens hallucis** is a fas occasionally found which extends from the short flexor or the medial intermuscular sep the body of the first metatarsal. This muscle is normal in some monkeys. An **adductor secundi** has been seen to arise from various sources and become attached to the lateral the plantar surface of the base of the first phalanx of the second toe. This muscle may b with the oblique adductor. A corresponding muscle is found normally in some apes, some of the lower animals there is a special adductor for each toe.

d. Intrinsic Muscles of the Little Toe (figs. 450–452)

In this group belong three muscles, an abductor, a flexor and an opp The largest of these, the **abductor digiti quinti,** extends superficially ov lateral margin of the foot from the lateral side of the tuber calcanei base of the little toe. The **flexor digiti quinti brevis** is a small, flat m which lies on the plantar surface of the fifth metatarsal. The **opponen** small muscle lying lateral to this. The two, which are often fused, aris the cuboid. The flexor brevis is inserted into the plantar side of the base first phalanx of the little toe. The opponens is inserted into the lateral s of the metatarsal. The abductor corresponds to the abductor of the finger. The opponens and flexor brevis probably correspond to the deep p the opponens of the little finger. The nerve supply is from the lateral p nerve.

The abductor digiti quinti (fig. 450)).—*Origin.*—From (1) the lateral process of th calcanei and the lateral and plantar surface of the body of the bone in front of this; (2) th intermuscular septum; (3) the deep surface of the lateral plantar fascia, including the band extending from the calcaneus to the lateral side of the base of the fifth metatars

Structure.—The fiber-bundles run obliquely to a flat tendon of insertion. This begin the muscle near the calcaneocuboid joint, soon emerges on the medial side of the deep and becomes free near the metatarsophalangeal joint. Considerable individual vari structure is found.

Insertion.—On the lateral surface of the first phalanx of the little toe and the me phalangeal capsule. Often a slip is sent to the extensor tendon. While usually the glides over the tuberosity of the fifth metatarsal, it frequently sends a second fasciculu attached to this bone (**abductor ossis metatarsi quinti**). A special fasciculus from the tul often constitutes the lateral margin of the muscle.

Nerve-supply.—The nerve arises from the lateral plantar. It may be distributed near the deep or the superficial surface of the muscle. The former appears to be the ca the muscle is slightly developed. The chief intramuscular branches then extend ac middle third of the constituent fiber-bundles near the deep surface. In case the calcan tarsal bundles are well developed, the nerve enters the proximal margin of the muscle chief branches extend across the middle third of the more superficial muscle-bundles, terminating in the distal margin of the muscle.

Relations.—It is ensheathed by the plantar fascia and the lateral intermuscular s It lies superficial to the quadratus plantæ (flexor accessorius), the opponens and flexo of the little toe, the long plantar ligament, and the tendon of the peroneus longus muscl

The flexor digiti quinti brevis (fig. 452)).—*Origin.*—From the sheath of the peroneus the tuberosity of the cuboid, and (3) the base of the fifth metatarsal.

Structure and insertion.—The fiber-bundles take a nearly parallel course, although th is slightly fusiform. They are attached by short tendinous bands to the base of t phalanx of the little toe, the capsule of the corresponding joint, and the aponeurosis dorsal surface of the toe.

Nerve-supply.—A branch of the superficial ramus of the lateral plantar nerve send to the middle third of the plantar surface of this and the following muscle.

Relations.—It is covered medially by the plantar fascia, laterally by the abductor fifth toe. Medially it lies superficial to the third plantar interosseous muscle.

The opponens digiti quinti.—This muscle *arises* from the sheath of the peroneus longus the tuberosity of the cuboid by a slender tendon which passes over the tuberosity of the metatarsal and gives rise to fiber-bundles which are *inserted* on the lateral surface of the metatarsal.

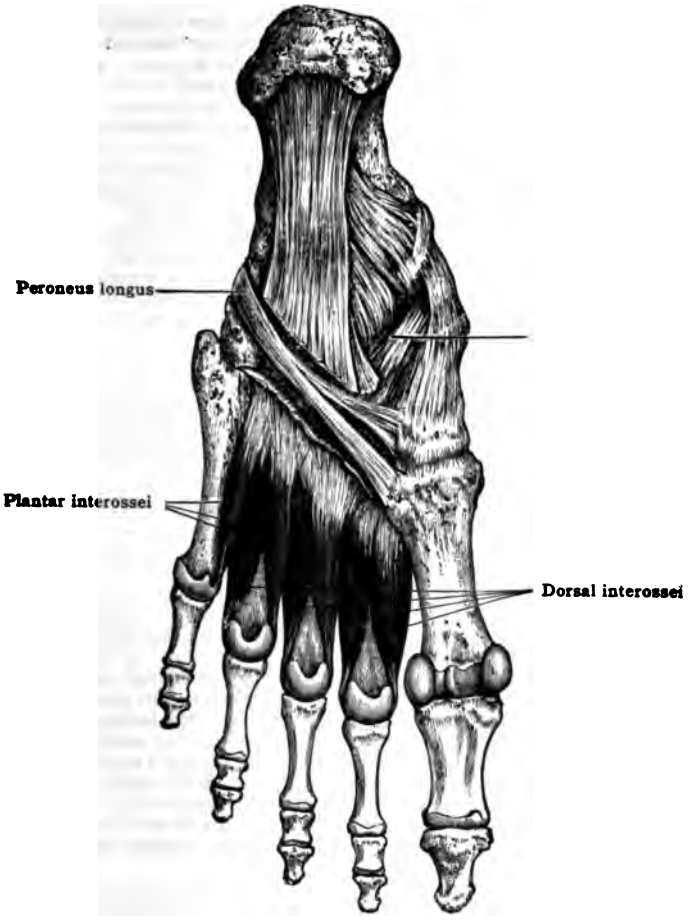
Nerve-supply.—From branches of the nerve to the flexor brevis.

Relations.—It is covered by the abductor of the fifth toe.

Actions.—The abductor and flexor brevis abduct the little toe and flex the first phalanx. act as extensors of the second phalanx. The opponens serves to draw the little toe medi- in a plantar direction.

Variations.—The muscles of this group may be more or less completely fused. The abduc-, in addition to the variations mentioned above, may send tendons to the third and fourth tatarsals. The opponens is frequently missing. The **abductor accessorius digiti quinti** is are muscle which arises from the lateral process of the tuber of the calcaneus and is inserted o the lateral surface of the base of the first phalanx of the little toe.

FIG. 453.—FOURTH LAYER OF THE MUSCLES OF THE SOLE.



e. THE INTEROSSEOUS MUSCLES (fig. 453)

Two groups of interosseous muscles are recognised, a dorsal and a plantar. The dorsal are the larger and fill the interspaces. The first two are inserted into each side of the base of the first phalanx of the second toe; the third and fourth into the lateral sides of the bases of the first phalanges of the third and fourth toes. The plantar interossei lie on the medial side of the ventral surfaces of the third, fourth, and fifth metatarsals, and are inserted each on the medial side of the base of the first phalanx of the corresponding toe. In the hand the axis about which the interosseous muscles are arranged passes through the middle finger, in the foot through the second toe. The dorsal interossei abduct from, the plantar adduct toward, this axis. The nerve-supply is from the lateral plantar nerve.

The interossei dorsales.—Each of the three lateral dorsal interosseous muscles *arises* from —(1) the sides of the shaft and the plantar surface of the bases of the metatarsal bones bounding

the space in which it lies; (2) from the fascia covering it dorsally; and (3) from fibrous proli... tions from the long plantar ligament. The first has a similar origin except that it is attac... medially to the base of the first metatarsal and to a fibrous arch extending from the base to ... head.

Structure.—The component fiber-bundles of each muscle are inserted bipinnately on a t... don which begins high in the muscle and becomes free near the metatarsophalangeal joint.

Insertion.—The first and second on each side of the base of the first phalanx of the ... toe. The third and fourth on the lateral side of the bases of the proximal phalanges of the ... and fourth toes. Each tendon is adherent to the capsule of the neighboring joint. T... send no well marked processes to the extensor tendons, as do those of the hand.

The interossei plantares.—Each plantar interosseus *arises.*—(1) from the proximal ... of the medial plantar surface of the shaft and from the base of the metatarsal on which it lies ... and (2) from expansions of the long plantar ligament.

Structure and insertion.—The obliquely placed fiber-bundles are longer than those of t... dorsal interossei, and are inserted in a tendon which lies near the medial border of the muscle ... becomes free near the metatarsophalangeal joint, and is inserted into a tubercle on the media... side of the base of the first phalanx of the digit to which it goes.

Nerve-supply.—From the deep branch of the lateral plantar nerve several rami are given off for the interossei. The nerve of each muscle enters the plantar surface in the proximal third. The interosseous muscles of the fourth interspace, however, are usually supplied by a branch from the superficial ramus of the lateral plantar nerve.

Relations.—The interosseous muscles are covered on the plantar surface by a thin fascia on which the deep branches of the lateral plantar nerve and vessels run. The first dorsal interosseous adjoins medially the flexor hallucis brevis and laterally on the plantar surface of the second metatarsal, adjoins the second dorsal interosseous. Dorsal and plantar interossei then alternate across the plantar surface of the foot until the fifth metatarsal is reached. Here the third plantar interosseous adjoins the flexor brevis of the little toe.

Action.—The chief axis of the foot may be taken to extend through the second toe. The dorsal interosseous muscles abduct—pull the digits to which they are attached away from this axis; the plantar interosseous muscles adduct—pull the digits toward the axis. The interossei all flex the first row of phalanges.

Variations.—The second dorsal interosseous may have no attachment to the third metatarsal.

Bursæ

B. intermetatarsophalangeæ.—Four bursæ between the neighboring sides of the heads of the metatarsal bones and dorsal to the transverse capitular ligaments. **B. mm. lumbricalium.**—Between the ends of the tendons of the lumbrical muscles and the transverse capitular ligaments. The three medial are more constant than the lateral.

For other bursæ in the foot, see pp. 514, 518 and 523.

MUSCLES GROUPED ACCORDING TO FUNCTION

The exact functions of many of the muscles have not yet been decisively determined Anatomical studies, the construction of mechanical models, the electrical stimulation of the musculature, and observation of the muscular activities of normal individuals and of individuals in whom given muscles or sets of muscles are absent or paralysed, have all proved valuable methods of investigation, but each method has its drawbacks, and knowledge of the part actually played by individual muscles in the normal activities of the body is as yet merely approximate. Owing to the influence of gravity, the relations of other muscles to the skeleton, and similar factors, a given muscle may perform functions which would not be deduced from a simple study of the relations of the muscle to the skeleton. Thus through the action ot gravity the iliacus flexes not only the hip, but also the knee, and the hamstring muscles flex he hip while flexing the knee. The functions ascribed to various muscles in the following table, although an attempt has been made to base them upon the more recent work on the action of the muscles, must be taken to be merely approximately correct.

The *axes* about which a bone moves at a given joint are frequently complex. For practical purposes, however, it is usually possible to determine an approximate axis about which any given movement takes place. From this standpoint diarthrodial joints may be divided into three groups, uniaxial joints, biaxial joints and multiaxial joints.

In the *uniaxial joints* movements of note may be made merely about one approximated axis. If a muscle acts on such a joint it exerts an effective pull either in one direction about this axis or in the opposite direction. Most joints of this sort are of the hinge-type, like those between the phalanges, and the movements are flexion and extension. In some joints as at the joint between the dens and atlas the joint is of the pivot-type and the movement is one of rotation in one direction or the other.

In *biaxial joints* there are two approximated primary axes of movement. Muscles acting on such joints may cause movement about either axis or about intermediate axes, the resultant of simultaneous movement about both primary axes. Joints of this sort are usually either of the saddle-type, like the carpometacarpal joint of the thumb, or of the condyloid type, like the wrist-joint. About one axis we usually get flexion and extension, about the other axis, abduction and adduction. A given muscle may cause movement about one axis or about both axes.

In *multiaxial joints* movements may be made about axes in three planes, each plane vertical to each of the other planes, and about various intermediate axes. Joints of this type are called ball-and-socket joints, although they are not always, like the shoulder- or hip-joints, similar in form to an ordinary mechanical ball-and-socket joint.

Muscles producing a movement in a common direction are called *synergists*, those which produce movements in opposite directions are called *antagonists*. If all joints were of the ginglymus type it would be relatively easy to arrange the muscles acting on the joints into synergists and antagonists although even in such joints a muscle might be so attached that it would act as a flexor after flexon has started, an extensor after extension has started. In case of arthrodial, and still more so in case of multiaxial joints, the direction of pull exerted by a given muscle with respect to a given axis varies so much with the positions of the articulating bones that muscles which in one position are antagonists in another position become synergists during the same general movement. Thus when the arm is at the side the clavicular and spinous portions of the deltoid are adductors, and the acromial portion is an abductor of the arm; but when the arm has been raised a certain distance all parts become abductors.

In the following table an attempt has been made to include the names of the main muscles acting upon the chief axes of each joint or joint groups of the head, trunk and limbs. In this table have been included not only the voluntary muscles described in the preceding section, but also several described in other parts of the book.

Facial muscles. (Cf. p. 364.)

These serve essentially to contract the various visceral orifices of the head or to retract the tissue surrounding them.

Ear.

Retractors: auricularis anterior, superior, and posterior.

Orbit.

(*a*) Retractor: epicranius (occipitofrontalis). The levator palpebræ superioris raises the upper eyelid.

(*b*) Contractors: orbicularis oculi, corrugator, and procerus.

Nasal orifice.

(*a*) Dilators: angular head of the quadratus labii superioris, transverse portion of the nasalis, and the dilatores naris.

(*b*) Contractors: pars alaris of the nasalis and the depressor septi nasi.

Oral orifice.

(*a*) Retractors:

Upward: zygomaticus, quadratus labii superioris, caninus.

Lateralward: zygomaticus, risorius, platysma, triangularis, buccinator.

Downward: triangularis, quadratus labii inferioris, platysma.

(*b*) Contractors: orbicularis oris, compressor labii, incisivus labii inferioris and superioris.

(*c*) Protractors of the lips: incisivus labii inferioris and superioris, mentalis.

2. Muscles acting on the eyeball (see Section on Eye).

To abduct the pupil: rectus medialis.

To abduct the pupil: rectus lateralis.

To direct the pupil upward: rectus superior, in association with the obliquus inferior.

To direct the pupil downward: rectus inferior, in association with the obliquus superior.

3. Muscles acting on the mandible (cf. p. 373).

(*a*) Transverse axis above the articular tubercles of the temporal bones (fig. 454 A (T)). As the articular disk glides forward over the articular tubercle it in part moves about an axis above this tubercle, in part takes a more horizontal course than if confined to movement about this axis. The condyles to some extent move forward on the lower surface of the disk. As the mandible moves forward it is depressed slightly so as to permit the incisor teeth of the lower jaw to pass those of the upper jaw.

Retraction of mandible	*Protraction of mandible*
Right and left temporal muscles, posterior two-thirds.	Right and left external pterygoids.

Protraction of the jaw is aided by the internal pterygoid and masseter muscles and the anterior part of the temporal. The digastric is an accessory retractor.

(*b*) Transverse axis through condyles of mandible (fig. 454 A (K)).

Elevation of teeth	*Depression of teeth*
Temporal muscles	Digastric muscles
Internal pterygoids	Geniohyoids
Masseters	Mylohyoids

In the elevation and depression of the anterior part of the mandible the articular disks and the condyles are pulled forward as the mandible swings about the transverse axis through the condyles. The region of the ramus near where the stylomandibular and pterygomandibular ligaments are attached moves comparatively little as the mouth opens. While some investigators have contended that these ligaments fix the jaw and make a transverse axis of movement, this is denied by others. (See Fick, bibliography.)

(*c*) Rotation about vertical axis through one condyle. (Fig. 454 B (KL)). Slight abduction about anteroposterior axis through same condyle (fig. 454 C).

Rotation about vertical axis left condyle. Upper and lower sets of molars of right side opposed to one another.

Forward movement of lower right molars
Right external pterygoid muscle

Backward movement of lower right molars
Right digastric muscle.

The right internal pterygoid, masseter and anterior third of the temporal muscles aid in the forward movement, the posterior two-thirds of the temporal in the backward movement.

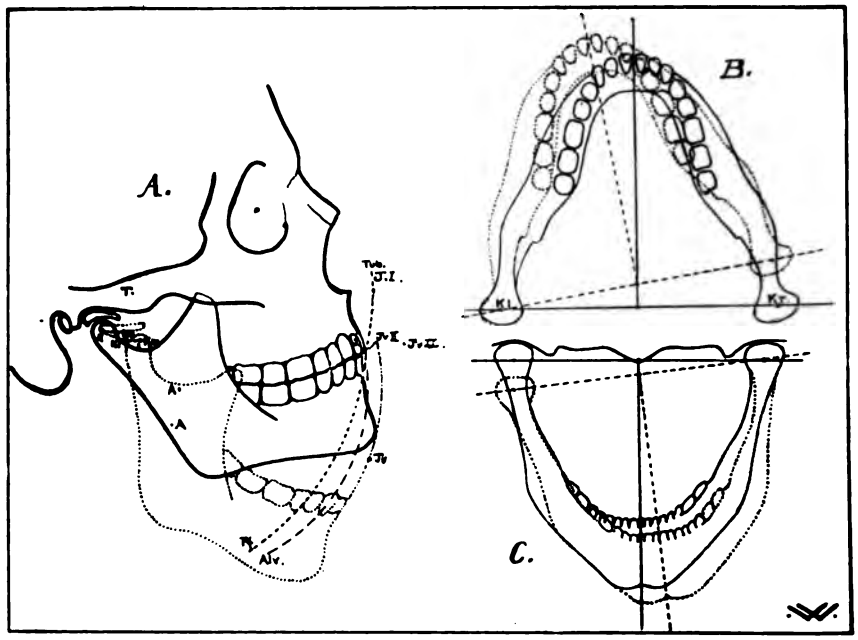
4. Muscles acting on the hyoid bone. (Cf. pp. 373, 384.)
   (*a*) To elevate it: digastric, stylohyoid, styloglossus, mylohyoid, geniohyoid, genioglossus, hyoglossus, and the middle constrictor of the pharynx.
   (*b*) To depress it: thyrohyoid, sternohyoid, omohyoid, sternothyroid.
   (*c*) To protract it: genioglossus (inferior portion), geniohyoid, anterior belly of digastric, and the mylohyoid.
   (*d*) To retract it: posterior belly of digastric, stylohyoid, and the middle constrictor of the pharynx.
5. Muscles acting on the larynx (see Section XI).
   (*a*) To elevate it: thyrohyoid, stylopharyngeus, pharyngopalatinus, the inferior constrictor of the pharynx, and the elevators of the hyoid.

FIG. 454.—CHIEF AXES IN MOVEMENTS OF THE MANDIBLE. (After Fick.)

A. Movement about transverse axis *T* through the articular tubercles of the temporal bone and *K* through the condyles of the mandible. *K*, K^{I}, K^{II}, K^{III}, successive positions of *K* as the mouth is opened. *J*, *JvII*, movement of the top edge of the incisors in protrusion of the mandible. *JvIII*, position of top edge of the incisors in extreme protrusion of the mandible. Dotted line *JI–Pf*, movement of top edge of central incisors when there is no protrusion of the mandible. Dotted line *JvII–Jv*, movement of the top edge of central incisors when the mandible is protruded.

B. Movement of mandible as seen from above about vertical axis through left condyle *Kl*. The line *Kl*, *Kr* indicates the position of the tranverse axis about which elevation and depression of the lower teeth takes place.

C. Mandible viewed from behind. Abduction about sagittal axis through right condyle.



   (*b*) To depress it: sternothyroid, sternohyoid, and omohyoid.
   (*c*) To approximate the vocal folds: cricoarytenoideus lateralis; vocalis; thyarytenoideus, arytenoideus transversus.
   (*d*) To make the vocal folds (cords) tense: cricothyroideus.
   (*e*) To widen the rima glottidis: cricoarytenoideus posterior.
   (*f*) To shorten and thicken the vocal folds: thyroarytenoideus (externus), vocalis.
   (*g*) To constrict the aditus and vestibule of the larynx: aryepiglottic, thyroarytenoideus.
   (*h*) To widen the aditus and vestibule of the larynx: thyroepiglottidei.
6. Muscles acting on the tongue (see Section X).
   (*a*) To elevate it: styloglossus (especially along the sides), glossopalatinus, glossopharyngeus, and the elevators of the hyoid bone.
   (*b*) To depress it: genioglossus (in the center), hyoglossus (at the sides), chondroglossus, and the depressors of the hyoid bone.

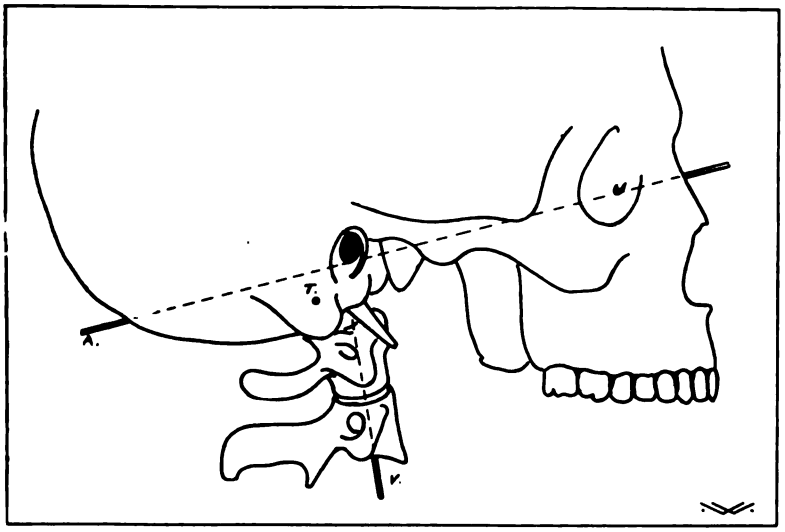
(*c*) To protrude it: genioglossus (middle and inferior portions).
(*d*) To retract it: genioglossus (anterior portion), styloglossus, chondroglossus.
(*e*) To shorten it and make it bulge upwards: longitudinalis superior and inferior.
(*f*) To narrow it and make it bulge upwards: transversus linguæ.
(*g*) To flatten it: verticalis linguæ.

When the muscles work symmetrically, these movements are symmetrical; when they do not work symmetrically, the tongue is moved from side to side, rotated, etc.

scles acting on the palate and pharynx (see Section X).

(*a*) To narrow the pharyngeal opening of the tuba auditiva (Eustachian tube): levator veli palatini.
(*b*) To widen the isthmus of the tuba: levator veli palatini.
(*c*) To open the tube: tensor veli palatini, pharyngopalatinus.
(*d*) To raise and shorten the uvula: m. uvulæ.
(*e*) To depress the soft palate: glossopalatinus, pharyngopalatinus.
(*f*) To make tense the soft palate: tensor veli palatini.
(*g*) To lift the soft palate: levator veli palatini.
(*h*) To approximate the glossopalatine arches; glossopalatinus.
(*i*) To approximate the pharyngopalatine arches: pharyngopalatinus, superior constrictor of the pharynx.
(*j*) To constrict the pharynx: superior, middle, and inferior constrictors.
(*k*) To widen the pharynx: stylopharyngeus and the muscles which protract the hyoid bone.
(*l*) To elevate the pharynx: stylopharyngeus, pharyngopalatinus.

FIG. 455.—CHIEF AXES OF MOVEMENT OF SKULL ON VERTEBRAL COLUMN
Sagittal axis; *T*, transverse axis; *V*, perpendicular axis.



uscles acting on the head (cf. pp. 382, 389, 444).

lanto-occipital and atlantoepistropheal joints. *Note.*—Flexion and extension (maximum exion, 30° extension, usually less) and abduction (15° to 20° from the midposition, fre-ly less) occur chiefly in the atlanto-occipital joints, rotation (about 30° from the mid-on) chiefly in the atlantoepistropheal joints. Abduction in the atlanto-occipital joint ompanied by rotation and extension toward the same side (Fick).

(*a*) Transverse axis above occipital condyles, (fig. 455,T).

Extension	*Flexion*
; and left trapezius	Right and left longus capitis
; and left semispinalis capitis	Right and left rectus capitis anterior
; and left obliquus capitis superior	Right and left rectus capitis lateralis
; and left rectus capitis posterior major	
; and left rectus capitis posterior minor	

ie supra- and infrahyoid muscles working together are accessory flexors. The right and sternocleidomastoids, splenius capitis, and longissimus capitis muscles are accessory sors.

(*b*) Vertical axis through dens of epistropheus (fig. 455,V).

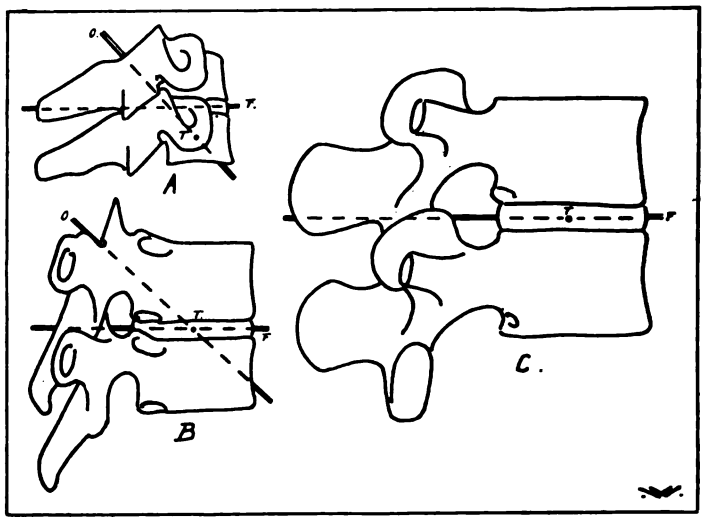
Rotation to right	*Rotation to left*
Left sternocleidomastoid	Right sternocleidomastoid
Left trapezius	Right trapezius
Right splenius capitis	Left splenius capitis
Right longissimus capitis	Left longissimus capitis
Right obliquus capitis inferior	Left obliquus capitis inferior
Right rectus capitis posterior major	Left rectus capitis posterior major
Right longus capitis	Left longus capitis

(*c*) Anteroposterior axis through base of occipital (fig. 455, A).

Lateral movement to right	*Lateral movement to left*
Right sternocleidomastoid and splenius capitis	Left sternocleidomastoid and splenius c
Right longissimus capitis	Left longissimus capitis
Right rectus capitis lateralis	Left rectus capitis lateralis
Right obliquus capitis superior	Left obliquus capitis superior
Right semispinalis capitis	Left semispinalis capitis

9. Muscles acting on the vertebral column (fig. 456) (cf. p. 444).
(1) *Cervical region.*

FIG. 456.—CHIEF AXES OF MOVEMENT OF ONE VERTEBRA ON THE NEXT BELOW *A*, cervical, *B*, thoracic and *C*, lumbar vertebræ. *O*, oblique axis in sagittal pla rotation combined with abduction; *F*, anteroposterior axis in sagittal plane for abdu *T*, transverse axis in frontal plane for flexion and extension.



(*a*) Transverse axes (fig. 456, A (T)).

Extension	*Flexion*
Splenius capitis and cervicis	Sternocleidomastoid
Semispinalis cervicis	Longus colli
Longissimus cervicis	Scaleni
Iliocostalis cervicis	
Semispinalis cervicis	
Spinalis	
Interspinales	
Multifidus	
Rotatores	

(*b*) Oblique axes (fig. 456 A (O)).

Oblique rotation to right	*Oblique rotation to left*
Right splenius capitis and cervicis	Left splenius capitis and cervicis
Right longissimus capitis and cervicis	Left longus capitis and cervicis
Left sternocleidomastoid	Right sternocleidomastoid
Right iliocostalis cervicis	Left iliocostalis cervicis
Left semispinalis cervicis	Right semispinalis cervicis
Left rotatores	Right rotatores
Upper part right longus colli	Lower part right longus colli
Lower part left longus colli	Upper part left longus colli
Left scaleni	Right scaleni

(c) Anteroposterior axes (fig. 456, A (F)).

duction to right	*Abduction to left*
ni	Left scaleni
ocleidomastoid	Left sternocleidomastoid
ius capitis and cervicis	Left splenius capitis and cervicis
stalis cervicis	Left iliocostalis cervicis
ssimus capitis and cervicis	Left longissimus capitis and cervicis
spinalis cervicis	Left semispinalis cervicis
transverse	Left intertransverse

ic region.

(a) Anteroposterior and transverse axes (fig. 456 B (F,T)).

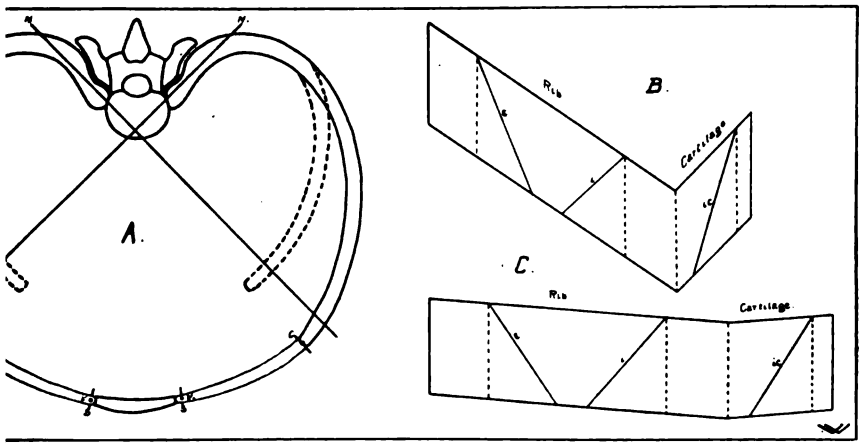
bduct to right and extend	*Abduct to left and extend*
stalis	Left iliocostalis
ssimus dorsi	Left longissimus dorsi
spinalis	Left semispinalis
ifidus	Left multifidus
tores	Left rotatores
tores costarum	Left levatores costarum
alis	Left spinalis
tores costarum	Left levatores costarum

—Scheme to Illustrate the Action of the Ribs. The Dotted Lines Represent the Position of the Ribs in Expiration.

about which the rib rotates; *C*, axis for costochondral joint; *S*, anteroposterior axis sternal joint; *v*, vertical axis of chondrosternal joint.

(After Fick).—Hamberger's Scheme for Illustrating the Action of the Intercostal Muscles.

nal intercostal; *i*, internal intercostal; *ic*, interchondral part of internal intercostal depressed.
elevated.



ercostal muscles and diaphragm slightly flex the thoracic region of the spine when ıe abdominal musculature. The scalene muscles and sternocleidomastoid may help he thoracic spine by acting through the ribs.

(b) Oblique axes (fig. 456, B (O))

que rotation to right	*Oblique rotation to left*
inalis	Right semispinalis
stalis	Left iliocostalis
idus	Right multifidus
res	Right rotatores
tores costarum	Left levatores costarum
us abdominis ext.	Right obliquus abdominis ext.
uus abdominis int.	Left obliquus abdominis int.
al intercostales	Right external intercostales
nal intercostales	Left internal intercostales

region.

(a) Transverse axes (fig. 456, C (O))

Extension	*Flexion*
left quadratus lumborum	Right and left abdominal muscles
left sacrospinalis	
left transverse	
left interspinal	

(*b*) Anteroposterior axes (fig. 456, C (F))

Abduction to right	*Abduction to left*
Right quadratus lumborum	Left quadratus lumborum

The psoas muscles are powerful accessory flexors and abductors of the lumbar regi spinal column. The right abdominal muscles abduct to the right, the left to the left.

10. Muscles acting on the thorax (fig. 457; A, B and C)

Longitudinal axes through necks of ribs, anteroposterior and vertical axes th cartilages near chondrosternal joints. The costochondral and interchondral joints involved.

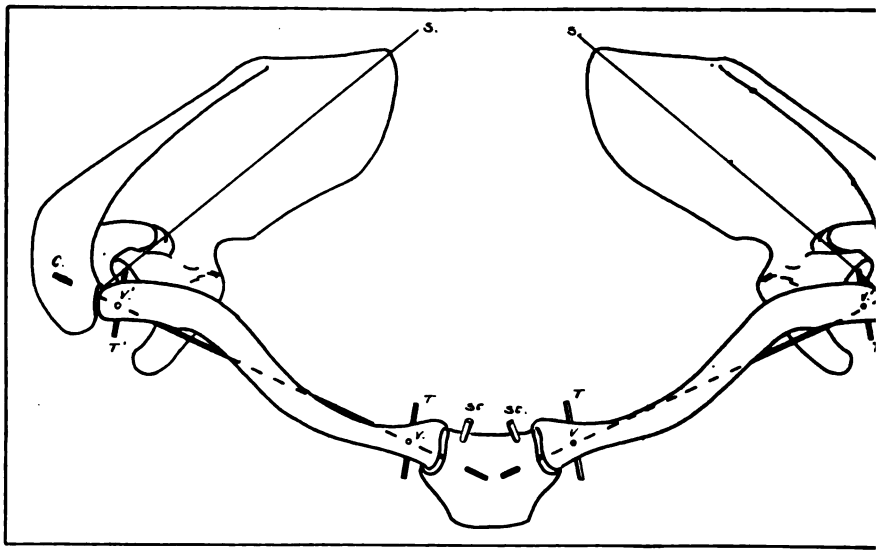
Inspiration.—Shafts of ribs swing outwards and upwards, costochondral angles flattened, sternum elevated and protracted.	*Expiration.*—Shafts of ribs s wards and downwards, costochondr increased, sternum depressed and re
External intercostals	Internal intercostals (costal part)
Interchondral muscles	Subcostals
	Transversus thoracis

The extensors of the thoracic region of the spine aid in inspiration. In forced inspi scalene, the sternocleidomastoid, the rhomboids and serratus anterior, the serratus superior, the trapezius and pectoralis minor, latissimus dorsi, pectoralis major and s may be brought into play. The abdominal muscles and the muscles of the pelvic essentially antagonists of the diaphragm. The abdominal muscles, the quadratus l the iliocostalis, the longissimus dorsi and the serratus posterior inferior lower the forced expiration.

The diaphragm plays an essential part in inspiration although according to Fick played by the diaphragm is frequently overestimated.

FIG. 458.—CHIEF AXES OF MOVEMENT OF THE SHOULDER GIRDLE.

Viewed from above. *S*, scapular axis; *C*, clavicular axis; *V*, vertical axis throu end of clavicle; *V'*, vertical axis through acromial end of clavicle; *St*, sternal axis ventral movements at sternoclavicular joint; *T*, ventrodorsal axis for elevation and d about the sternoclavicular joint; *T'*, dorsoventral axis for acromioclavicular joint.



11. Muscles acting on the abdomen. (Cf. p. 455.)
    (*a*) Constriction of the abdominal cavity: obliquus abdominis exte internus, the transversus and rectus abdominis, and phragm, levator ani, and coccygeus.
    (*b*) Reduction of pressure in the abdominal cavity: the muscles of in with the exception of the diaphragm, serve to lessen pression of the abdominal viscera.
12. Action of the muscles of the perineal region. (Cf. p. 472.)
    (*a*) To close anal canal: sphincter ani externus.
    (*b*) To constrict the anal portion of the rectum: levator ani (pubococcygea
    (*c*) To constrict the bulbus urethræ and the corpus cavernosum urethr spongiosum): bulbocavernosus.
    (*d*) To elevate the prostate gland: leavtor ani.
    (*e*) To constrict the vagina: bulbocavernosus, levator ani (pubococc tion), constrictor vaginæ.

(*f*) To cause erection of penis and clitoris: ischiocavernosus, bulbocavernosus, and sphincter urethræ membranaceæ.

(*g*) To compress the urethra and the bulbourethral (Cowper's) or the great vestibular (Bartholin's) gland: sphincter urethræ membranaceæ and the transversus perinei profundus.

(*h*) To support and lift the pelvic floor: levator ani, coccygeus, transversus perinei profundus and superficialis.

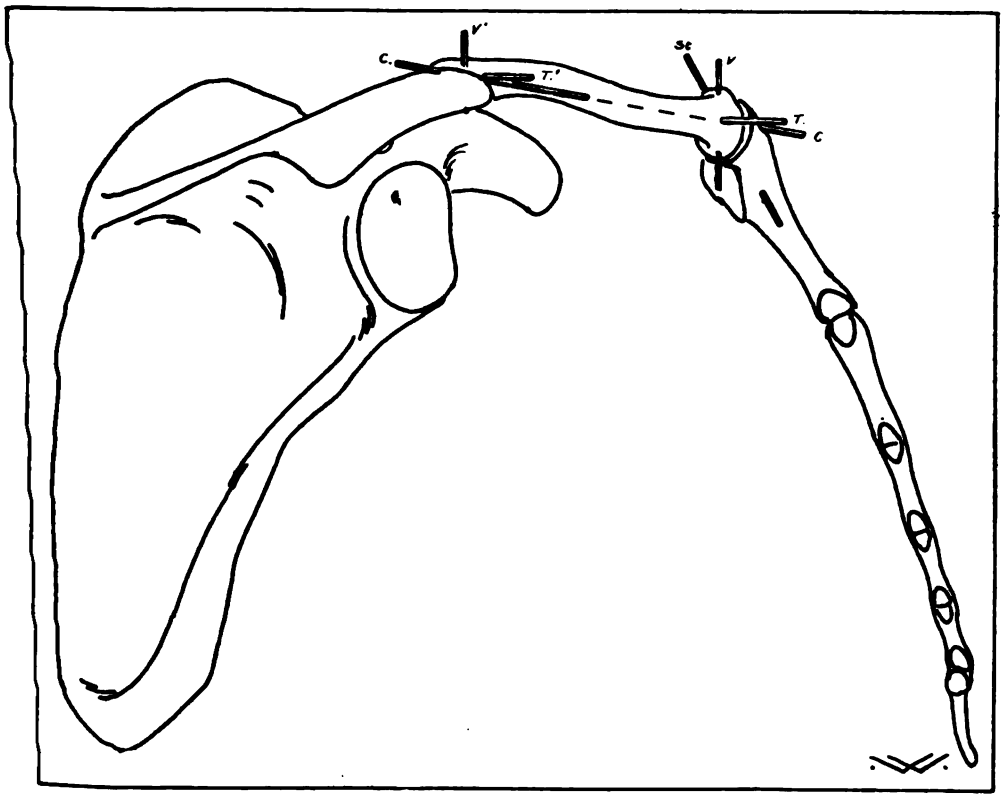
Muscles acting on the shoulder-girdle at the sternoclavicular joint (fig. 458) (cf. p. 382, 391, 403).

It is assumed that movement at the acromioclavicular joint, while enabling the scapula to accommodate itself to the chest wall, at the same time increases the extent of the rotation of the scapula about the clavicular (acromiosternal) axis.

(*a*) Dorsoventral axis (figs. 458, T, 459, T)

Abduction (scapula raised)	*Adduction (scapula depressed)*
Levator scapulæ	Pectoralis minor
Trapezius (upper part)	Subclavius
	Trapezius (lower part)

FIG. 459.—CHIEF AXES OF MOVEMENT OF THE SHOULDER GIRDLE. Viewed from the side. For explanations, see fig. 458.



The lower part of the serratus anterior is an accessory abductor. The pectoralis major (lower part) and latissimus dorsi, adductors of the arm, also indirectly adduct the scapula. The clavicular part of the sternocleidomastoid and the middle part of the serratus anterior are accessory abductors.

(*b*) Vertical axis (figs. 458, 459, V, St.)

The clavicle moves on the interarticular disk about a vertical axis through the head of the clavicle; the clavicle and disk move about an oblique axis through the sternum.

Retraction (scapula carried backward)	*Protraction (scapula carried forward)*
Rhomids	Serratus anterior
Trapezius (middle part)	Pectoralis minor
(The latissimus dorsi aids this movement)	(The pectoralis major, upper sternal part, aids this movement)

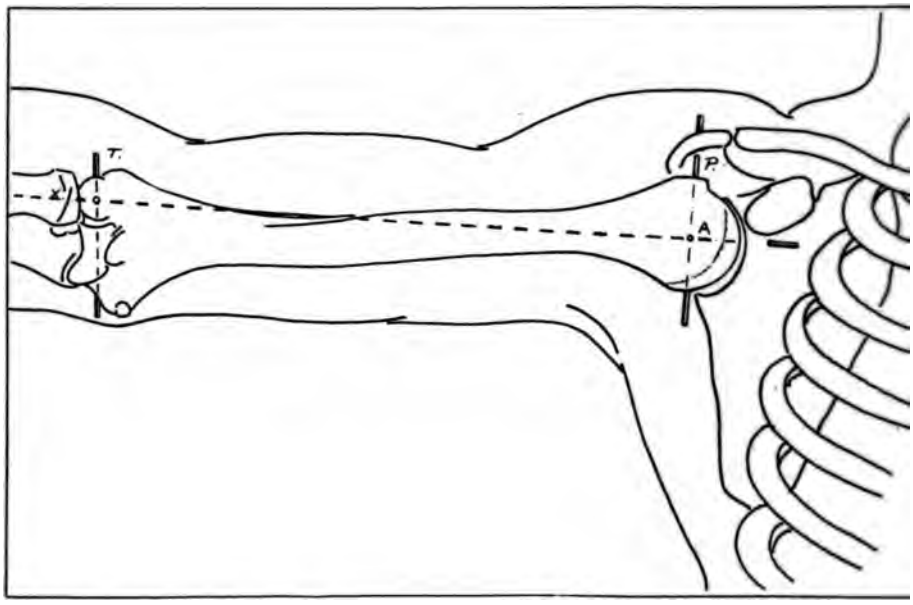
(*c*) Clavicular axis (figs. 458, 459, C)

Rotation in the direction of supination (glenoid cavity turned upward)	*Rotation in direction of pronation (gl cavity turned downward)*
Trapezius	Pectoralis minor
Serratus anterior (lower part)	Rhomboidius major

In the upward rotation the acromion and outer end of the clavicle are elevated and backwards, as well as rotated. The reverse is true of the downward rotation. The pect major (pectoral portion), and latissimus dorsi are accessory rotators in the directi pronation.

FIG. 460.—CHIEF AXES OF MOVEMENT AT SHOULDER AND ELBOW JOINTS.

A, dorsoventral axis of shoulder-joint for abduction and adduction; *P*, perpendicular shoulder-joint, arm adducted for flexion and extension. When the arm is at the side thi passes transversely through the body; *A–X*, longitudinal axis through humerus, for rot *T*, transverse axis through humerus for flexion and extension at elbow joint.



14. Muscles acting on the shoulder-joint (fig. 460) (cf. p. 397).

(*a*) Dorsoventral axis (fig. 460, A)

Abduction	*Adduction*
Deltoid	Pectoralis major (lower part)
Supraspinatus	Latissimus dorsi
	Teres major

With the arm at the side the clavicular and spinal parts of the deltoid are adductors the arm is abducted these parts become abductors. The subscapularis meanwhile chang an abductor to an adductor. The long head of the biceps and the upper part of th spinatus are strong accessory abductors. The long head of the triceps, the coracobra the short head of the biceps and the teres minor are strong accessory adductors when t is at the side.

(*b*) Transverse axis, arm at side; perpendicular axis, arm at 90° (fig. 460, P)

Extension	*Flexion*
Deltoid (spinal part)	Deltoid (clavicular part)
	Pectoralis major (clavicular part)
	Coracobrachialis

The latissimus dorsi, teres major, and subscapularis (lower part), when the arm is at t are strong accessory extensors; the short head of the biceps is a strong accessory flexor subscapularis is a powerful accessory flexor when the arm is abducted. The infraspin a flexor.

(*c*) Humeral axis (fig. 460, A–X)

Lateral rotation (supination)	*Medial rotation (pronation)*
Infraspinatus	Subscapularis
Teres minor	

The **spinal part** of the deltoid is also a lateral rotator. The adductor muscles, the clavicular part of the **deltoid**, and the long head of the biceps are strong accessory medial rotators. An important **function** of the coracobrachialis muscle and of the scapular attachments of the **biceps and triceps** muscles appears to be to hold the head of the humerus in the glenoid cavity.

Muscles acting on the forearm at the elbow-joint (figs. 460, 461) (cf. p. 411, 413, 416).

Transverse axis (figs. 460, 461, T)

Extension	*Flexion*
Triceps	Brachialis
Anconeus	Brachioradialis

The **biceps** muscle, a powerful flexor when the forearm is supinated, is a much weaker one when the **forearm** is pronated. The pronator teres and extensor carpi rad. long. are strong accessory **flexors** of the elbow-joint, the flexor carpi radialis, extensor carpi radialis brevis and palmaris **longus** are weaker accessory flexors.

Muscles acting on the radioulnar joints (figs. 461, 462) (cf. p. 416).

In the **ordinary** use of the upper extremity, supination of the foreman is usually accompanied by **extension** at the elbow-joint and lateral rotation at the shoulder-joint; pronation with flexion at the elbow-joint and medial rotation at the shoulder-joint.

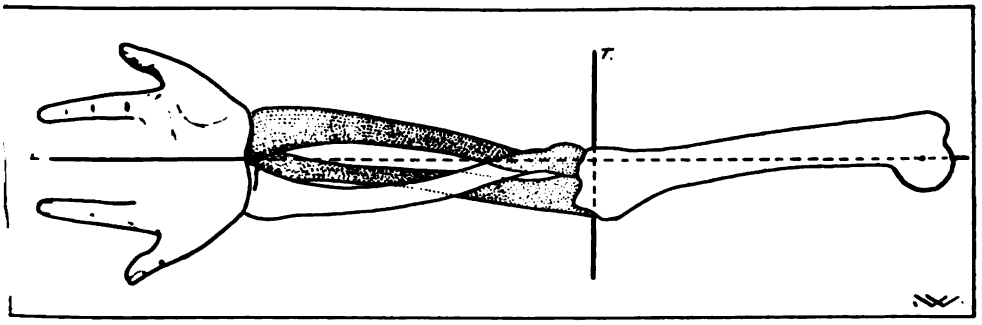
Longitudinal axis

Supination	*Pronation*
	Pronator teres
Supinator	Pronator quadratus

The **brachioradialis** and extensor carpi rad. long. bring the forearm into an intermediate position. When the arm is extended they supinate, but as the arm is flexed they tend more and more to **bring** the arm into a pronate position. The flexor carpi radialis is a powerful accessory pronator.

FIG. 461.—FOREARM IN PRONATION AND SUPINATION. (After Fick.)

T, **transverse axis** at elbow-joint for flexion and extension; *L*, longitudinal axis of forearm for pronation **and** supination.



17. **Muscle acting** on the hand at the wrist-joint. (fig. 462). (cf. p. 416.)

(*a*) Transverse axis (fig. 462, T)

Extension (dorsal flexion)	*Flexion (volar flexion)*
Extensor carpi radialis brevis	Flexor carpi ulnaris
Extensor carpi radialis longus	Flexor carpi radialis
Extensor carpi ulnaris	Palmaris longus.

The long flexors and extensors of the thumb and fingers are accesory flexors and extensors of the wrist-joint. The long abductor of the thumb is also an accessory flexor of the wrist.

(*b*) Perpendicular axis (fig. 462, V)

Radial abduction	*Ulnar abduction*
Extensor carpi radialis longus	Flexor carpi ulnaris
Extensor carpi radialis brevis	Extensor carpi ulnaris

The abductor pollicis longus and extensor pollicis longus muscles are powerful accessory radial abductors.

18. **Muscles acting** on the carpometacarpal joints (fig. 462) (cf. p. 437). Combined transverse and perpendicular axes (A and T)

Thumb

According to Fick and others there is some voluntary rotation possible at the first carpometacarpal joint.

Abduct and repose	*Adduct and oppose*
Abductor pollicis longus	Opponens
Abductor pollicis brevis	Adductor

The extensors of the thumb are accessory reposers. The long and short flexors a opposing.

Little finger

Abduct and repose	*Adduct and oppose*
Extensor carpi ulnaris	Opponens

The abductor digiti quinti and extensor digiti quinti proprius aid in reposing; the volar interosseous, the fourth lumbrical and the flexors of the little finger in opposing.

19. Muscles acting on the metacarpophalangeal joints (fig. 462).

(*a*) Transverse axes

Extension	*Flexion*
Thumb	
Extensor pollicis brevis	Flexor pollicis brevis

The extensor pollicis longus is an accessory extensor. The adductor and abductor and the flexor pollicis longus are accessory flexors.

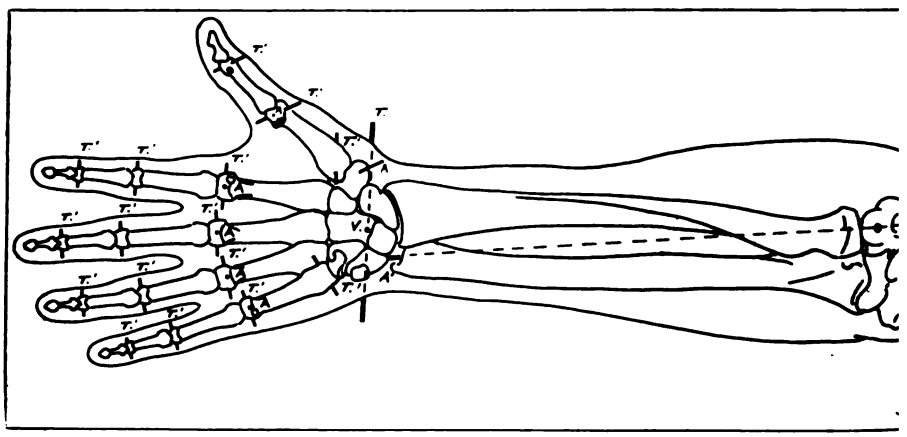
Little finger

Extensor digiti quinti proprius	Flexor digiti quinti brevis Fourth lumbrical Third volar interosseous

The abductor and long flexors of the little finger are accesory flexors of this joint.

FIG. 462.—CHIEF AXES OF MOVEMENT OF FOREARM, WRIST AND HAND.

L, longitudinal axis of forearm for pronation and supination; *T*, compromise transve for flexion and extension at wrist; *V*, volardorsal axis through carpus for ulnar and radial tion of the hand; *T'*, transverse axes for flexion and extension of the thumb and fing volardorsal axes for radial and ulnar abduction of the thumb and fingers.



Other fingers

Extension	*Flexion*
Extensor digiti communis	Lumbricals
Extensor indicis proprius	Interossei

The flexor sublimus and flexor profundus are accessory flexors of these joints.

(*b*) Perpendicular axes

Abduct from the long axis of the middle finger	*Adduct toward the long axis of the finger*
1st and 2nd lumbricals	Volar interossei
Dorsal interossei	3d and 4th lumbricals
Abductor digiti quinti	

20. Muscles acting on the interphalangeal joints (fig. 462).

Transverse axes

Extension	*Flexion*
Thumb	
Extensor pollicis longus	Flexor pollicis longus

The flexor pollicis brevis and abductor pollicis brevis are accessory extensors of this jo

Fingers; proximal joints

Interossei	Flexor digitorum sublimis
Lumbricals	
Abductor digiti quinti	

Fingers; distal joints

Extension	*Flexion*
Interossei	Flexor digitorum profundus
Lumbricals	
Abductor digiti quinti	

The extensor digitorum communis, extensor indicis proprius and extensor digiti quinti proprius are accessory extensors of the joints.

21 Muscles acting on the pelvis.

Thoracic and thoracolumbar joints (fig. 463).

Vertical spinal axes

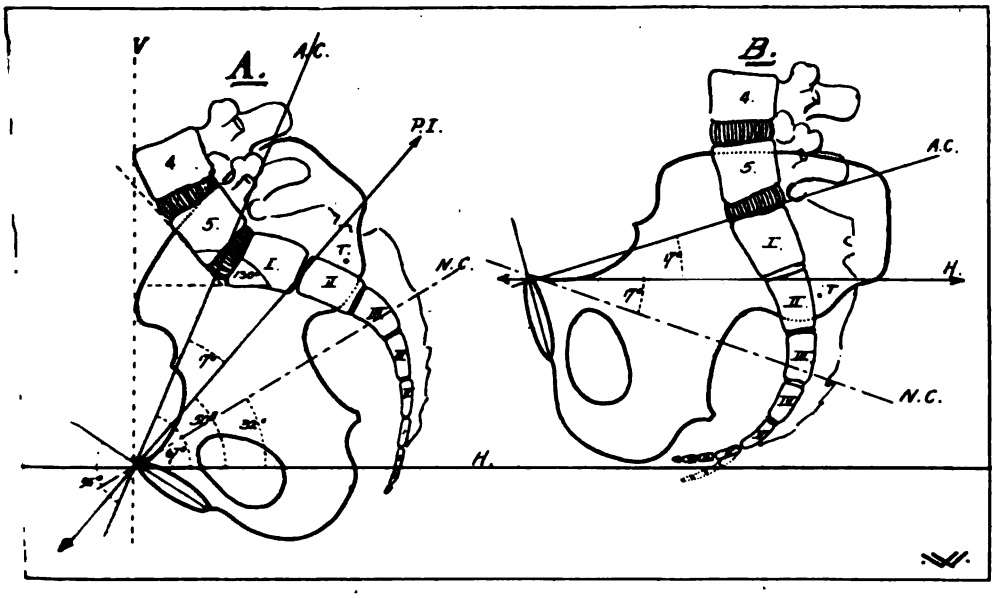
Rotation of pelvis to right	*Rotation of pelvis to left*
Left internal oblique	Right internal oblique
Right external oblique	Left external oblique

The intrinsic dorsal muscles also play a part. See action of muscles on the vertebral column.

Lumbar and lumbosacral joints (figs. 456, 463)

FIG. 463.—EXTENSION AND FLEXION OF THE PELVIS. (After Fick.)

A, pelvis, standing position; *B*, pelvis, sitting position; *A.C.*, anatomical conjugate; *N.C.*, normal conjugate; *H*, horizontal plane; *V*, vertical plane; *P.I.*, pelvic inclination; *T*, approximate position for transverse axis in movements at the sacroiliac joint.



(*a*) Ventrodorsal axes

Abduction of pelvis to right	*Abduction of pelvis to left*
Right quadratus lumborum	Left quadratus lumborum
Right sacrospinalis	Left sacrospinalis

The abdominal, the latissimus dorsi and the psoas muscles are accessory abductors.

(*b*) Transverse axes

Extension of pelvis	*Flexion of pelvis*
Quadratus lumborum	Rectus abdominis
Sacrospinalis	Oblique abdominal muscles
	Psoas minor

The psoas major muscle is a powerful accessory flexor of the pelvis, the latissimus dorsi is an accessory extensor.

22. Muscles acting on the thigh at the hip-joint. (fig. 464, B) (cf. pp. 487, 497)

(*a*) Transverse axes

Extension	*Flexion*
Gluteus maximus	Iliopsoas

The adductor magnus (posterior lower part) and also the hamstring muscles are accessory extensors; the gluteus medius, piriformis and obturator internus are weaker accessory extensors. The rectus femoris and the adductor longus and brevis, the obturator externus,

tensor fasciæ latæ, pectineus and sartorius, are powerful accessory flexors of the hip-joint th· gluteus minimus, adductor minimus, gracilis and quadratus femoris are weaker accessory fle·.·.

(*b*) Ventrodorsal axis

Abduction	*Adduction*
Gluteus medius	The adductors
Gluteus minimus	Pectineus
Piriformis	Obturator externus

The rectus femoris, tensor fasciæ latæ and sartorius are accessory abductors. The glu··· maximus and quadratus femoris are powerful accessory adductors in the standing pos··· The gracilis, adductor minimus, biceps, semitendinosus, semimembranosus and obturator ex··· nus are weaker accessory flexors.

(*c*) Vertical axis (thigh flexed 90°)

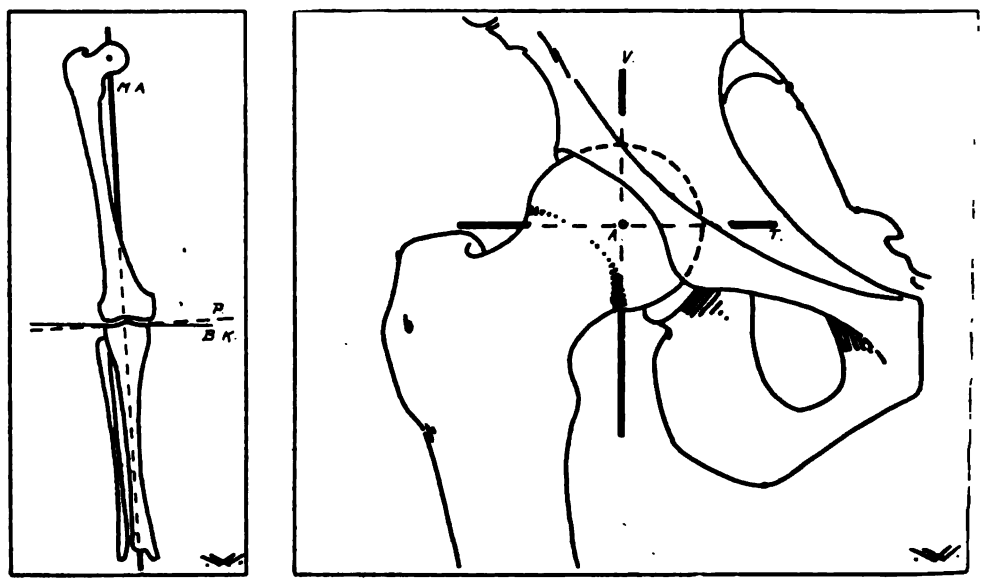
Abduction	*Adduction*
Gluteus maximus	Iliopsoas

(In addition to the abductors and adductors given above).

FIG. 464.—AXES OF LOWER LIMB.

A. Mechanical axes of thigh and leg (after Fick). *M.A.*, mechanical axis; *P*, perpendi··· to mechanical axis; *B.K.*, base of knee.

B. Axes for movements at the hip-joint. *A*, dorsoventral axis for abduction and adduc··· *T*, transverse axis for flexion and extension; *V*, vertical axis for rotation.



(*d*) Femoral axis

Lateral rotation	*Medial rotation*
Quadratus femoris	Gluteus minimus (ventral part)
Obturator internus and gemelli	Gluteus medius (ventral part)
Obturator externus	
Piriformis	

The gluteus maximus is a powerful lateral rotator as well as an extensor; the rectus femoris the lower part of the adductor magnus, the biceps, sartorius, gracilis and the dorsal part of the gluteus medius are accessory lateral rotators. The iliopsoas and the adductors longus brevis and minimus are strong medial rotators; the pectineus, semitendinosus, semimembranosus and tensor fasciæ latæ are weaker accessory medial rotators.

23. Muscles acting on the leg at the knee-joint (fig. 465) (cf. pp. 497, 516).

(*a*) Transverse axis

Extensors	*Flexors*
Quadriceps femoris	Semimembranosus
	Semitendinosus
	Biceps
	Gracilis
	Sartorius
	Popliteus

gastrocnemius is a powerful accessory flexor of the knee-joint. The gluteus maximus or fasciæ latæ through the iliotibial band help to hold the extended knee firm.

(*b*) Tibial axis (knee flexed)

Lateral rotation	*Medial rotation*
Biceps	Semimembranosus
Tensor fasciæ latæ	Semitendinosus
	Sartorius
	Popliteus
	Gracilis

scles acting on the foot at the ankle-joint (fig. 466). (cf. p. 508).

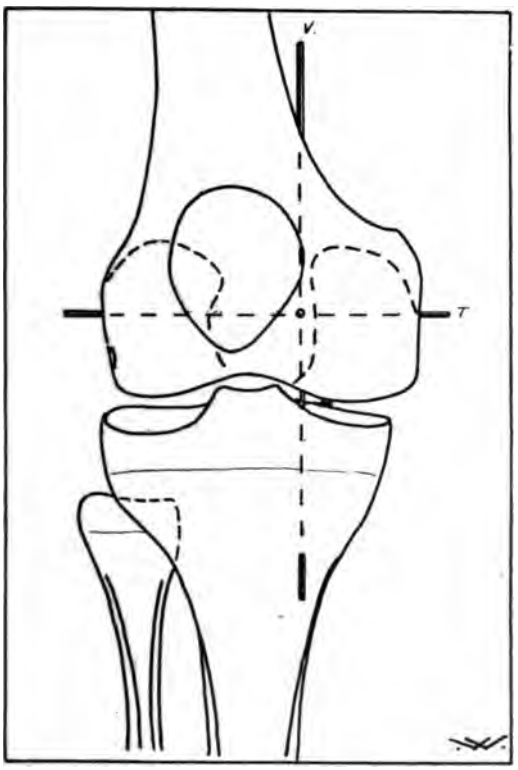
Transverse axis

Extension (plantar flexion)	*Flexion* (hyperextension)
Gastrocnemius	Tibialis anterior
Soleus	Peroneus tertius
Peroneus longus	
Tibialis posterior	
Peroneus brevis	

long extensors of the toes and the peroneus tertius flex; the long flexors of the toes he foot at this joint.

FIG. 465.—AXES OF MOVEMENT AT KNEE-JOINT.

ansverse axis, for flexion and extension. *V*, vertical (tibial) axis, for lateral and medial



cles acting on the foot at the inferior articulation of the talus (artic. talocalcanea and aneonavicularis). (fig. 466).

Talocalcaneal axis

Inversion (adduction)	*Eversion* (abduction)
Tibialis posterior	Peroneus longus
	Peroneus brevis
	Peroneus tertius

gastrocnemius, soleus, tibialis posterior, flexor hallucis longus, flexor digitorum longus alis anterior are accessory inverters at this joint; the extensor digitorum longus and hallucis longus are accessory everters.

26. Muscles acting on the foot at Chopart's joint (talonavicular-calcaneocuboid joints).

Calcaneo-midmetatarsal axis

Inversion (medial rotation)	*Eversion* (lateral rotation)
Tibialis posterior	Peroneus longus
	Peroneus brevis
	Peroneus tertius

The tibialis anterior, flexor digitorum longus, flexor hallucis longus, and extensor hallucis longus are accessory inverters at this joint; the extensor digitorum longus is an accessory everter.

27. Muscles acting on the metatarsophalangeal joints.

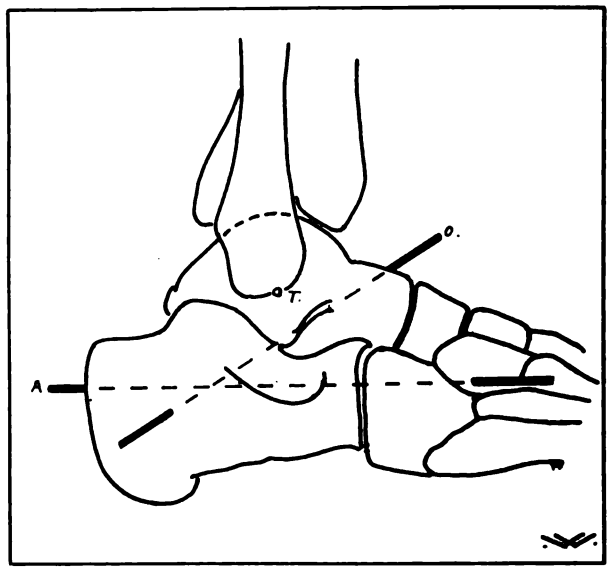
(*a*) Transverse axes

Extension	*Flexion*
Big toe	
Extensor hallucis longus	Flexor hallucis brevis.

The abductor and adductor hallucis muscles and the flexor hallucis longus are accessory flexors.

FIG. 466.—CHIEF AXES FOR ANKLE-JOINT AND FOOT.

T, transverse axis for flexion and extension at talotibial joint; *O*, compromise axis for inversion and eversion at talocalcanial and talonavicular joints; *A*, compromise axis for inversion and eversion at Chopart's joint.



Little Toe

Extensor longus digitorum	Flexor brevis digiti quinti
Extensor brevis digitorum	4th lumbrical
	3rd. plantar interosseus

The abductor digiti quinti and the long and short flexors of the toes are accessory flexors at this joint.

Other Toes

Extensor longus digitorum	1st., 2nd., and 3d. lumbricals
Extensor brevis digitorum	Dorsal interossei
	1st. and 2nd. plantar interossei

The long and short flexors of the toes are accessory flexors at these joints.

(*b*) Perpendicular axes

Abduction from long axis through second toe	*Adduction toward long axis through second toe*
Abductor hallucis	Adductor hallucis
Dorsal interossei	Plantar interossei
1st. lumbrical	2nd., 3d., and 4th. lumbricals
Abductor digiti quinti	

The transverse head of the adductor of the big toe draws the distal ends of the metatarsals closer together. The axes for this slight movement pass through the cuneiform and cuboid bones.

2. **Muscles acting on the interphalangeal joints.**

Transverse axes	
Extension	*Flexion*
Big Toe	
Extensor hallucis longus Extensor hallucis brevis	Flexor hallucis longus
Other Toes	
Extensor digitorum longus Extensor digitorum brevis	Flexor digitorum longus Quadratus plantæ Flexor digitorum brevis (2nd. phalanx only)

The adductors and abductors of the big and little toes may be accessory extensors of the interphalangeal joints.

References.—For *development* of the muscular system, consult the list given by W. H. Lewis, Development of the Muscular System, in Keibel and Mall's Human Embryology; for *variations:* LeDouble, Traité des variations du systeme musculaire de l'homme; for *action of muscles:* Duchenne, Physiologie des movements démontrée à l'aide de l'expérimentation électrique et l'observation clinique, etc. (1867); Fick, Handbuch der Anatomie und Mechanik der Gelenke unter Berücksichtigung der bewegenden Muskeln, in von Bardeleben's Handbuch; Strasser, Lehrbuch der Muskel und Gelenkmechanik; Sherrington, the integrative action of the nervous system (1906), and Mackenzie, the action of the Muscles, including Muscle Rest and Muscle Re-education; for the *extremities:* Frohse und Fränkel, Die Muskeln des menschlichen Armes und Beines, in von Bardeleben's Handbuch; for the *head* and *trunk:* Eisler, Die Muskeln des Stammes, in von Bardeleben's Handbuch; for the *pelvis:* Holl, Die Muskeln und Fascien des Beckenausganges. Further references to the literature upon the muscular system may be found in Poirier and Charpy's Traité d'anatomie humaine.

SECTION VI

THE BLOOD-VASCULAR SYSTEM

REVISED FOR THE SIXTH EDITION

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organs of circulation consist of a system of tubes or vessels which during are filled with fluid constantly moving in one direction. The major tion of the system is concerned with the continuous distribution of blood ut the body and is called the **hemal or blood-vascular** system. A ibed part of the hemal circulation is differentiated into a rhythmically ig propulsory organ called the heart. The minor portion of the system he **lymphatic system.** The lymphatic vessels convey fluid, the lymph, tissues to the hemal system.

ssential functions of the blood-vascular system are performed by the of all the blood-vessels, the **capillaries** [vasa capillaria], which form a ervading practically all the tissues of the body. Blood is carried to and capillaries by larger vessels called the **arteries** and **veins** respectively. t receives blood from the veins and propels it, in turn, into the arteries.

r to distribute oxygen to the tissues, the blood must of necessity pass through the organ before being delivered to the body at large. In gill-breathing vertebrates, the ng received oxygen in its passage through the gills, passes on to the tissues. The it is here accomplished by a single continuous chain of vessels in which capillaries , once in the gills and again in the organs and tissues in general. In man, as in other ebrates, lungs assume the function of the gills. Having received oxygen in the lungs is returned again to the heart before being redistributed throughout the body. hus in man two separate circuits or systems of blood-vessels, one traversing the lungs id ramifying throughout the body. The former is known as the **pulmonary** circula- tter as the **systemic.** Each has its own arteries, capillaries and veins; the heart is both. From the time of birth the heart is longitudinally divided into right and left that the two streams which enter it are entirely separated. The blood entering the the heart has issued from the pulmonary circulation to be driven into the systemic; ntering the right side, having traversed the systemic circuit, is returned again to the

art and blood-vessels have a continuous lining of flattened cells called endothelium; system is, therefore, a closed circuit.* The main thickness of the heart, arteries consists of additional tissue developed around the endothelial lining. It is due to hat the blood is continuously delivered to, and withdrawn from, the capillaries under nditions of pressure and velocity. The heart is mainly composed of rhythmically ; muscle and its valves are so arranged that the blood contained within it is driven tly in one direction. The walls of the largest arteries are formed to a great extent of ie, and, being constantly under tension from within, are instrumental in converting , intermittently received from the heart, into a continuous flow. The walls of the ed to smallest arteries are mainly muscular. The smallest arteries are microscopic known as **arterioles** [arteriolæ]. The muscular arteries are capable of general or tions of caliber; they are thus largely concerned in the maintenance of the arterial id in the regulation of the volume of blood which enters given localities under varying

The veins have much thinner walls than the arteries, and the venous pressure y low.

n artery divides, the combined caliber of its branches is greater than that of the f. Since the arteries divide repeatedly the bed of the blood-stream increases in as the vessels diminish in size. The rate of increase, slow at first, becomes enormous rioles. Conversely, the bed of flow diminishes as the heart is approached from the . The velocity of flow in the capillaries must necessarily be much lower than in the ies and veins. From the relative slowness of the blood flow in the systemic capil- s been estimated that their total bed is eight hundred times greater than that of the ial stem.

spleen and bone marrow the blood-channels intermediate between the arteries and ssible exceptions to this statement, but the essential conditions here are still imper- rstood.

Variations.—The distribution of the chief arteries and veins of different individuals varies so slightly in the aggregate that the descriptions given by anatomists nearly two hundred years ago differ but slightly from those in current use. Deviations from the usual type of vascular distribution are occasionally encountered in the adult, however, and their presence seems always to depend upon some disturbance of the usual course of development. When once the primitive vessels have made their appearance, the progress of vascular development is characterized by the successive appearance of alternative arterial or venous channels for the transit of blood to, or from, the capillaries of the various regions of the body. Some of the earlier channels persist throughout development; while others, remaining for a shorter or longer period, eventually disappear. Others, again, by forming connections with their fellows, or with channels of later development, may take a larger or smaller share in the composition of one or more of the adult arteries or veins. The normal vascular pattern of the human body, having been repeatedly modified during the progress of development, may be said, at length, to attain its permanent form. The production of an adult vascular system of so-called normal type in any particular individual, depends, therefore, upon the exact repetition of a complicated series of developmental changes. Should one of the numerous embryonic vessels concerned in the process fail to perform its customary role, some noticeable departure from the normal type will be encountered in the adult vascular system. Variations thus produced are more prone to occur in some regions than in others. Apart from such extensive anomalies as those in which imperfections of the aorta or pulmonary artery occur in association with arrested development of the cardiac septa, variations of blood vessels are not, as a rule, attended with impairment of function. A list of the chief variations in the arteries and veins is given later, in connection with their morphogenesis.

In the following section the heart and pericardium will first be considered followed by the arteries and veins.

A. THE HEART AND PERICARDIUM

1. THE HEART

The **heart** [cor] is a hollow organ principally composed of muscle, the **myocardium.** It is lined internally by **endocardium** which is continuous with the intima of the blood-vessels. Externally, it is covered by the **epicardium,** a serous membrane continuous with the serous lining of the pericardium. The form of the heart, when removed from the body without previous hardening, is that of a fairly regular truncated cone. The **base** [basis cordis] is poorly circumscribed but corresponds, in the general way, to the area occupied by the roots of the great vessels and the portion of the heart-wall between them. The base of the heart is held in position chiefly by the great vessels, which are attached to the pericardium. It is not fixed, however, for during systole the base performs a greater excursion than does the apex. The remainder of the organ is capable of free movement within the pericardial cavity.

The interior of the heart is longitudinally divided into right and left cavities by a septum passing from base to apex. Each cavity is subdivided into an **atrium** [atrium cordis] and a **ventricle** [ventriculus cordis], the former receiving the ultimate venous trunks and the latter giving rise to the main arteries. Thus the left atrium receives the four pulmonary veins, and the right atrium the superior and inferior vena cava and the coronary sinus; the aorta issues from the left ventricle and the pulmonary artery from the right. The ventricles, which constitute the major portion of the heart, may be recognised by their very thick walls. The atria have thinner walls and are less capacious than the ventricles; projecting from each is a diverticulum or **auricle** [auricula cordis]. The auricles (which receive their name from their resemblance to dog's ears) partially embrace the roots of the pulmonary artery and aorta.

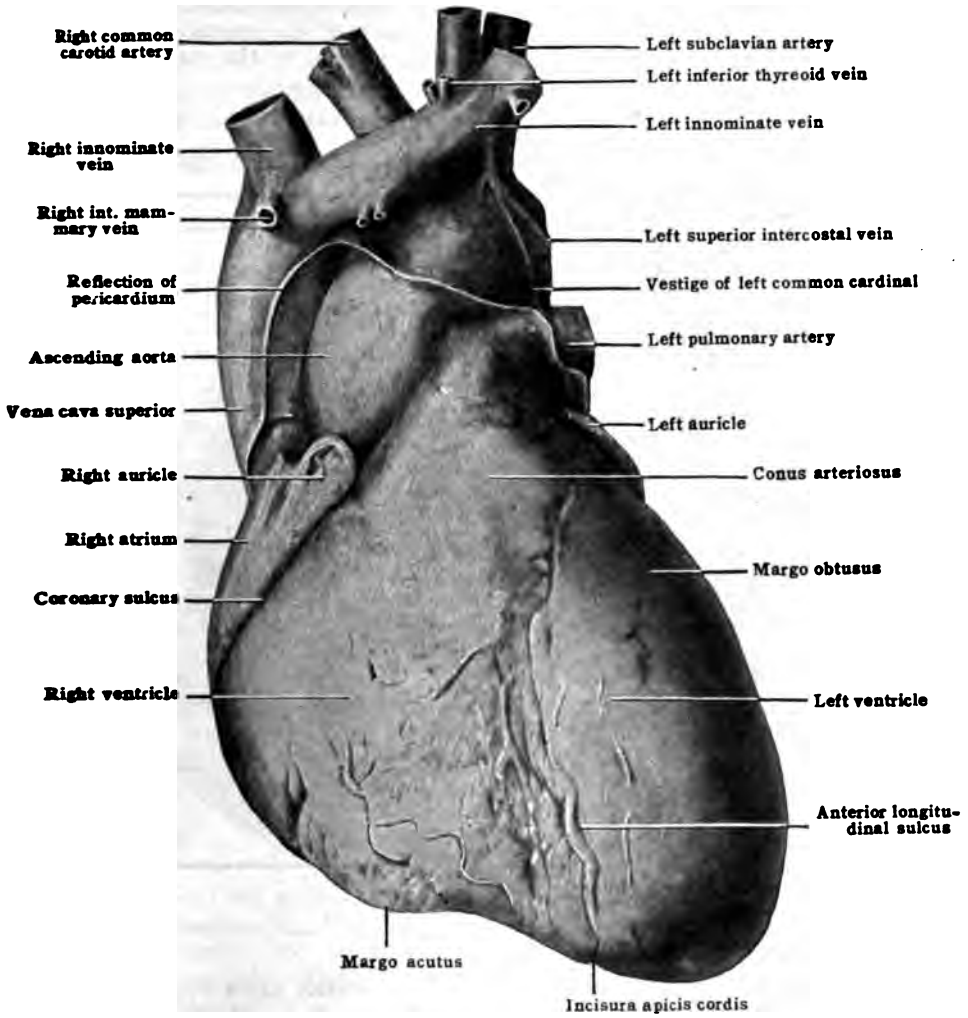
Orientation of the heart.—The apex of the heart [apex cordis] points forward, to the left and downward. The base is directed backward, to the right and upward The longitudinal axis of the heart forms an angle of about 40° with the horizontal plane and also with the median sagittal plane of the body.

The long axis of the heart is therefore slightly more horizontal than vertical, and slightly more anteroposterior than transverse, and the atria are posterior to, rather than above the ventricles. To arrive approximately at the direction of the longitudinal axis of the heart, it is necessary to select the central point of the base. By cutting the vessels short in several hearts, hardened by formalin before removal, a point immediately to the left of the left lower pulmonary vein was selected in determining the data above given. A steel pin was passed through this point to the apex cordis, and the angles controlled by frontal and transverse sections of the thorax. Mention of angular measurements of the axis of the heart could be found only in the

[illegible]-books of Testut and Luschka; the former gives 40° to the horizontal plane, the latter 60° to the midsagittal. Luschka's angle appears to be too large; but further investigation in this direction is desirable.

Size and weight.—The heart measures about 12.5 cm. (5 in.) from base to apex in the adult, and 8.7 cm. (3½ in.) at its broadest, and 6.2 cm. (2½ in.) at its thickest portion. In the male its weight averages about 312 gm. (eleven ounces), and in the female about 255 gm. (nine ounces). The weight of the heart forms approximately 0.55 per cent. of the total body-weight in the male of normal build and about 0.53 per cent. in the female; in emaciated individuals it usually weighs relatively more, and relatively less in the fat. The *volume* of the heart in diastole may be estimated during life in cubic centimeters by the use of the following formula,

FIG. 467.—STERNOCOSTAL SURFACE OF THE HEART.



0.53 A ¾, A being the X-ray silhouette of the diastolic area in square centimeters, after making due allowance for divergence of rays (Bardeen). The heart weight may be computed by multiplying 1/20 A ¾ by 0.0055.

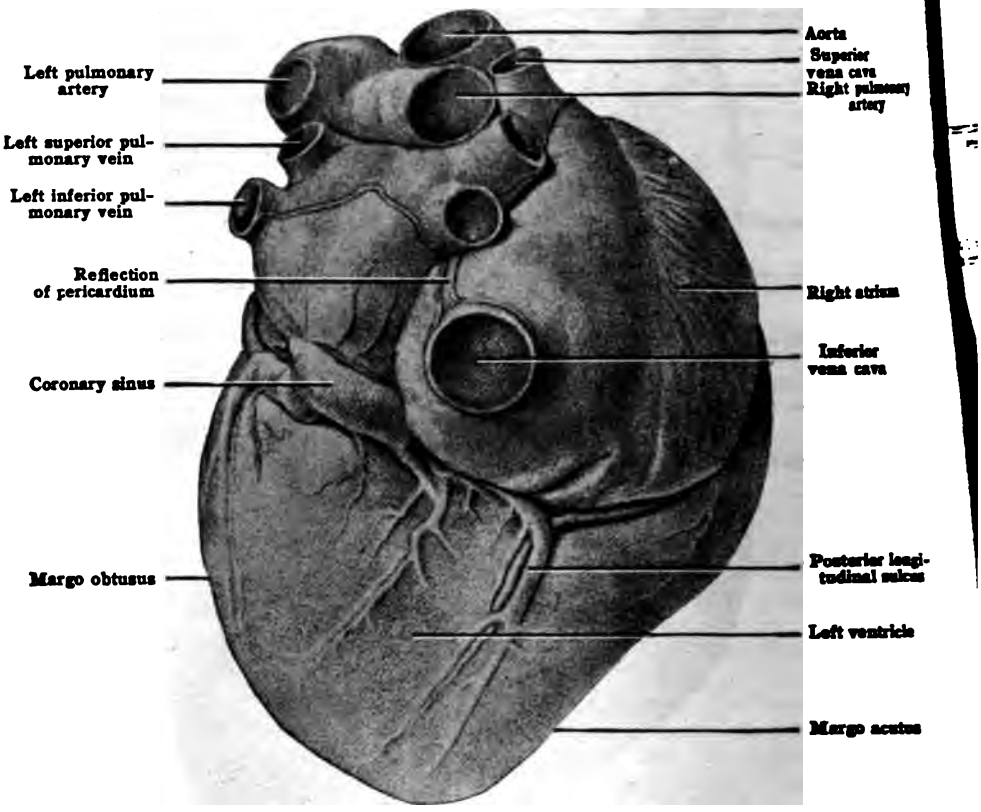
EXTERIOR OF THE HEART

In hearts which have been hardened by injection before removal from the body, the regularity of the heart-cone is disturbed by a well-marked triangular facet, imparted by contact with the diaphragm. This facet is the **diaphragmatic surface** [facies diaphragmatica], which is directed downward and slightly backward (fig. 468). It ends abruptly along a sharp margin extending from the apex toward the right. This margin is the **margo acutus** (fig. 467); it separates the diaphragmatic surface from the sternocostal surface. The other margin of the diaphragmatic surface is more rounded and shades gradually into the rounded

margo obtusus (fig. 467), which passes almost insensibly into the sternocostal surface. The convex **sternocostal** surface [facies sternocostalis] (fig. 467) is directed forward and somewhat upward and to the right, is triangular and bounded below by the margo acutus. To the left it goes over into the margo obtusus along a line extending from the apex of the heart to the root of the pulmonary artery. The **margo obtusus** corresponds to the rounded left side of the left ventricle.

The interventricular sulcus is a slightly marked groove indicating the separation of the ventricles upon the exterior of the heart. It lodges coronary blood-vessels and a moderate quantity of fat which can be seen through the epicardium. The part of this groove seen on the sternocostal surface is the **sulcus longitudinalis anterior.** It runs obliquely over the upper part of the margo obtusus on to the sternocostal surface. Crossing the margo acutus to the right of the apex

FIG. 468.—BASE AND DIAPHRAGMATIC SURFACE OF THE HEART. (After His.)



it is continuous with the **sulcus longitudinalis posterior** upon the diaphragmatic surface. The diaphragmatic surface is formed about equally by the right and left ventricles, and the sternocostal surface mainly by the right. Where the longitudinal sulcus crosses the margo acutus it produces a slight notch, the **incisura (apicis) cordis.**

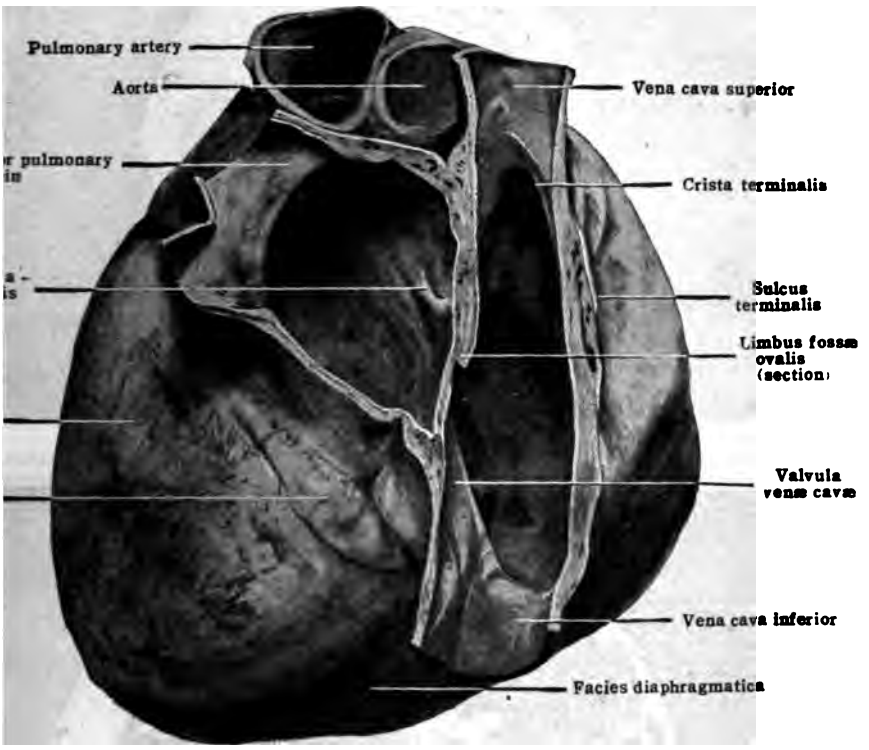
The atria are separated externally from the ventricles by the **sulcus coronarius.** This is a horseshoe-shaped groove well marked below and laterally, and interrupted above by the roots of the pulmonary artery and aorta. It lodges the coronary sinus, smaller coronary vessels and fat.

ATRIAL PORTION

The **atrial portion of the heart** is situated behind, and slightly to the right of and above, the ventricular portion. On the external surface, its separation into right and left atria is not indicated posteriorly, except in distended hearts (such as that shown in fig. 468); in these it is marked by a slight groove connecting the

s of the superior and inferior vena cava. The auricles are separated y by the deep notch which lodges the aorta and pulmonary artery. A ove on the back of the right atrium which connects the right sides of the and inferior vena cava, is the **sulcus terminalis** (figs. 468, 469). This s the right limit of what was, in the embryo, the sinus venosus. It also that the embryonic sinus venosus has become an integral part of the ht atrium. The superior and the inferior cava join the posterior part ht atrium above and below, respectively. The coronary sinus courses d, backward and to the right to enter the right atrium anteriorly to and t above the place of entrance of the inferior vena cava. The four pulmo- is run nearly transversely and somewhat forward into the right and left he left atrium.

G. 469.—ATRIA OPENED POSTERIORLY TO SHOW THE SEPTUM ATRIORUM.

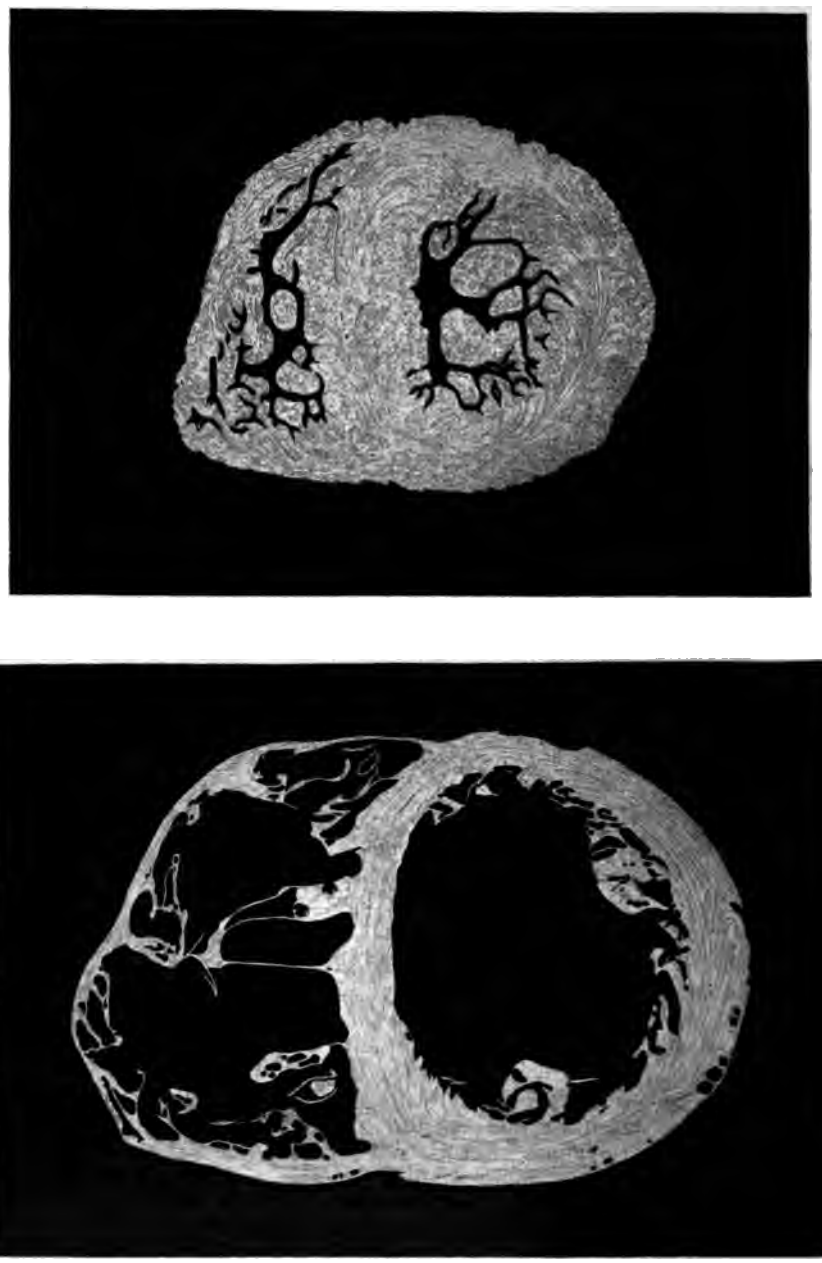


nterior of the atrial portion of the heart is divided into right and left y the **septum atriorum.** This septum is a composite structure, having eloped (see p. 567) in two independent parts, neither of which is a com- tum in itself. The two incomplete septa, however, partly overlap her so that, by lateral fusion at the time of birth, they together produce rvious structure of the adult heart (fig. 469). Of these septa, the first rmed is the **membranous septum** [pars membranacea septi atriorum]. ight of this is developed a muscular septum, the margin of which forms er part of the **limbus fossæ ovalis** of the adult right atrium. The margin mbranous septum is recognizable as a fold of endocardium on the septal he left atrium; it is called the **valvula foraminis ovalis.**

. the septal wall of the adult **right atrium** [atrium dextrum] (fig. 469), imme- bove the inferior cava is the **fossa ovalis,** of which the floor is formed by ibranous septum. Surrounding the fossa ovalis except below (indeed g the fossa) is the limbus fossæ ovalis which is continuous anteriorly and ith the **valvula venæ cavæ** (inferioris Eustachii). Anterior to the fossa the orifice of the coronary sinus, which is guarded by the **valvula sinus** (Thebesii) (fig. 472). Leading from the front of the atrium forward tly downward and to the left is the **ostium venosum** of the right ventricle

(right atrioventricular orifice) guarded by the tricuspid valve. Above and behind the venous ostium is the auricle, the exterior of which is in contact medially with the root of the aorta. To the right of the superior and inferior caval orifices there is a vertical ridge, the **crista terminalis,** which corresponds to the sulcus terminalis on the exterior (figs. 469, 472).

FIG. 470.—SECTION OF THE VENTRICLES IN SYSTOLE AND DIASTOLE. (After Krehl.)



The portion of the atrium bounded laterally by the crista terminalis and medially by t septum atriorum is smooth, the **sinus venarum;** in the embryo it is separated from the ati cavity proper by the right and left sinus valves. The crista terminalis marks the original l of attachment of the right sinus valve. The valve itself has disappeared, excepting the lo part which persists as the caval and the coronary valves. These valves vary in size considera in different specimens, and are frequently netlike from numerous perforations.

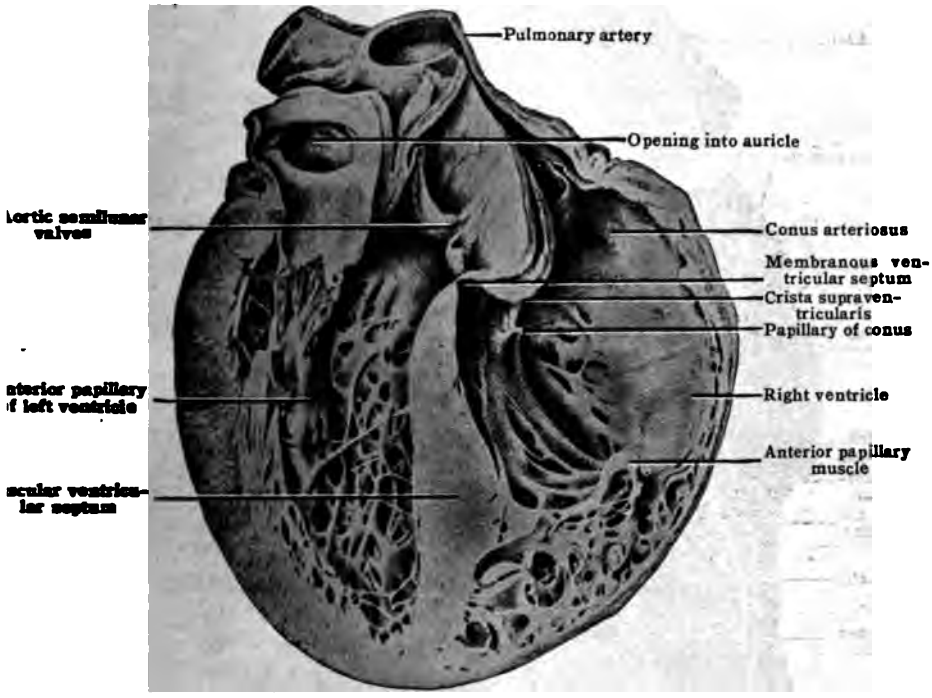
The conversion of a portion of a single valve into two separate parts, which meet at acute angle, is brought about by local blending between the sinus valve and an embryo

ucture called the sinus-septum. This septum is a ridge dividing the right horn of the sinus nosus from the transverse portion of the sinus (the coronary of the adult); it probably tributes somewhat to the formation of both the coronary and caval valves. The left sinus ve usually disappears by blending with the septum atriorum, becoming a part of the limbus ae ovalis; it occasionally remains partially separate in the adult.

The interior of the right auricle and of the portion of the atrium upon the teral side of the crista terminalis is thrown into ridges (**musculi pectinati**) by ominent bands of the atrial myocardium. The musculi pectinati end abruptly joining the crista. The orifice of the superior cava has no valve and is directed ownward and somewhat forward; below it, on the posterior wall of the atrium, ere has been described the **tuberculum intervenosum** (Loweri).

Apart from the posterior circumference of the superior cava itself and the limbus fossæ alis, the human heart appears to contain nothing in this region that could be described as a ercle. With regard to the segregation of the streams entering the fetal right atrium from

FIG. 471.—THE INTERIOR OF THE VENTRICLES, ANTERIOR HALF. (After His.)



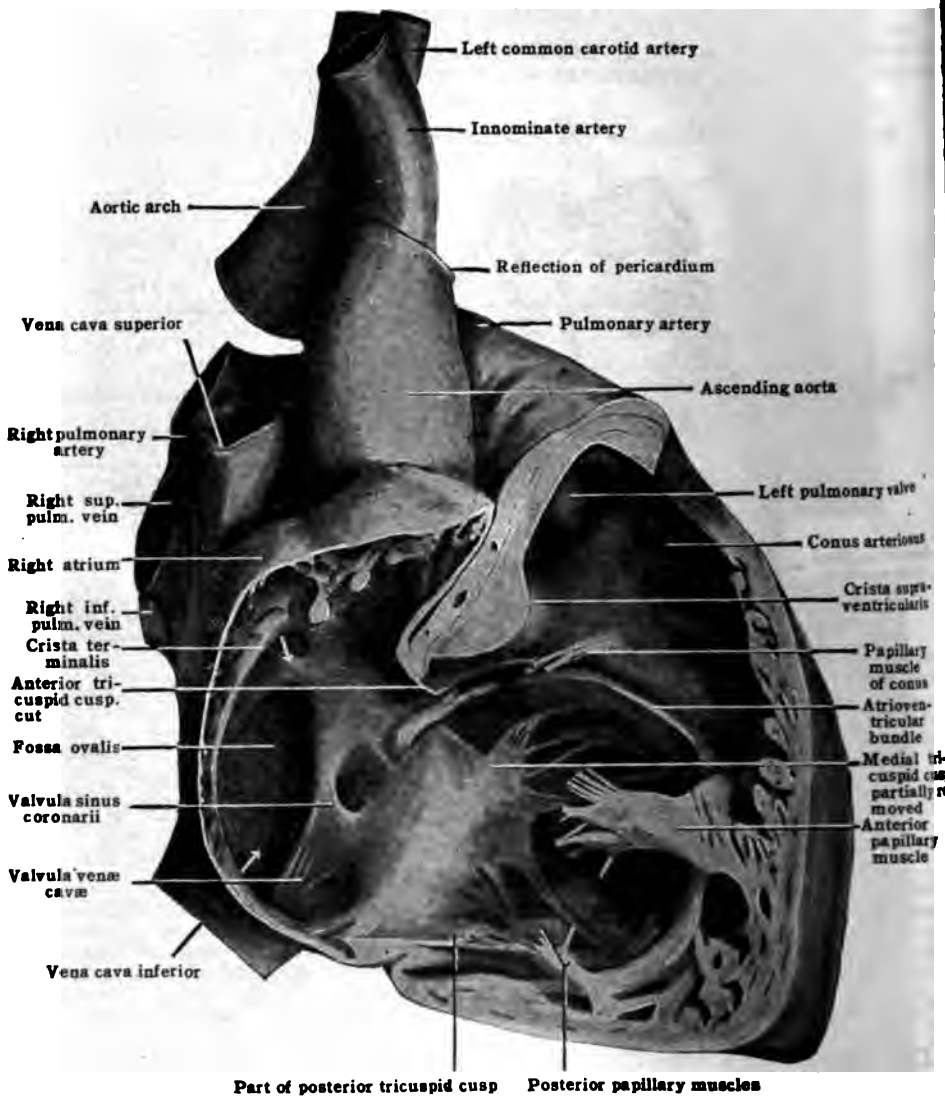
superior and inferior cava, respectively, in which the tubercle of Lower has been supposed articipate, it is to be noted that the fossa ovalis is just above (almost within) the inferior al orifice. In hearts well hardened before removal the inferior caval opening and the fossa lis occupy a diverticulum to the left of the remainder of the atrium. Between this diverdum and the atrium proper, the caval valve and the limbus fossæ ovalis form a prominent ge, better marked in the fetus than the adult. Opening into the right atrium, particularly n the septal and right lateral walls, are numerous *foramina venarum minimarum* (Thebesii).

The left atrium [a. sinistrum] (fig. 469) is situated upon the left side of, and newhat posteriorly to the right. It is behind the root of the aorta, and the t auricle lies to the left of the root of the pulmonary artery. Opening into the t atrium posteriorly, on the right and left sides, respectively, are the right and t upper and lower pulmonary veins. The valvula foraminis ovalis forms a ore or less distinct crescentric ridge on the septal wall (fig. 469). The valvula ay not be attached to the limbus fossæ ovalis, in which case there is a comunication between the two atria. This, however, does not necessarily lead to mixture of arterial and venous blood during life. The **ostium venosum** (atrioatricular orifice) of the left ventricle, guarded by the mitral valve, leads from e anterior part of the atrium forward and slightly downward and to the left. ie interior of the left atrium proper is smooth; in the auricle musculi pectinati well marked.

ATRIOVENTRICULAR VALVES

The **atrioventricular valves** (figs. 471–473, 475) are attached around the venous ostia of the ventricles in such a way as to give freely into the ventricles, but to prevent regurgitation of blood into the atria during ventricular systole. Each valve is continuous along its line of attachment, but its free edge is notched so as to produce an irregular margin; some of the notches are so deep as to partially divide the valve into cusps. The rght atrioventricular valve is commonly

FIG. 472.—INTERIOR OF THE RIGHT ATRIUM AND VENTRICLE.
The atrioventricular bundle is dissected out.

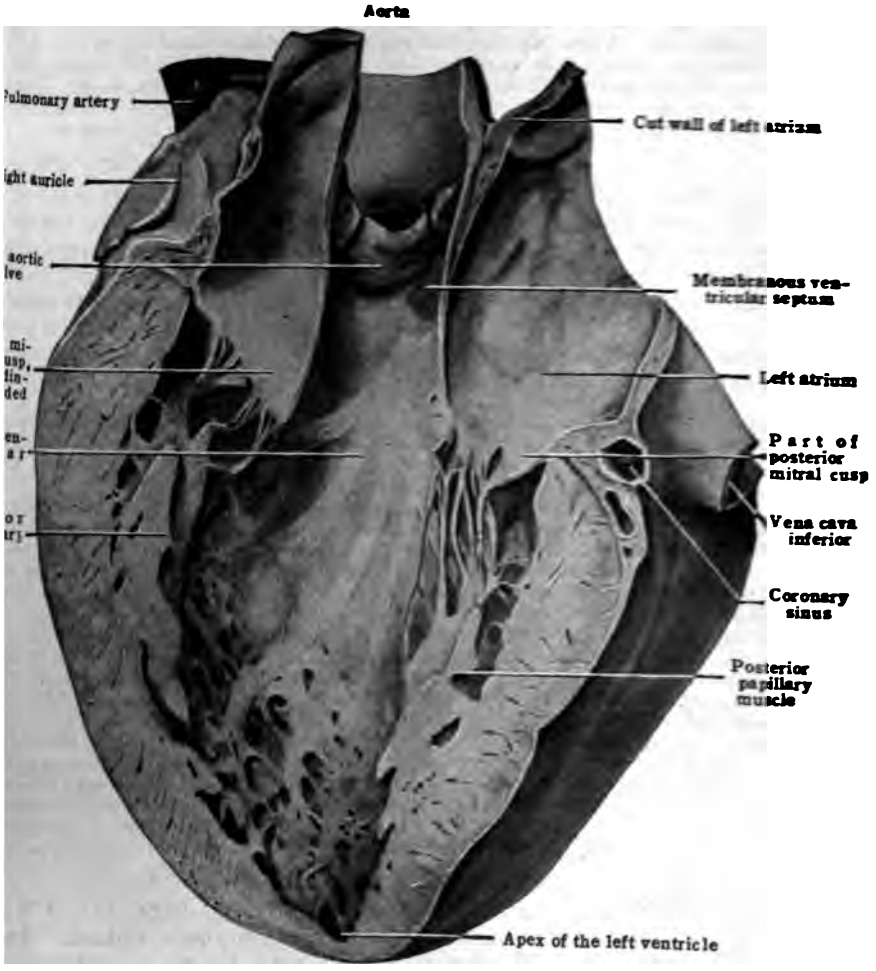


divided by three deep notches into three cusps; this valve is therefore called the **tricuspid** [valvula tricuspidalis]. The left is similarly divided into two cusps and is called the **bicuspid** [v. bicuspidalis] or **mitral.** The depth of the notches, however, is very variable and there may be an increase or (more rarely) a diminution in the number of cusps; the addition of subsidiary cusps is quite common. Each valve cusp is tied down to the **papillary muscles** [mm. papillares] of the ventricle by **chordæ tendineæ.** The latter are fibrous cords, generally branched, of varying thickness. The thinnest cords are attached to the free margin of the cusp; those of intermediate thickness to the ventricular surface a few millimeters from the free margin, and the thickest to the ventricular surface near the

ched margin. The valves are smooth and glistening on the atrial aspect, rough and fasciculated, from the attachment of the chordæ, on the ventricular aspect. The cusps of the *mitral valve* are called *anterior* and *posterior* ns of the *tricuspid, anterior, posterior* and *medial*. Each cusp receives chordæ n more than one papillary muscle and each papillary muscle sends chordæ to e than one cusp. The chordæ tendineæ of the mitral valve are thicker than se of the tricuspid (figs. 472, 473).

FIG. 473.—LEFT VENTRICLE AND PART OF THE ATRIUM.

Aorta is opened through the anterior cusp of the mitral valve. The plainly visible left limb of the atrioventricular bundle has been accentuated.



VENTRICULAR PORTION

ventricles form the greater part of the heart. In the adult the relation ventricles to one another is as follows. The left [ventriculus sinister] form of a narrow cone, the apex of which forms the apex of the heart. ht ventricle [ventriculus dexter] is crescentic in section and appears to be y wrapped around the right or lower wall of the left ventricle which forms tum ventriculorum (fig. 470). The **left ventricle** forms the margo ob- the heart, about half the diaphragmatic surface, and a small part of the ostal surface. The **right ventricle** forms about half the diaphragmatic and the major part of the sternocostal surface; it takes no share in the on of the apex of the heart.

interventricular septum [septum ventriculorum] is thick and muscular or a small area near the root of the aorta which is membranous [septum naceum *ventriculorum*]. *The latter* can be seen from the left ventricle

in the angle between the attached edges of the right and posterior aortic valves (fig. 473). The membranous septum is partly concealed on the right side by the medial cusp of the tricuspid valve which is attached to it near its upper end. The portion of the membranous septum above the attachment of the medial tricuspid cusp is therefore atrioventricular, since it intervenes between the right atrium and the left ventricle.

The membranous septum is the extreme lower part of the independent septum (s. orticum) which divides the aortic root from the pulmonary artery and conus arteriosus. The aortic septum partially subdivides, also, the right ventricle by separating the conus arteriosus from the remaining part of the interior. The relation borne by the part of the aortic septum which intervenes between the conus arteriosus and aortic root to the septum ventriculorum is well shown by His, in fig. 471.

The greater part of the interior of both ventricles is thrown into ridges by myocardial bundles of large size. These fasciculi [**trabeculæ cordis**] either stand out in relief only, or, by being undermined, form bands enveloped by endothelium. A careful examination of the endocardium of fresh hearts will reveal a plexiform network of **Purkinje fibers.** These fibers, belonging to the atrioventricular conducting system, become visible to the naked eye when the endocardium has been exposed to the air long enough to become partially dry.

The wall of the **right ventricle** [ventriculus dexter] (figs. 471, 472) is much thicker than that of the atria, but not so thick as that of the left ventricle. The upper and anterior part of the right ventricle lies in front of the root of the aorta. This portion of the ventricle is called the **conus arteriosus** and is separated from the remainder of the right ventricle by a muscular spur which extends from the back of the conus to the right venous ostium. The spur is the **crista supraventricularis;** its relation to the partition between the conus and aorta, and to the septum membranaceum, shows that it forms part of the embryonic aortic septum (see morphogenesis of the heart).

Two papillary muscles in the right ventricle are constant in position, the large **anterior papillary muscle,** and the small **papillary muscle of the conus** (Luschka). The anterior papillary is situated on the sternocostal wall, near the junction of this with the septal wall. The papillary of the conus is placed just below the septal end of the crista supraventricularis. The **posterior papillary muscles** form an irregular group springing from the diaphragmatic wall of the ventricle. Some of the chordæ tendineæ stretch directly from the septal wall (with or without small muscular elevations at their bases) to the medial cusp of the tricuspid valve. The chordæ tendineæ from the anterior papillary go to the anterior and posterior cusps; those from the conus papillary to the medial and anterior, and those from the posterior papillary muscles to the medial and posterior cusps of the tricuspid valve, respectively.

A band of myocardium is often found to extend from the septal wall of the right ventricle to the anterior papillary muscle; this is the **moderator band,** which contains a part of the right limb of the atrioventricular bundle. If the moderator band joins the anterior papillary near its base, as it frequently does, it is difficult to distinguish it from the trabeculæ cordis which ordinarily occupy this situation.

The term moderator band was originally applied to this bridge or band of muscle under the impression that it prevented overdistention of the ventricle. Since the discovery of the conducting system of the heart it has been known that there is always a band which conducts the right limb of the atrioventricular bundle from the septum to the anterior papillary muscle. Whether the band is isolated from the other trabeculæ, and therefore readily recognizable, appears to depend somewhat upon the relation of the base of the papillary muscle to the septum ventriculorum.

The wall of the **left ventricle** [ventriculus sinister] (figs. 471, 473) is very thick except at the extreme apex, and at the membranous septum. In the left ventricle are two large papillary muscles, generally known as **anterior and posterior;** both send chordæ tendineæ to each cusp of the mitral valve. On the septal wall of the ventricle the left limb of the atrioventricular bundle can usually be seen as a broad, flattened band beneath the endocardium. The band appears just below the septum membranaceum and divides into strands which go to the two papillarly muscles. The strands in many places bridge across part of the ventricle to reach the papillary muscles, covered only by tubes of endocardium.

These bridging strands connecting the papillary muscles with the septum ventriculorum, which were formerly called 'false chordæ tendineæ,' are exactly comparable to the moderator band of the right ventricle which occasionally consists of atrioventricular bundle and endocardium only.

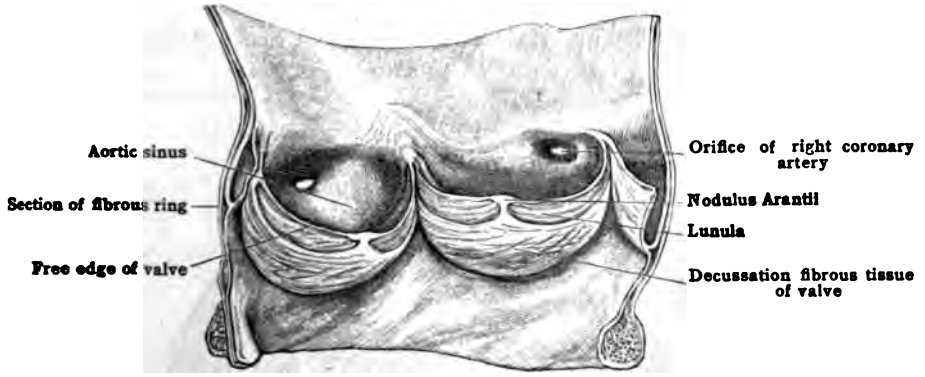
SEMILUNAR VALVES

The **semilunar valves** [valvulæ semilunares] guard the arterial ostia of the ventricles. The aortic ostium is directed upward and slightly forward and to the

ght; the pulmonary backward and slightly upward and to the left. Each valve, of which there are three to each ostium, is a pocket-like fold of endocardium strengthened by fibrous tissue (fig. 474). The free edge of each valve is directed away from the ventricle, so that excess of pressure within the great vessels brings the three valves of either ostium into mutual apposition. In the middle of the free edge of each valve there is a small fibrocartilaginous **nodule**; radiating from this toward the entire fundus, and along the extreme free edge of the valve, are fibrous thickenings. On either side of the nodule, between the thicker margin and fundus, the valve is thin over a crescentic area called the **lunula**.

The aortic valves are called the right, left, and posterior; the pulmonary valves, the right, left, and anterior.* The aortic semilunar valves are stronger than the pulmonary; opposite them there are three dilations in the aortic wall, the aortic sinuses [**sinus aortæ**] or sinuses of Valsalva. From the right and left sinuses the right and left coronary arteries, respectively, arise.

FIG. 474.—INTERIOR VIEW OF THE AORTIC SEMILUNAR VALVES.



After ventricular systole the increased pressure in the great vessels distends the valves with blood. The noduli meet in the center and the lunulæ, coming into mutual contact, produce a triradiate line of contact between the valves.

ARCHITECTURE OF THE MYOCARDIUM

In the adult heart the myocardium of the atria is separate from that of the ventricles. There is, between the atria and ventricles, a fibrous partition, the upper and lower surfaces of which give attachment to the muscle fibers of these cavities, respectively.

The fibrous partition (fig. 475) is thickest in the interval between the right and left atrioventricular ostia immediately behind the right end of the posterior circumference of the aorta; this part of it is called the right *trigonum fibrosum*. The *left trigonum fibrosum* is smaller than the right, and occupies the angular interval between the left side of the root of the aorta and the left atrioventricular ostium. Spreading out from the trigona are the *annuli fibrosi* which surround the root of the aorta and the two atrioventricular ostia. A particularly dense and strong portion of the fibrous partition of the heart extends forward from the right trigonum fibrosum; it forms the *septum membranaceum ventriculorum* and blends with the right circumference of the aortic annulus. From the anterior aspect of the aorta it passes forward upon the posterior aspect of the conus arteriosus, where it is known as the *tendon of the conus*, and ends by uniting with the annulus fibrosus of the pulmonary ostium. The tendon of the conus, the septum membranaceum and the greater part of the right trigonum fibrosum are derived from the embryonic aortic septum.

The atrial musculature is attached to the trigona and atrioventricular rings. The superficial fibers are attached to both rings and either encircle both atria in one loop, or enter the septum and form a figure 8. The deeper fibers are attached to one ring and encircle one atrium only; some fibers encircle only the auricle.

The ventricular musculature is very complex and consists of numerous superimposed layers distinguished from one another by the direction taken by the muscle fibers. In a general way,

*The BNA names of the aortic and pulmonary valves are not based upon their relative positions in the body. From transverse sections through the thorax (see any good atlas) it may be seen that one aortic valve is anterior, one pulmonary valve posterior, and the other aortic and pulmonary valves are right and left. If the removed heart is held so that the ventricles are on the right and left of the septum, respectively, the valves take the positions indicated by the BNA. The names given by the BNA to the valves, although conventional (like many other terms of orientation applied to parts of the heart), are convenient, particularly from a developmental standpoint.

the fibers of the deepest layer have a direction crossing those upon the surface of the same area at a right angle. The intervening layers of fibers pass through all stages of obliquity.

Recent work upon the origin and distribution of the ventricular fibers has resulted in the recognition of a certain uniformity of behavior, thus:—

1. All fibers arise from, and are inserted into, the fibrous partition at the base. The fibers are either attached directly to the trigona or annuli, or indirectly to them by means of the chordæ tendineæ and atrioventricular valves.

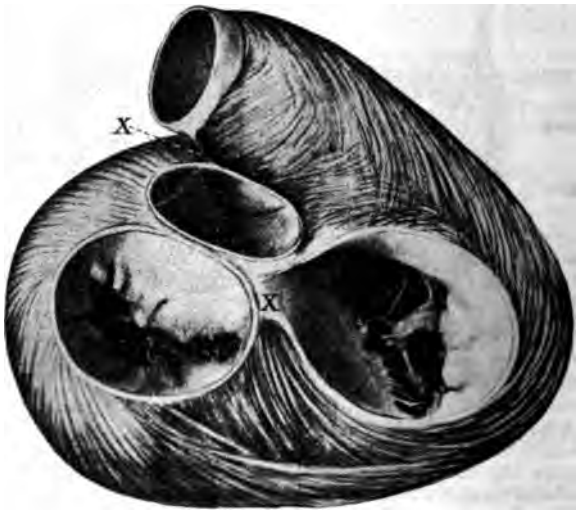
2. The more superficial fibers (fig. 476) tend to encircle the entire heart, passing over the longitudinal sulci. If they enter the septum they do so by passing into the vortex or whirl at the apex of the left ventricle. These fibers have always a definite direction upon the surface, i.e., from right to left upon the sternocostal surface and from left to right on the diaphragmatic (fig. 475).

3. The deeper fibers all enter the septum, and pass across it in a direction oblique or perpendicular to its longitudinal axis. They completely encircle one or both ventricles forming, in the latter case, a double loop (fig. 477).

During systole, as a result of this arrangement:—(1) The papillary muscles and the longitudinal and anteroposterior axes of the ventricles are simultaneously shortened. (2) There is a movement of torsion or 'wringing' which reduces the ventricular cavities to their minimum dimensions.

FIG. 475.—BASE OF A WELL DEVELOPED HEART SHOWING THE COURSE OF THE SUPERFICIAL MUSCLE FIBERS.

From X to X′ around the front of the aorta indicates the course of the aortic septum. (Mall, $\times \frac{3}{4}$.)



Conducting system.—Although the ordinary myocardium of the atria is distinct from that of the ventricles there is, at one place, a connection between them. This connection is effected by means of a small band of muscle which differs histologically from ordinary heart muscle. It is known as the **atrioventricular bundle**, and serves to transmit the atrial rhythm of contraction to the ventricles.

The atrioventricular bundle begins in the septal wall of the atrium a short distance in front of the coronary orifices (fig. 472). It has an expanded free end, the **atrioventricular node**, from which branches pass to be quickly lost in the atrial myocardium. The bundle passes forward covered by endocardium and by one or two millimeters of myocardium, and passes beneath the medial cusp of the tricuspid valve. In passing from the atrium to the ventricle, the bundle skirts the lower margin of the septum membranaceum. Immediately in front of the septum membranaceum it divides into a left and right limb, of which the former pierces the muscular interventricular septum. The right limb now passes beneath the crista supraventricularis and above the papillary muscle of the conus, giving off branches to the latter and to other small papillaries on the septum (fig. 472). Bending somewhat toward the apex, it enters the moderator band which conducts it to the large anterior papillary muscle. From here it passes along one of the trabeculæ connected with the sternocostal wall of the ventricle, or in the wall itself, to reach the posterior papillary muscle or muscles. The right limb is compact and rounded and in the intact heart is usually invisible from the endocardial side except near the root of the moderator band or in the band itself.

The left limb of the bundle appears in the left ventricle a little below the septum membranaceum. It forms a flat, wide band immediately beneath the endocardium, which usually cannot be stripped off without injuring the bundle (fig. 471). It passes along the septal wall toward the apex and divides into two parts, which again subdivide to be distributed to the anterior and the posterior papillary muscles. The branches for the papillary muscles may reach them by traversing the trabeculæ carneæ in the neighborhood, or they may form thin strands

overed by endocardium only, bridge the gap between the septum and the papillary

ddition to the comparatively distinct branches to the papillary muscles of both ven- he bundle gives off finer fibers which form a subendocardial plexus. This plexus, visible aked eye (p. 558) is made up of fibers having a structure similar to those of the ventri- rtion of the bundle. The fibers were described by Purkinje as long ago as 1845 (Arch. ., Physiol. u. wiss. Med.) but it was not until 1906, thirteen years after the discovery of idle by W. His, Jr., that Tawara (Das Reitungssystem des Saügertierherzens, Fischer, ecognised their significance.

re is another node of muscle having characters similar to that of the conducting system, h not connected with it except by myocardium of the ordinary character. This is the ode which is situated at the upper end of the crista terminalis of the right atrium. Una- is still lacking with regard to the physiological significance of this structure.

Vessels and Nerves of the Heart

arteries.—There are two coronary arteries, the right and left; the former takes origin e right sinus of the aorta and the latter from the left.

right coronary artery [a. coronaria dextra] passes forward between the pulmonary and the right atrium, and then follows the right coronary sulcus to the diaphragmatic of the heart (fig. 479), to anastomose with the left coronary artery. The **posterior**

. 476.—Diagram of one Anterior ne Posterior Superficial Bundle rdiac Muscle Fibers seen from). (After MacCallum.)

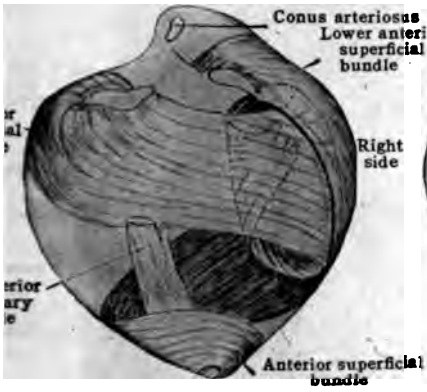
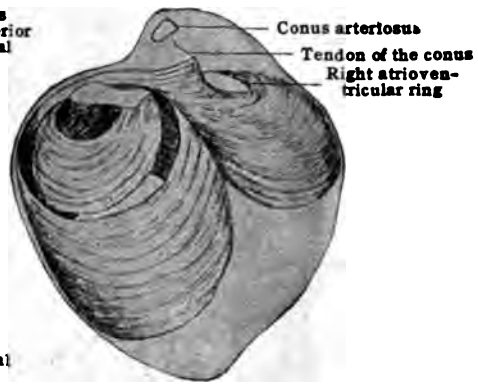


Fig. 477.—Diagram of a Deeper Bundle of Muscle Fibers. (After MacCallum.)



ding branch [ramus descendens posterior] arises at the posterior longitudinal sulcus. It in the furrow between the ventricles toward the apex, near which it anastomoses with es derived from the left coronary artery. The right coronary artery supplies branches right atrium and to the root of the pulmonary artery and aorta; also a branch that ls near the margo acutus (**right marginal**), and a second (**preventricular**) that runs to the r wall of the right ventricle. It supplies both ventricles and the septum.

left coronary artery [a. coronaria sinistra] passes for a short distance forward, between monary artery and the left auricle, and then divides into two principal branches, one of the **anterior descending branch**, runs in the anterior longitudinal sulcus to the apex of the around which it sends branches to anastomose with the right coronary; whilst the other, **:umflex** [ramus circumflexus], winds to the diaphragmatic surface in the coronary groove, stomose with the corresponding twigs of the right artery. In this course it gives off a which follows the margo obtusus (**left marginal**) as well as smaller branches to the left , both ventricles, and the commencement of the aorta and some pulmonary vessels.

cardiac or **coronary veins** accompany the coronary arteries and return the blood from lls of the heart.

great cardiac vein [v. cordis magna], (fig. 478) runs in the anterior longitudinal sulcus, round the left side of the heart in the coronary sulcus to terminate in the commence- f the coronary sinus. Its mouth is usually guarded by two valves. It receives in its the posterior vein of the left ventricle, and other smaller veins from the left atrium and le, all of which are guarded by valves.

middle cardiac vein [v. cordis media], sometimes the larger of the two chief veins, com- ites with the foregoing at its commencement above the heart apex. It ascends in the or longitudinal groove, receiving blood from the ventricular walls, and joins the coronary hrough an orifice guarded by a single valve, close to its termination.

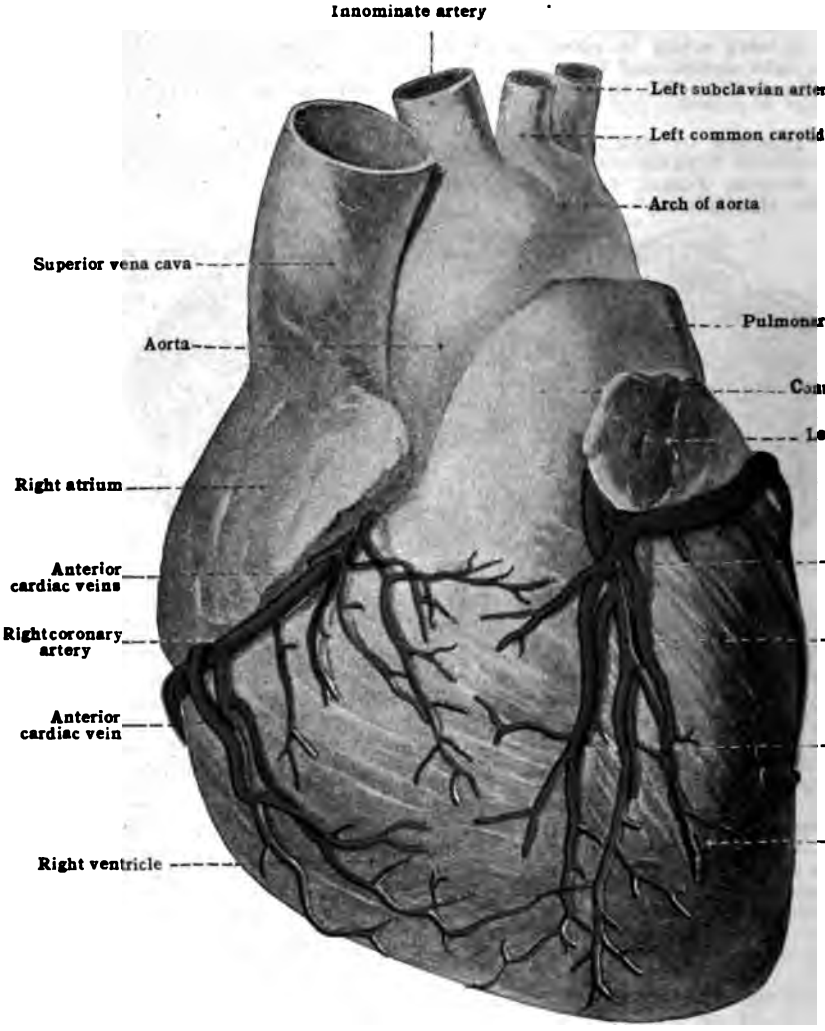
posterior vein of the left ventricle [v. post. ventriculi sinistri], lies upon the posterior of the ventricle and, receiving branches from it, passes upward to terminate directly coronary sinus.

anterior cardiac veins [vv. cordis anteriores] consist of several small branches from the f the right ventricle, which vary in number; they either open separately into the right or join the lesser cardiac vein (fig. 478).

The **small cardiac** vein [v. cordis parva] is a small vessel which receives branches from b the right atrium and ventricle, and winds around the right side of the heart, in the coron sulcus, to terminate in the coronary sinus.

The **coronary sinus** [sinus coronarius] (fig. 479) may be regarded as a much dilated term portion of the great cardiac vein. It is about 2.5 cm. (1 in.) in length, is covered by musc fibers from the atrium, and lies in the coronary sulcus below the base of the heart. Its cardi orifice, with the coronary (Thebesian) valve, has already been described. Besides the tributa veins already named, a small **oblique vein** [v. obliqua atrii sinistri] of the left atrium may some times be traced, upon the back of the left atrium; it passes from the ligament of the left vena cava (Marshall) to the coronary sinus. This little vein, which is not always pervious or easy of demonstration, never possesses a valve at its orifice. Like the coronary sinus it is a remnant of the left superior vena cava of early fetal life.

FIG. 478.—STERNOCOSTAL SURFACE OF THE HEART, SHOWING ITS ARTERIES AND VEINS. (After Spalteholz.)



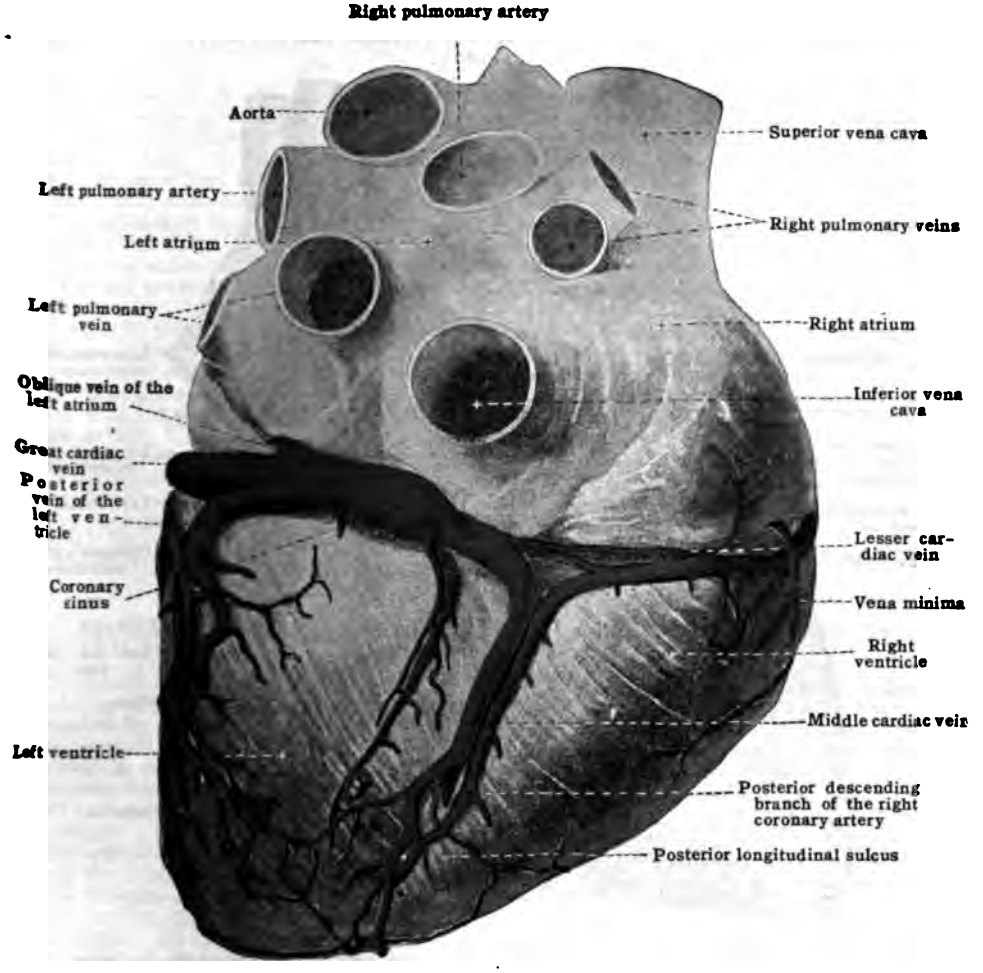
The **smallest cardiac** veins [vv. cordis minimæ] drain blood from the septum and lateral walls of the atria, particularly the right; also from the conus arteriosus. They open directly into the right atrium.

Although *anastomoses* occur between the two coronary arteries, these are by no means extensive, and are not sufficiently free to allow of the establishment of a satisfactory collateral circulation in the case of the blocking of one coronary artery. Interference with the cardiac circulation is apt to produce rapid pathological changes in the heart musculature, provided it is sudden in occurrence. If obliteration of the artery take place gradually, however, some relief may be afforded by the establishment of a collateral circulation through the venæ minimæ, which open out from both the atrial and ventricular cavities and communicate with the finer branches of the cardiac veins, and also with the general capillary network in the cardiac walls.

The lymphatic vessels of the heart pass chiefly through the anterior mediastinal lymph-[illegible] into the bronchomediastinal trunk. (See Section VII.)

The cardiac nerves, derived from the vagus and the cervical sympathetic, descend into the [illegible]erior mediastinum, passing in front of and behind the arch of the aorta; they unite to form superficial and deep cardiac plexuses. The superficial plexus lies above the right pul-[illegible]ary artery as the latter passes beneath the aortic arch. The deep plexus lies between [illegible] trachea and the arch of the aorta, above the bifurcation of the pulmonary trunk. For [illegible] connections of the plexuses see section on NERVOUS SYSTEM.

FIG. 479.—BASE AND DIAPHRAGMATIC SURFACE OF THE HEART, SHOWING ITS ARTERIES AND VEINS. (After Spalteholz.)



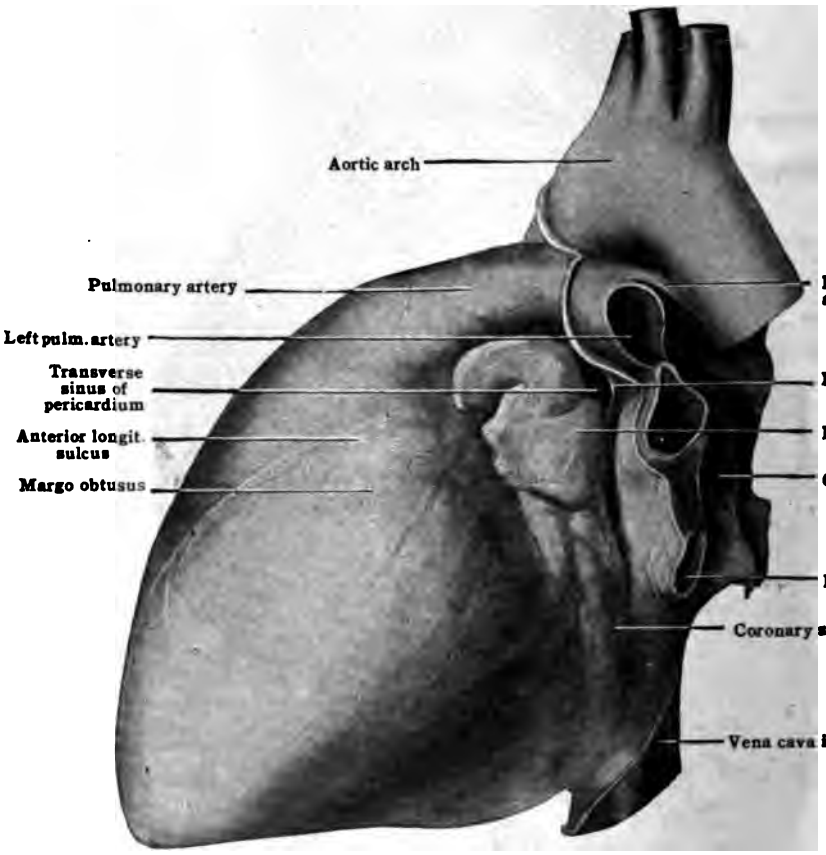
2. THE PERICARDIUM

The **pericardium** is a cone-shaped, fibroserous sac which surrounds the heart and contains a small amount of fluid [liquor pericardii]. Its apex is above at the root of the great vessels, and its base below, adherent to the diaphragm. It consists of an outer *fibrous* layer and an inner *serous* layer. The virtual space between the serous pericardium and the epicardium is commonly called the *pericardial cavity.*

The fibrous layer is strong and inelastic, made of interlacing fibers. Its connection with the central tendon of the diaphragm is intimate, particularly in the region of the caval opening, but elsewhere it is attached loosely by means of areolar tissue. Above, it is lost on the sheaths of the great vessels, all of which receive distinct investments, with the single exception of the vena cava inferior, which pierces it from below. The aorta, vena cava superior, the pulmonary artery, and the four pulmonary veins, are all ensheathed in this manner. The pericardium is connected above with the deep cervical fascia. Two variable bands of fibrous tissue, the **sternopericardial ligaments** connect the front of the pericardium above and below, with the posterior surface of the sternum.

The serous layer is smooth and glistening and consists of connective tissue, rich in elastic fibers, covered by endothelium. It lines the interior of the fibrous layer and is continuous with the epicardium or serous covering of the heart. The reflection of the serous layer from the heart to the fibrous layer of the pericardium occurs both at the arterial and at the venous attachments of the heart. At the arterial attachment a simple tube of epicardium is reflected along the pulmonary artery and aorta. At the venous attachment the serous layer is reflected from the front of the pulmonary veins on the left, and from the front of these and from the roots of the vena cava on the right. This reflection is separated above from that around the aorta and pulmonary artery (figs. 468, 480). Around the lower margin of the left lower pulmonary vein (fig. 480) and the root of the vena cava inferior, this reflection is continuous with an arched reflection from the back of the atria (figs. 468, 480). The latter reflection forms a pocket which extends upward upon the posterior aspect of the atria which is called the *oblique sinus* of the pericardium.

FIG. 480.—LEFT POSTERIOR VIEW OF THE HEART TO SHOW THE REFLECTIONS OF THE PERICARDIUM.



Between the reflections of the epicardium at the arterial and venous attachments of the heart there is a dorsal communication between the right and left sides of the pericardial cavity This is the **transverse sinus** of the pericardium [s. transversus pericardii]; it passes behind the aorta and pulmonary artery and in front of the superior cava and left atrium.

During early embryonic life the sinus transversus is closed by the dorsal mesocardium (see p. 569). The ventral part of the embryonic mesocardium, which divides the right and left sides of the pericardial cavity, is lost even earlier than the dorsal.

The **ligament of the left superior cava** [lig. venæ cavæ sinistræ] (figs. 467, 480) is a doubling of the serous layer which passes between the left pulmonary artery above and the left superior pulmonary vein below. It contains, besides some fatty and areolar tissue, the shrunken remains of the left vena cava superior. It is usually connected above with the left superior intercostal vein by means of a small tributary of the latter. Passing from its lower end to the left end of the coronary sinus is the small **vena obliqua atrii sinistri** (oblique vein of Marshall). The root of the left superior intercostal (and the adjacent part of the left innominate) vein; the vein passing from the superior intercostal to the lig. venæ cavæ sinistræ; the oblique vein of the left atrium, and the coronary sinus all represent parts of the embryonic left vena cava superior.

Relations.—In front of the pericardium are found the thymus gland or its remains, areolar ue, the sternopericardial ligaments, the left transversus thoracis muscle, the internal mam- ry vessels, the anterior margins of the pleural sac and lungs, and the sternum. Later- , it is overlapped by the lungs with their pleural sacs, and it is in contact with the phrenic ves and their accompanying vessels. Posteriorly, it is in relation with the esophagus and us nerves, the descending aorta, the thoracic duct and vena azygos, and the roots of the lungs. ow it is separated by the diaphragm from the stomach and the left lobe of the liver.
Vessels.—The arteries of the pericardium are derived from the pericardiac, esophageal, bronchial branches of the thoracic aorta and from the internal mammary and phrenic ries.

RELATIONS OF THE HEART AND PERICARDIUM TO THE THORACIC WALL

Heart (fig. 481 A and B).—The **base** of the heart is opposite the fifth to the ninth acic vertebra *posteriorly*. *Anteriorly* the **apex** is in the fifth intercostal space, 7.5 to 8 (3 to 3¼ in.) from the median line. The **base** (above) corresponds to a line (A) drawn a point 1 cm. (⅜ in.) below the second left chondrosternal articulation, and 3 cm. (1⅛ in. the median line, to another point (the same distance from the median line) 1 cm. above right third chondrosternal articulation. The **margo acutus**, or lower border corresponds line (B) drawn from the apex through the xiphisternal articulation, to a point on the sixth al cartilage 2 cm. to the right of the median line. The **right border** of the heart may be cated approximately by a line (slightly convex to the right) joining the right ends of A and The **left border** corresponds to a line (slightly convex to the left) joining the left end of the **apex**.
If a line be drawn from the upper margin of the left third chondrosternal articulation to the t edge of the sternum in the fifth intercostal space, its upper end will lie over the center of **pulmonary ostium**, and its lower two-thirds (approximately) will overlie the main axis of he **tricuspid ostium**. The **aortic ostium** is immediately to the left of the line mentioned re, with its center at the left edge of the sternum opposite the third space. The **mitral** um is very largely behind the third left interspace; its upper end is behind the third ilage, its lower behind the left margin of the sternum opposite the fourth cartilage and space. Of the **ostia of the heart**, the pulmonary is nearest the anterior thoracic wall, the aortic is itly in advance of the tricuspid, and the mitral is the deepest of all.
The **pericardium** follows the heart closely. The upper end (apex) in the subject used in aring fig. 481 extended up, behind the sternum, to the lower margin of the first costal lage on the right and the upper margin of the second on the left.

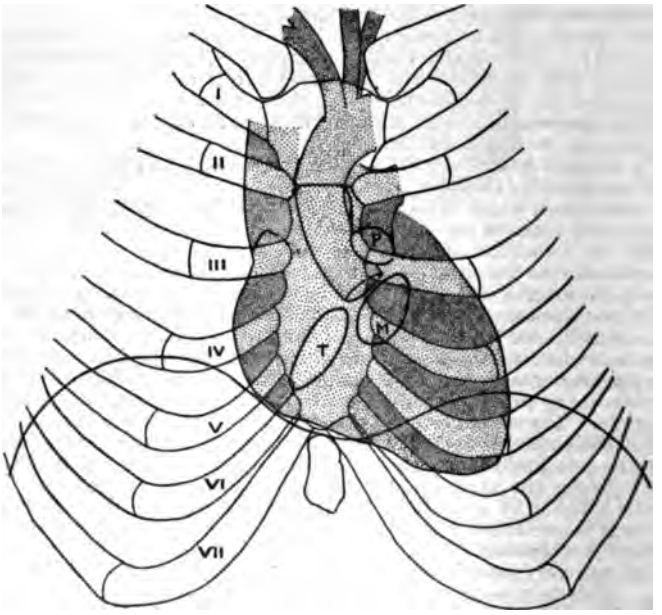
MORPHOGENESIS OF THE HEART AND PERICARDIUM

The heart is formed by the blending in the median line of two longitudinal endothelial s lying upon the ventral aspect of the foregut of the early embryo. Each tube is partially ounded by the splanchnic mesoderm which forms a septum between the right and left sides ie celomic cavity. The blended endothelial tubes form the **endocardium**; the splanchnic derm in relation with them becomes the **myoepicardium**. The double layer of splanchnic derm which unites the myoepicardium with the somatic mesoderm forms the (temporary) al and ventral mesocardia. The somatic mesoderm of the heart region becomes the **ardium**. (See also Section I, fig. 34.)
The originally straight heart-tube grows rapidly and becomes tortuous, since its length soon eds the limit assigned by its fixed arterial and venous ends. Its arterial end is continued the truncus arteriosus, which is later divided into the pulmonary artery and the ascending a. Its venous end receives the right and left ducts of Cuvier, with the vitelline and um- al veins. By the formation of a series of alternate bulgings and constrictions the heart mes differentiated into the sinus venosus, atrium, ventricle and conus arteriosus, counting the venous to the arterial end. These parts by a process of progressive differentiation and ing (fig. 482) soon occupy relative positions somewhat approaching those of the adult.
The sinus venosus lies on the dorsal wall of the atrium, and is composed of right and left s united by a median portion. The sinus is separated from the atrium by a sagitally ted slit-like opening, guarded by right and left lateral valves which project into the atrium. atrium is wide, being prolonged into a ventrally projecting pouch on either side, the future and left auricle. The ventricle is situated caudally and somewhat ventrally to the atrium. right limb of the common ventricle, which leads into the conus arteriosus, is the future ventricle; the left limb, connected with the atrium, is the future left ventricle. The nunication between the atrium and the ventricle, known as the atrial canal (fig. 483), licated on the exterior by a constriction; its interior consists of a transversely placed slit. conus arteriosus is continued from the ventricle without obvious constriction and passes into the truncus arteriosus.
The **sinus venosus** early loses its bilateral symmetry owing to the rapid enlargement of the sinus-horn. This horn soon receives, through the proximal portion of the right vitelline (*vena cava inferior*), all the blood from the left vitelline and both umbilical veins. The common cardinal (duct of Cuvier) eventually gains ascendency over the left and becomes *ena cava superior*. The left horn of the sinus venosus, which now drains the dwindling left non cardinal (duct of Cuvier) (*left superior cava*) and the coronary veins, become the *ary sinus*. The right horn gradually becomes absorbed into the right end of the atrial

FIG. 481.—A, TELEROENTGENOGRAM OF A FORMALIN PREPARATION OF THE ANTERIOR THORAX WALL WITH THE HEART, PERICARDIUM AND DIAPHRAGM IN SITU. (LE WALD, X ¼.) B, EXPLANATORY OUTLINE DRAWING, TRACED FROM THE NEGATIVE AND CONTROLLED STEREOSCOPIC VIEWS.

The ostia have been accurately fitted with wire rings. P, pulmonary ostium; *M*, mitral; *T*, tricuspid; aortic ostium is unlabelled; I–VII, right costal cartilages.

A

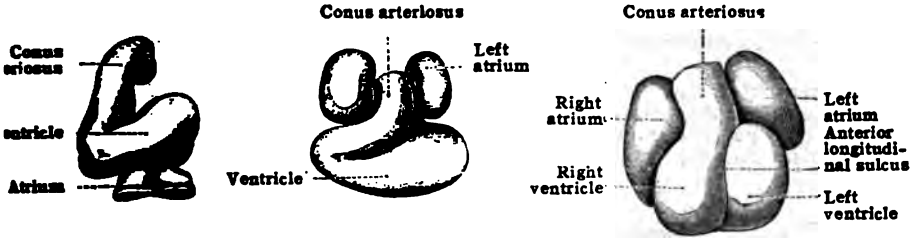


B

r and the superior and inferior cava and the coronary sinus acquire separate openings in chamber.

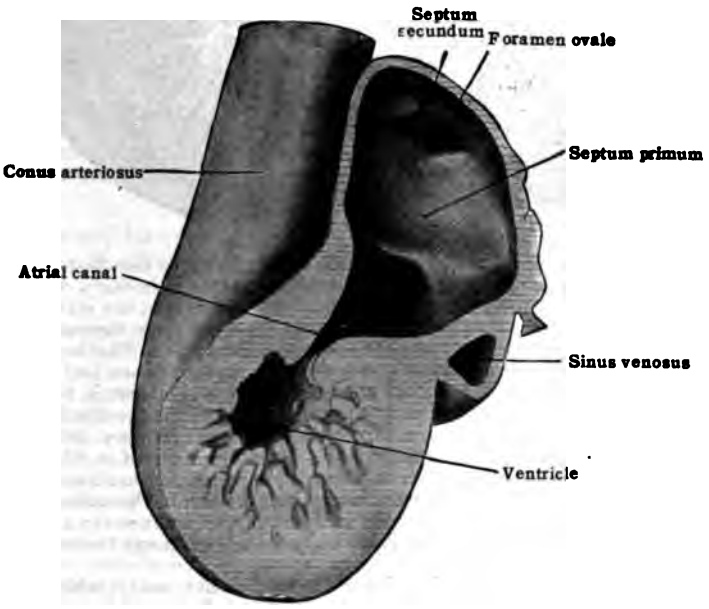
the atrium a septum begins early to grow from the ventrocephalic wall of the atrium, rd the atrial canal. As the interatrial communication (ostium primum) around the edge of rowing septum is becoming narrow a perforation occurs near the attached margin of the im (ostium secundum); the *septum primum* thus remains incomplete (fig. 483). To the of the septum primum another septum (s. secundum) is formed later; this never stretches letely across the atrium and is rather a crescentic ridge than a true septum. Until the edges of the two septa overlap one another there is a direct passage leading from one side

482.—MODELS SHOWING THE DEVELOPMENT OF THE HEART. VENTRAL VIEW. (After His.)



he atrium to the other; when overlapping finally occurs, the interatrial communication amen ovale) becomes oblique but persists until birth. (For fetal relations, see p. 34; for lt, see p. 553.) The cavities resulting from the division of the common atrium are the t *and left atria* of the adult. The foramen ovale is bounded on the right side by the septum undum the free edge of which forms the *limbus fossæ ovalis*. The channel is bounded on the by the septum primum which slants into the left atrium. The free edge of the septum mum becomes the *valvula foraminis ovalis*, while the remainder becomes the membranous ial septum of the adult.

g. 483.—SAGITTAL SECTION THROUGH A RECONSTRUCTION OF THE HEART OF A 9 MM. HUMAN EMBRYO SEEN FROM THE LEFT SIDE. (Tandler, × 75.)



The portion of the dorsal wall of the right atrium immediately adjoining the septa is derived the sinus venosus. This part of the atrium (the *sinus venarum*) receives the venæ cavæ the coronary sinus. The left sinus-valve is attached to both of the embryonic atrial septa assists the septum secundum in the formation of the *limbus foraminis ovalis*. The cephalic of the right sinus-valve disappears along the line of the (adult) *crista terminalis*, which efore forms the right margin of the portion of the right atrium derived from the sinus sus. The caudal part of this valve persists as the *inferior caval and coronary valves*.

The left atrium receives, through the dorsal mesocardium, the originally single pulmonary . This common stem is absorbed into the atrial wall; later, the primitive right and left taries are absorbed in a similar way, leaving the four pulmonary veins of the adult open- separately into the left atrium. The part of the left atrium between the pulmonary veins nerefore, not part of the original atrial wall.

The ventricles are divided by a septum (*s. musculare ventriculorum*) (fig. 484, *SV*) wh grows from the caudal wall of the common ventricular cavity toward the atrial canal. T canal moves to the right, and the dorsal part of the septum blends with its dorsal lip. The ventral edge of the interventricular septum helps to bound the foramen through which bl from the left ventricle must enter the right on its way to the conus arteriosus. The fora persists until its free margin, having been joined by the aortic septum, becomes the circum ence of the *aortic ostium*.

The aortic septum is a composite structure formed partly by a septum growing betwee fourth and sixth pairs of aortic arches, and partly by endocardial swellings which appe the interior of the conus and truncus arteriosus. When fully formed it extends spirally along truncus and conus, and enters the right half of the common ventricular cavity, where it join right side of the free edge of the interventricular septum. The septum is spirally curved in s a way that the blood from the left ventricle passes no longer through the right ventricle

FIG. 484.—RECONSTRUCTION OF THE HEART OF AN 11 MM. HUMAN EMBRYO. CAUDAL VI (Mall, ×50.)

The lower part of the ventricular portion has been cut off. Connective tissue septa colo yellow. *Ao*, aorta; *Ap*, anterior papillary muscle; *La*, left atrium; *Lo*, left venous ostium; large (anterior) papillary muscle of right ventricle; *Mpm*, medial papillary muscle; *PP*, terior papillary muscle; *P*, pulmonary artery; *RA*, right atrium; *SV*, septum ventriculo

traverses a channel (*the aorta*) through the conus and truncus to the first four pairs of a arches. The blood from the right ventricle passes through *the pulmonary* division of the and truncus arteriosus, anteriorly and to the left of the aorta, into the sixth arches. Fu differentiation brings about the external separation of the aorta from the pulmonary arter their common covering of epicardium persists as such in the adult. The lower end of the septum persists in the adult as the *septum membranaceum ventriculorum* and the *crista sup tricularis*, the relations of which to the septum musculare are well shown in fig. 472. Duri formation of the aortic septum four endocardial swellings appear at the distal part of the in of the conus. These are arranged as smaller and larger opposite pairs; the smaller and swellings, therefore, alternating around the lumen. The larger pair of swellings assists (b tial blending) in the formation of the aortic septum. When the septum is complete, half o of the larger swellings is contained in the aorta and half of each in the pulmonary artery. of the smaller swellings remains in the aorta and one in the pulmonary artery, so that are now three swellings in each vessel. Each of these six swellings becomes undermi form a *semilunar valve* of the adult.

The atrioventricular valves.—The interior of the ventricular cavity, which is at first sm becomes undermined in an irregular way, to form a system of myocardial trabeculæ. Th of the transversely directed atrial canal become thickened into prominent anterior and po endocardial cushions; these project into the ventricular cavity and become involved in its cardial trabecular system. The atrial canal, which has now moved to the right, be divided sagittally, into a right and a left *venous ostium venosum*, by the septum primum. interventricular septum joins the ventricular side of the posterior endocardial cushion. anterior and posterior endocardial cushions blend with one another and with the s primum to form an atrioventricular valve-cusp on either side of the interventricular se viz., the anterior cusp of the mitral in the left ostium, and the medial cusp of the tricuspid right. The posterior cusp of the mitral and the anterior and posterior cusps of the tricus formed later, partly from endocardial tubercles developing in either ostium, and partly process of undermining of the ostia from the ventricular side. The atrial musculature e into the atrioventricular valves and remains for a while continuous with the trabecular s

the ventricles. This connection between atrial and ventricular musculature eventually becomes non-muscular. Muscle is found at the basal region of the valve-cusps in the adult, and occasionally persists in the chordæ tendineæ.

The connection between the atrial and ventricular musculature is not confined to that of the valvular and trabecular system. The connection between the atrial and ventricular portions of the myocardium remains complete until the embryo has reached the length of about 4 mm. From that time on the myocardium of the atrioventricular junction begins to be replaced by the developing fibrous annuli of the venous ostia. The original connection between the atrial and ventricular musculature persists at one place only, i. e., the site of the *interventricular bundle*.

The pericardial cavity is the original cephalic end of the intraembryonic celom (see p. 565). The somatic mesoderm of the pericardial region forms the adult *pericardium*. The splanchnic mesoderm persists only in the part which furnishes the *myoepicardium*. The ventral and dorsal mesocardia, both of which are formed by the splanchnic mesoderm, are, in the main, transitory. The early disappearance of the ventral mesocardium unites the right and left sides of the pericardial celom upon the ventral side of the heart. The dorsal mesocardium persists at the arterial and venous ends of the heart only. The loss of the dorsal mesocardium between the latter points gives rise to the *sinus transversus pericardii* of the adult.

During development, the heart and pericardium migrate from a point opposite the cephalic end of the pharynx to the region of the caudal end of the esophagus. This migration is evidenced in the adult by the course of the recurrent and of the cardiac nerves.

B. THE ARTERIES AND VEINS

The **arteries** [arteriæ], proportionately to their size, have much thicker walls than the veins. After death they retain their natural form, but are contracted and usually contain a small amount of pale clot. In a very general way the thickness of wall is proportional to caliber.

The larger arteries usually take a direct course and branch dichotomously. In descriptive anatomy if dichotomous branches are of nearly equal size it is common for each to take another name; if one branch preponderates in size, it usually retains the name of the parent trunk, while the smaller is regarded as a collateral branch [vas collaterale]. There are numerous exceptions to dichotomous branching; branches may run perpendicularly or recurrently to the vessel from which they arise; or several branches may arise simultaneously.

Anastomosis between large or medium sized arteries occurs less frequently than in veins of corresponding magnitude. Anastomoses do occur, however, particularly in the form of arches, such as the palpebral, plantar and volar arches, or the arches between the intestinal arteries. This form of anastomosis is sometimes called inosculation. Between smaller arteries anastomosis is usually free as in the case, for instance, of the articular retia. In some organs anastomosis (excepting capillary) between neighboring arteries can scarcely be said to exist at all; the a. centralis retinæ affords a good example, as do the arteries of the brain, spleen, and kidney; such arteries are called terminal.

The larger arteries are supplied by *vasa vasorum*, frequently arising from their own recurrent branches.

The **veins** [venæ] have thin walls, and after death are either collapsed or filled with clot or discolored serum. They are characterized by the presence of valves.

Frequent anastomoses occur between veins of all sizes; plexuses are of frequent occurrence. *Venæ comitantes* are veins which, usually in pairs, accompany many of the larger arteries; they communicate with one another, around the artery, very freely. Veins do not primitively accompany arteries. In the case of the extremities the primitive veins ramify upon the surface of the limb. The deep veins of the limbs are of later formation and to them the superficial veins subsequently become tributary.

The veins from the stomach, spleen, pancreas and intestine are collected into a large trunk, the **portal vein**. This does not open into the vena cava inferior directly, but breaks up into numerous capillaries (sinusoids) in the liver. From these the blood is returned, through the hepatic veins, to the inferior cava.

Many veins are provided with **valves**, the free borders of which are directed toward the heart. In the small veins the valves are single; in the larger veins they are usually double, rarely treble. Valves are much more numerous in the veins of infants than those of the adult; their number diminishes progressively with advancing age. Valves are most numerous in the superficial veins, and in the deep veins of the extremities; in many veins of the head and neck valves occur only at the point of termination in a larger trunk.

The cranial *venous sinuses* are modified veins, consisting of intima only which lines channels in the fibrous dura mater. The venous spaces in cavernous tissue, such as occurs in the corpora cavernosa, may be looked upon as specially modified veins.

The larger veins, like the arteries, have *vasa vasorum*.

The section dealing with arteries and veins is divided as follows: 1, pulmonary artery and veins; 2, the systemic arteries; and, 3, the systemic veins. At the heads of the second and third divisions are brief accounts of morphogenesis and variations.

1. THE PULMONARY ARTERY AND VEINS

The **pulmonary artery** [a. pulmonalis] (fig. 485) passes from the right ventricle to the lungs. It differs from all other arteries in the body in that it contains venous blood. It arises as a short, thick trunk from the **conus arteriosus** of the right ventricle, and, after a course of about 5 cm. (2 in.) within the pericardium, divides into a right and a left branch. These branches pass to the right and the left lung respectively.

The **trunk of the pulmonary artery** at its origin is somewhat anterior to the ascending aorta, and slightly overlaps that vessel. It passes upward, backward, and to the left, forming a slight curve around the front and left side of the ascending aorta; having reached the concavity of the aortic arch, on a plane posterior to the ascending aorta, it divides into its right and left branches, which diverge from each other at an angle of about 130°. The division of the pulmonary artery occurs immediately to the left of the second left chondrosternal articulation.

In the fetus, the pulmonary artery continues its course upward, backward, and to the left under the name of the **ductus arteriosus (Botal'li)**, and opens into the descending aorta just below the origin of the left subclavian artery. After birth, the lumen of the ductus arteriosus becomes obliterated, and its wall is represented in postnatal life by a fibrous cord, the **ligamentum arteriosum** (fig. 480).

Relations.—In front, the trunk of the pulmonary artery is covered by the remains of the thymus gland, and the pericardium. The artery lies, at its commencement, behind the upper margin of the third left chondrosternal articulation. The right margin of the artery is behind the second piece of sternum but the greater part of the vessel is behind the medial end of the second intercostal space.

Behind, it lies successively upon the ascending aorta and the left atrium.

To the **right** are the ascending aorta, the right atrium, the right coronary artery, and the cardiac nerves.

To the **left** are the pericardium, the left pleura and lung, the left auricle, the left coronary artery, and the cardiac nerves.

The **right pulmonary artery** [ramus dexter] longer than the left, passes almost horizontally under the arch of the aorta to the root of the right lung, where it divides, either directly or indirectly, into three branches, one for each lobe. These branches follow the course of the bronchi, dividing and subdividing for the supply of the lobules of the lung. The terminal branches do not anastomose with each other.

Relations.—In its course to the lung it has **in front** of it the ascending aorta, the superior vena cava, the phrenic nerve, the anterior pulmonary plexus, and the reflection of the pleura. **Behind** are the right bronchus and the termination of the azygos vein. **Above** is the arch of the aorta, and **below** are the left atrium and the upper right pulmonary vein.

At the root of the lung it has the right bronchus **above** and **behind it;** the pulmonary veins **below** and in **front.** Crossing in front of it and the other structures forming the root of the lung are the phrenic nerve and the anterior pulmonary plexus; behind are the azygos vein, the vagus nerve, and the posterior pulmonary plexus.

The **left pulmonary artery** [ramus sinister], shorter and slightly smaller than the right, passes in front of the descending aorta to the root of the left lung, where it divides into two branches for the supply of the upper and lower lobes respectively. These divide and subdivide as on the right side.

Relations.—At the root of the lung it has the left bronchus **behind and also below** it, in consequence of the more vertical direction taken by the left bronchus than by the right. **Below** and **in front** are the pulmonary veins, while passing from the artery and the upper left pulmonary vein is the ligament of the left superior cava. Crossing in front of it and the other structures forming the root of the lung are the phrenic nerve, the anterior pulmonary plexus, and the reflection of the left pleura; crossing behind it are the descending aorta, the left vagus nerve, and the posterior pulmonary plexus.

The **pulmonary veins** [vv. pulmonales] (figs. 468, 485) return the aërated blood from the lungs to the heart. They are usually four in number, superior and inferior, of the right and left sides. Occasionally, however, there are three pulmonary veins on the right side, the result of the vein from the middle lobe of the right lung opening separately into the left atrium instead of joining as usual the upper of the two right pulmonary veins. The relations of the pulmonary veins to the pulmonary arteries and bronchi in the lungs are given with the anatomy of the lungs (Section X).

The pulmonary veins are about 15 mm. in length. In the pericardium the [illegible] pulmonary veins [vv. pulmonales dextræ] both pass behind the superior [illegible] cava. The superior vein receives the vein from the right middle lobe and [illegible] below and in front of the right pulmonary artery.

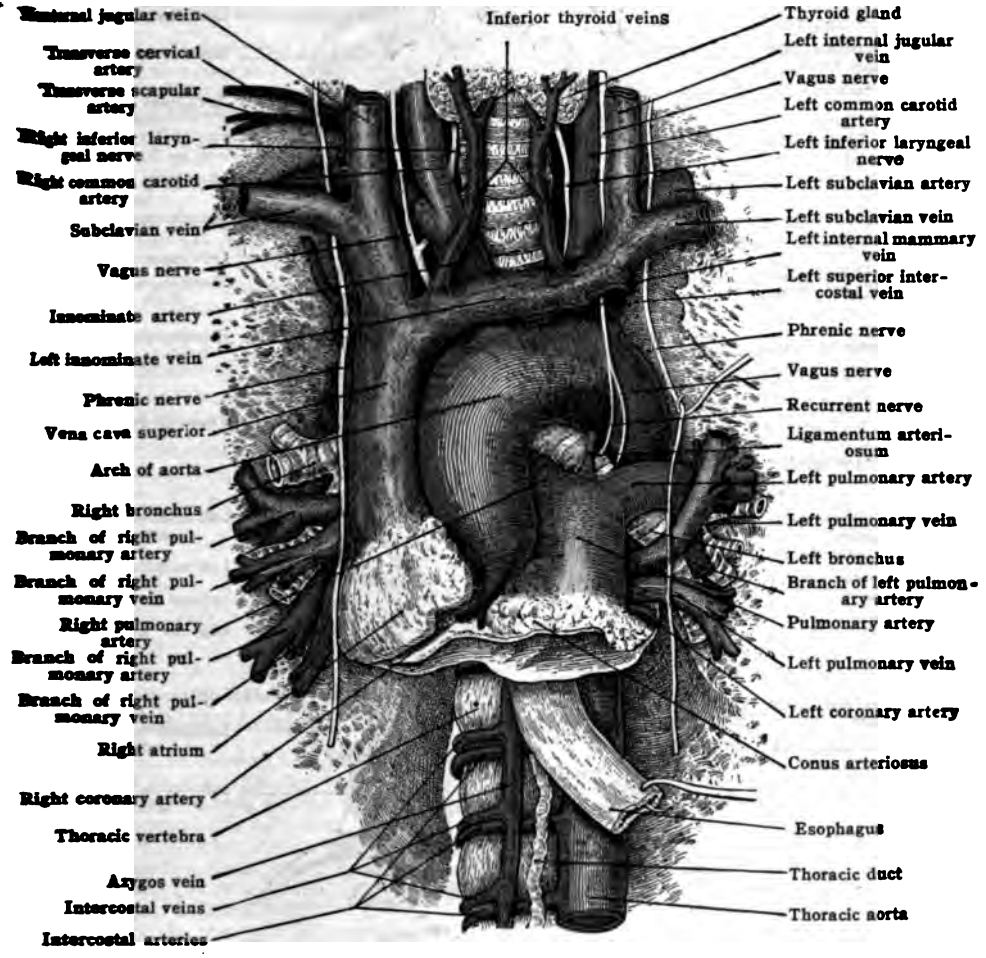
The left pulmonary veins [vv. pulmonales sinistræ] enter the left atrium about [illegible]m. in front of the veins of the right side. The superior vein is below the left [illegible]monary artery.

2. THE SYSTEMIC ARTERIES

THE AORTA

The aorta (fig. 486) is the main systemic arterial trunk, and from it all the [illegible]stemic arteries are derived. It begins at the left ventricle of the heart, and [illegible]cends near the anterior thoracic wall as high as the second right chondrosternal

FIG. 485.—THE GREAT VESSELS OF THE THORAX.
(Modified from a dissection in St. Bartholomew's Hospital Museum.)

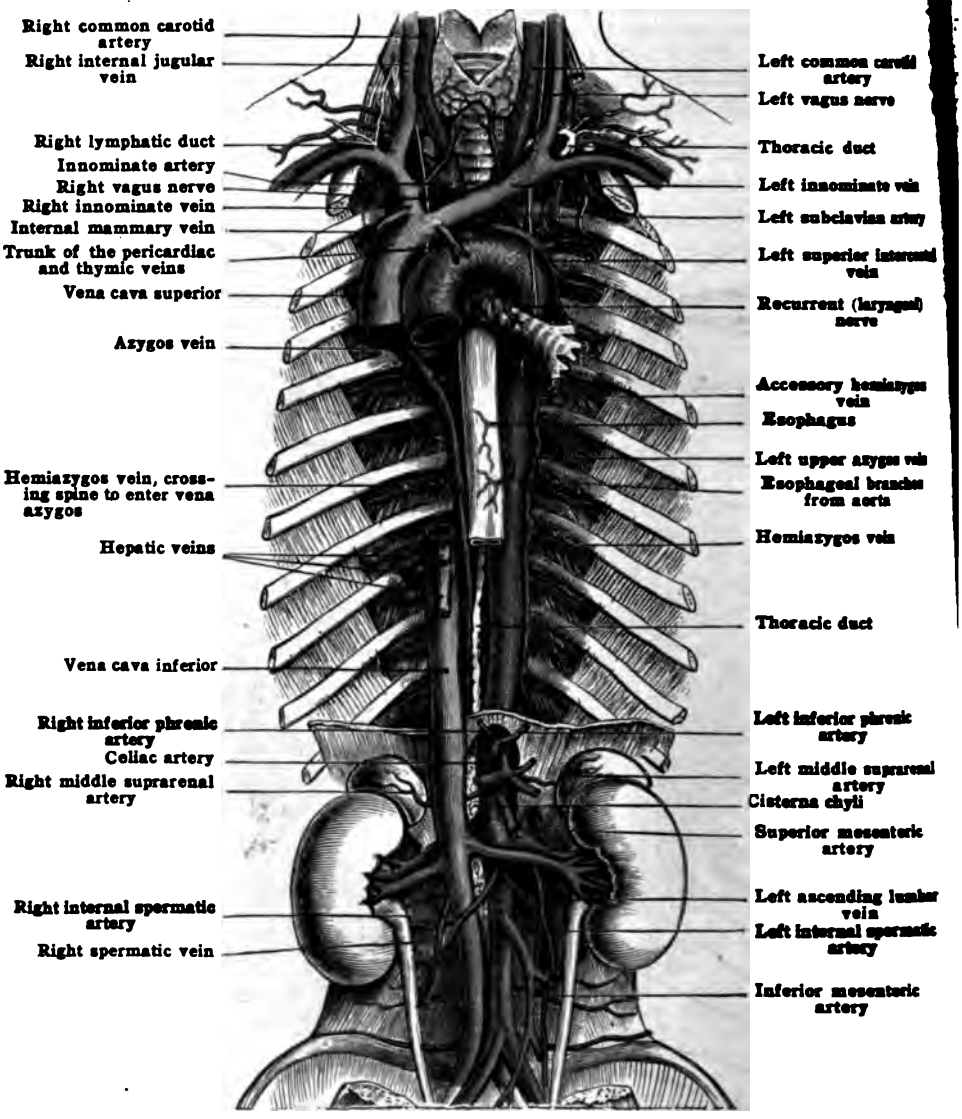


articulation [aorta ascendens]. It then turns backward and to the left forming **an arch [arcus aortæ] which** reaches the posterior thoracic wall at the left side of **the fourth thoracic vertebra.** From here it runs downward along the vertebral **column [aorta descendens] through** the thorax and abdomen and ends by dividing, **opposite the fourth lumbar** vertebra, into the right and left common iliac arteries. **From the point of bifurcation a** small vessel, the middle sacral, is continued down **the middle line in front of the** sacrum and coccyx. The middle sacral represents **the sacrococcygeal aorta.**

The Ascending Aorta

The **ascending aorta** [aorta ascendens] (fig. 486) begins at the upper part of the left ventricle, on a level with the third intercostal space, and ascends behind the sternum to the upper border of the right second chondrosternal articulation. It measures about 5 to 5.5 cm. (2 to 2¼ in.), forming, as it ascends, a gentle curve with its convexity to the right. It is enclosed for the greater part of its length in the pericardium, being invested, together with the pulmonary artery, in a common sheath formed by the serous layer of that membrane. A dilation known

Fig. 846.—The Thoracic and Abdominal Aorta.



as the **bulbus aortæ** occurs immediately above the heart upon which are three localized bulgings, known as the **aortic sinuses** (sinuses Valsalva); they are placed, one to the right, one to the left, and one posteriorly. From the right and left are derived the coronary arties of the heart. (See **Heart.**)

Relations.—In front the ascending aorta is overlapped at its commencement by the right auricle, conus arteriosus and pulmonary artery. Higher up, as the pulmonary artery and auricle diverge, it is separated from the manubrium by the pericardium, the remains of the thymus gland, and by the loose tissue and in the superior mediastium. It is here slightly overlapped also by the right pleura and by the edge of the right lung in full inspiration. The root of the right coronary artery is also in front. Behind are the left atrium of the heart, the right

The pulmonary veins are about 15 mm. in length. In the pericardium the **right pulmonary veins** [vv. pulmonales dextræ] both pass behind the superior **vena cava**. The superior vein receives the vein from the right middle lobe and runs **below** and in front of the right pulmonary artery.

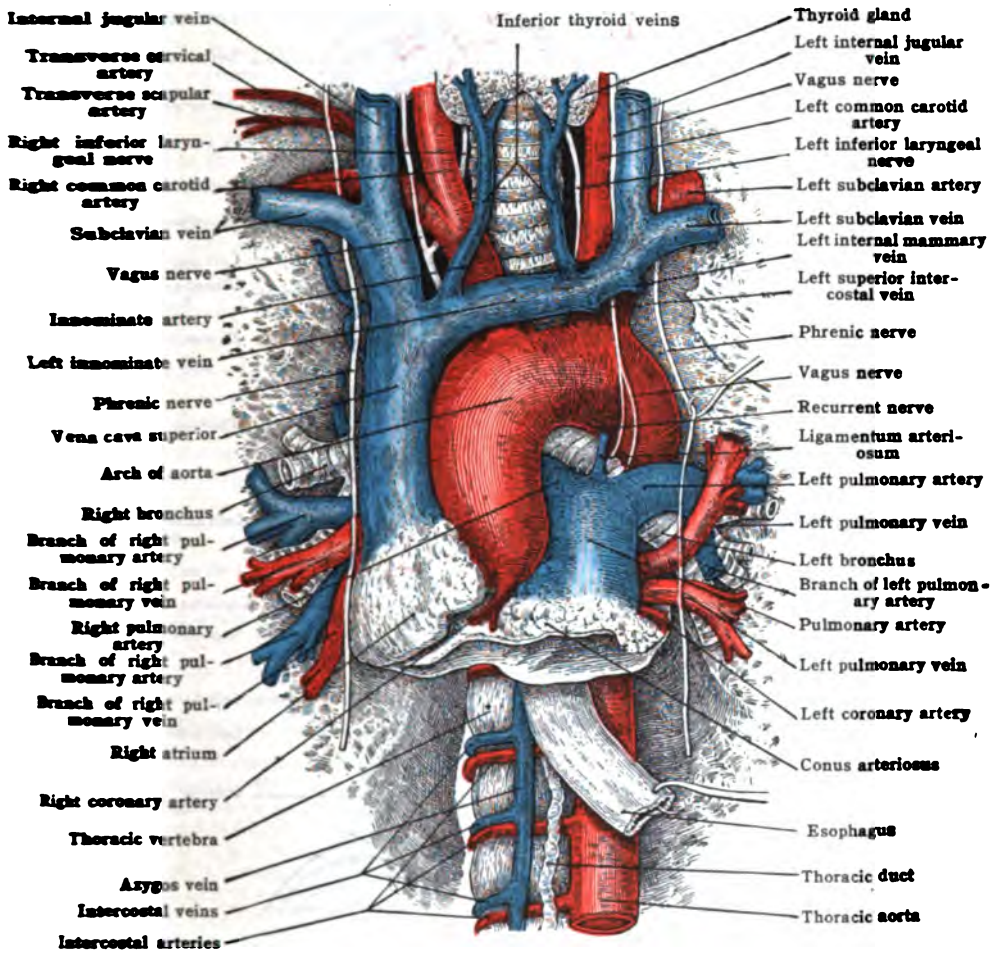
The left pulmonary veins [vv. pulmonales sinistræ] enter the left atrium about 3 cm. **in** front of the veins of the right side. The superior vein is below the left **pulmonary** artery.

2. THE SYSTEMIC ARTERIES

THE AORTA

The aorta (fig. 486) is the main systemic arterial trunk, and from it all the **systemic arteries** are derived. It begins at the left ventricle of the heart, and **ascends** near the anterior thoracic wall as high as the second right chondrosternal

FIG. 485.—THE GREAT VESSELS OF THE THORAX.
(Modified from a dissection in St. Bartholomew's Hospital Museum.)

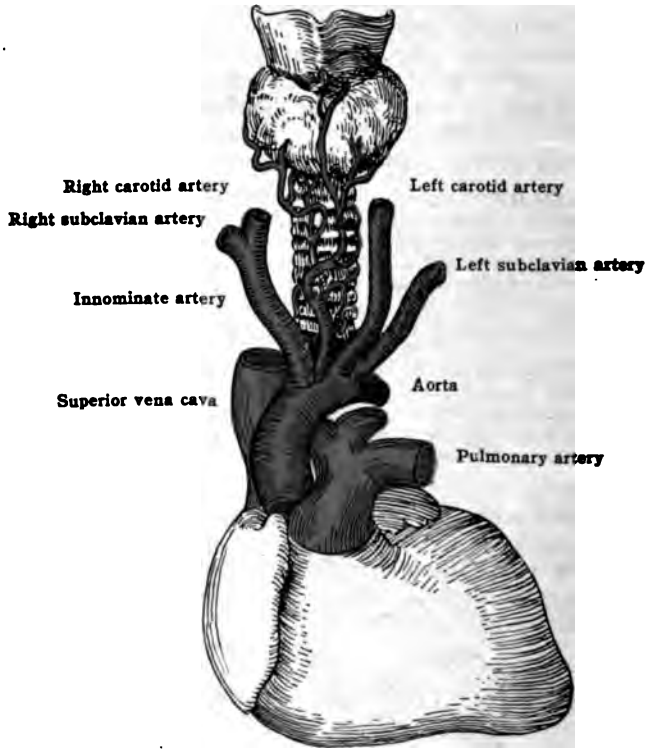


articulation [**aorta ascendens**]. It then turns backward and to the left forming an arch [**arcus aortæ**] which reaches the posterior thoracic wall at the left side of the fourth thoracic vertebra. From here it runs downward along the vertebral column [**aorta descendens**] through the thorax and abdomen and ends by dividing, opposite the fourth lumbar vertebra, into the right and left common iliac arteries. From the point of bifurcation a small vessel, the middle sacral, is continued down the middle line in front of the sacrum and coccyx. The middle sacral represents the sacrococcygeal aorta.

THE COMMON CAROTID ARTERIES

The **common carotid** arteries [aa. carotides communes] pass up deeply the thorax on either side of the neck to about the level of the upper border thyroid cartilage, where they divide into the external and internal ca arteries. The **external carotid** supplies the structures at the upper part c neck, the larynx, pharynx, tongue, face, the structures in the pterygoid re the scalp, and the membranes of the brain. The **internal carotid** gives c branch in the neck, but enters the cranium and supplies the greater part c brain, the structures contained in the orbit, and portions of the membra the brain.

FIG. 487.—THE THYROIDEA IMA. (After Henle.)



The common carotid artery on the right side arises from the bifurcation o innominate at the upper limit of the sternoclavicular joint; on the left side the arch of the aorta a little to the left of the innominate artery, and on a somewhat posterior to that vessel (fig. 485). The portion of the left com carotid artery which extends from the arch of the aorta to the upper limit sternoclavicular articulation lies deeply in the chest, and requires a sep description; but above the level of the sternoclavicular joint the relations right and left carotids are practically the same.

THORACIC PORTION OF THE LEFT COMMON CAROTID ART

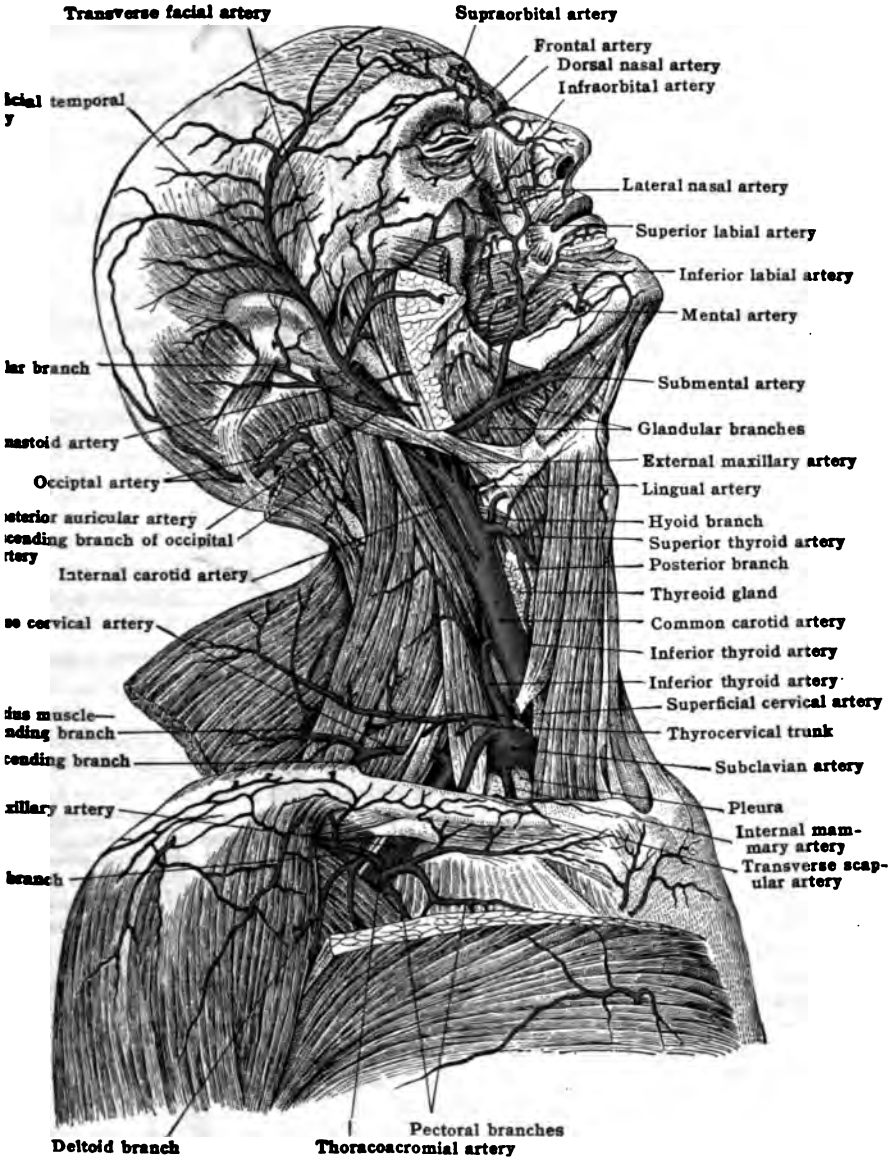
Within the thorax the left common carotid is deeply placed behin manubrium of the sternum, and is overlapped by the left lung and pleur arises from the middle of the aortic arch, close to the left side of the innon artery, and a little posterior to the vessel, and ascends obliquely in front trachea to the left sternoclavicular articulation, above which its relatio similar to those of the right common carotid (fig. 486).

Relations.—In front, but at some little distance, are the manubrium and the origins left sternohyoid and sternothyroid muscles, whilst in contact with it are the remains thymus gland, and the loose connective tissue and fat of the superior mediastinum. C

s the left innominate vein. Behind, it lies successively upon the trachea, the left ; (inferior laryngeal) nerve, the esophagus (which here inclines a little to the left) and ıcic duct. To its **right side** is the root of the innominate artery, and higher up are the ınd the inferior thyroid veins. To its **left side,** but on a posterior plane, are the left ın artery and the left vagus nerve; and, slightly overlapping it, the edge of the ra and lung.

.—Arteries of the Head and Neck. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

s case the external maxillary artery ends by inosculating with the infraorbital. The ıeal branch of the ophthalmic is larger than usual (Cf. fig. 493.)



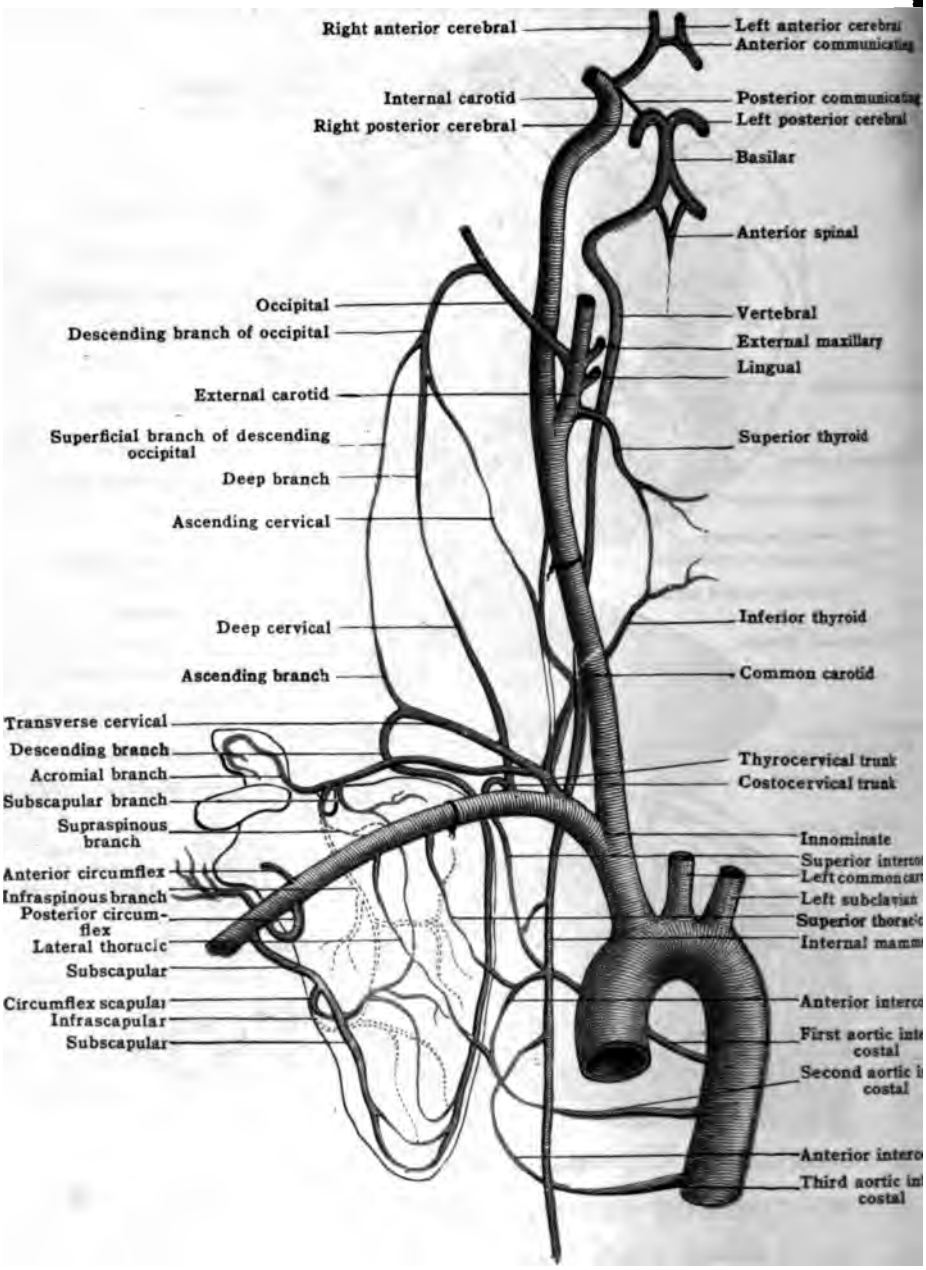
THE COMMON CAROTID ARTERY IN THE NECK

common carotid artery in the neck extends from the sternoclavicular ıtion to the upper border of the thyroid cartilage on a level with the cervical vertebra, where it divides into the external and internal carotid ;. A line drawn from the sternoclavicular joint to a point just behind the f the mandible would indicate its course. The artery is at first deeply beneath the sternomastoid, sternohyoid, and sternothyroid muscles, and evel of the top of the sternum is only 2 cm. ($^3/_4$ in.) distant from its fellow

of the opposite side, and merely separated from it by the trachea. As the ca
arteries run up the neck, however, they diverge in the form of a V and be
more superficial, though on a plane posterior to that in which they lie at the
of the neck, and are separated from each other by the larynx and pharynx.
their bifurcation they are about 6 cm. (2¼ in.) apart. The common caro

FIG. 489.—THE COLLATERAL CIRCULATION AFTER LIGATURE OF THE COMMON CAROTID
SUBCLAVIAN ARTERIES.

(A ligature is placed on the common carotid and on the third portion of the subclavian ar

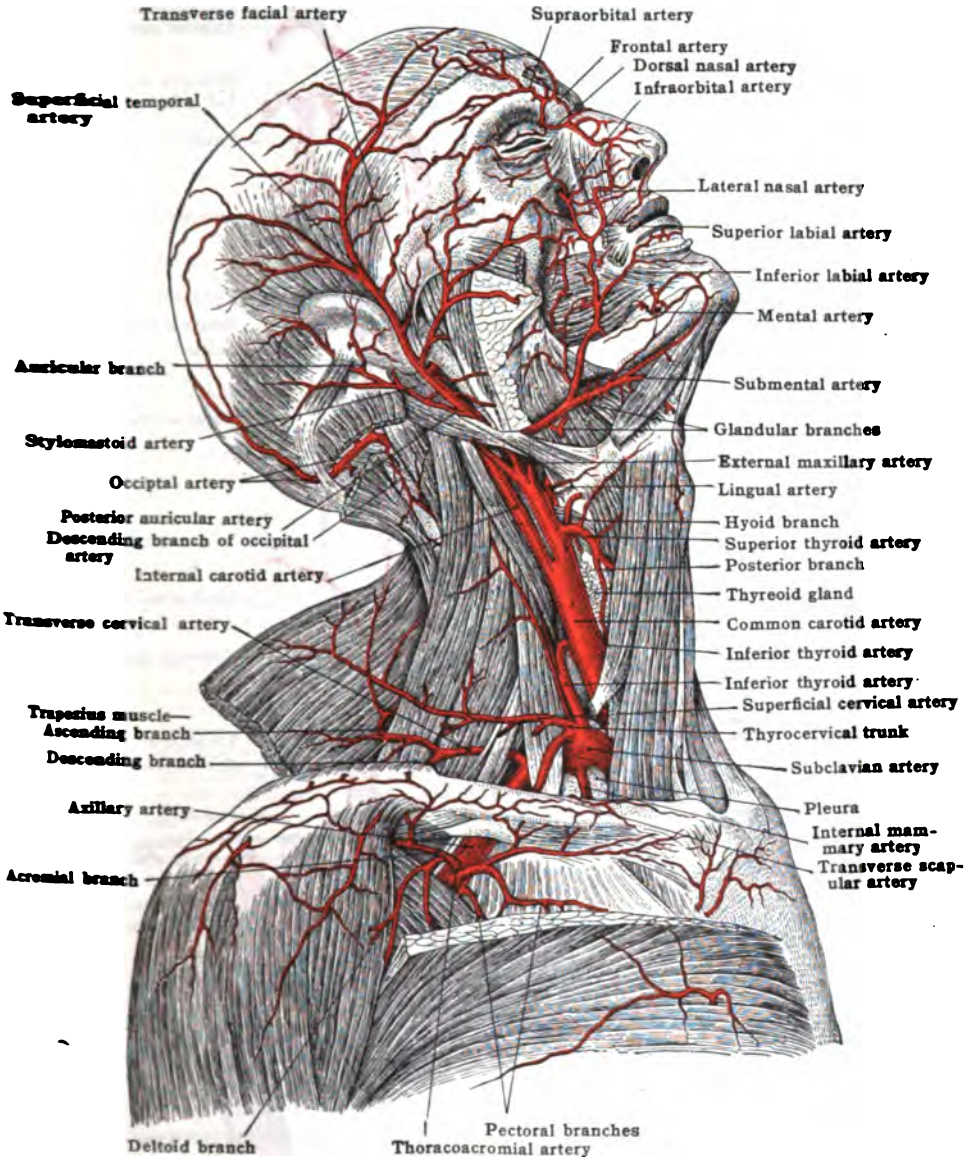


contained in a sheath of fascia common to it and the internal jugular vein
vagus nerve. The artery, vein, and nerve, however, are not in contact, but se
rated from one another by fibrous septa, which divide the common sheath i
three compartments: one for the artery, one for the vein, and one for the ne
The vein, which is larger than the artery, lies to the lateral side, and somew
overlaps it. The vagus nerve lies behind and between the two vessels.

its root is the left innominate vein. **Behind,** it lies successively upon the trachea, the left recurrent (inferior laryngeal) nerve, the esophagus (which here inclines a little to the left) and the thoracic duct. To its **right side** is the root of the innominate artery, and higher up are the trachea and the inferior thyroid veins. To its **left side,** but on a posterior plane, are the left subclavian artery and the left vagus nerve; and, slightly overlapping it, the edge of the left pleura and lung.

FIG. 488.—ARTERIES OF THE HEAD AND NECK. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

In this case the external maxillary artery ends by inosculating with the infraorbital. The dorsal nasal branch of the ophthalmic is larger than usual (Cf. fig. 493.)



THE COMMON CAROTID ARTERY IN THE NECK

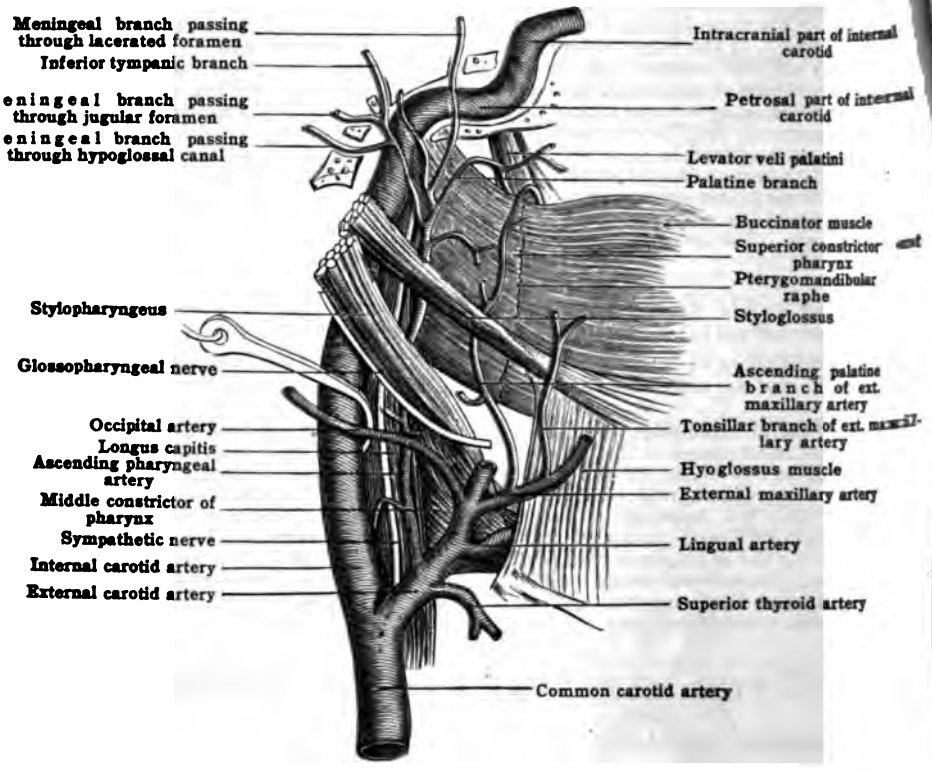
The **common carotid artery in the neck** extends from the sternoclavicular articulation to the upper border of the thyroid cartilage on a level with the fourth cervical vertebra, where it divides into the external and internal carotid arteries. A line drawn from the sternoclavicular joint to a point just behind the neck of the mandible would indicate its course. The artery is at first deeply placed beneath the sternomastoid, sternohyoid, and sternothyroid muscles, and at the level of the top of the sternum is only 2 cm. (¾ in.) distant from its fellow

yngeal branch of the vagus nerve, a portion of the parotid gland, and the stylohyoid ligament. It measures about 6.5 cm. (2⅗ in.) in length.

Relations.—**In front,** in addition to the skin, superficial fascia, platysma, and deep fascia, it has the hypoglossal nerve, the lingual, common facial and posterior facial veins, the posterior belly of the digastric and stylohyoid muscles, the superior cervical lymphatic glands, branches of the facial nerve, and the parotid gland. The sternomastoid also overlaps it in the natural state of the parts. **Behind,** it is in relation with the internal carotid, from which it is separated by the styloglossus and stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, the stylohyoid ligament, and the parotid gland. The superior laryngeal nerve crosses behind both the external and internal carotid arteries. **Medially,** it is in relation with the hyoid bone, the pharyngeal wall, the ramus of the mandible, the stylomandibular ligament which separates it from the submaxillary gland, and the parotid gland. **Laterally,** in the first part of its course, it is in contact with the internal carotid artery.

The **branches of the external carotid** are usually given off in the following order, from below upward:—(1) Ascending pharyngeal; (2) superior thyroid; (3) lingual; (4) external maxillary (facial); (5) sternocleidomastoid; (6) occipital; (7) posterior auricular; (8) superficial temporal; (9) internal maxillary.

FIG. 490.—RIGHT ASCENDING PHARYNGEAL ARTERY. (Walsham.)
The internal carotid artery is hooked aside.



1. THE ASCENDING PHARYNGEAL ARTERY

The **ascending pharyngeal** artery [a. pharyngea **ascendens**] (**fig. 490**) is usually the first or second branch of the external carotid. **Occasionally it** comes off at the bifurcation of the common carotid from the **common carotid itself.** It is a long slender vessel which runs deeply seated up the neck **to the base** of the skull, having the walls of the pharynx and the tonsil **medially, the internal** carotid artery **laterally,** and the vertebral column, the **longus capitis** (**rectus** capitis anterior major), and the sympathetic nerve **posteriorly. In front it is** crossed by the styloglossus (fig. 490) and the stylopharyngeus **muscles and** the glossopharyngeal nerve.

BRANCHES OF THE ASCENDING PHARYNGEAL ARTERY

The branches of the ascending pharyngeal **artery are small** and variable. They supply the longus and rectus capitis muscles, the **upper cervical** sympathetic

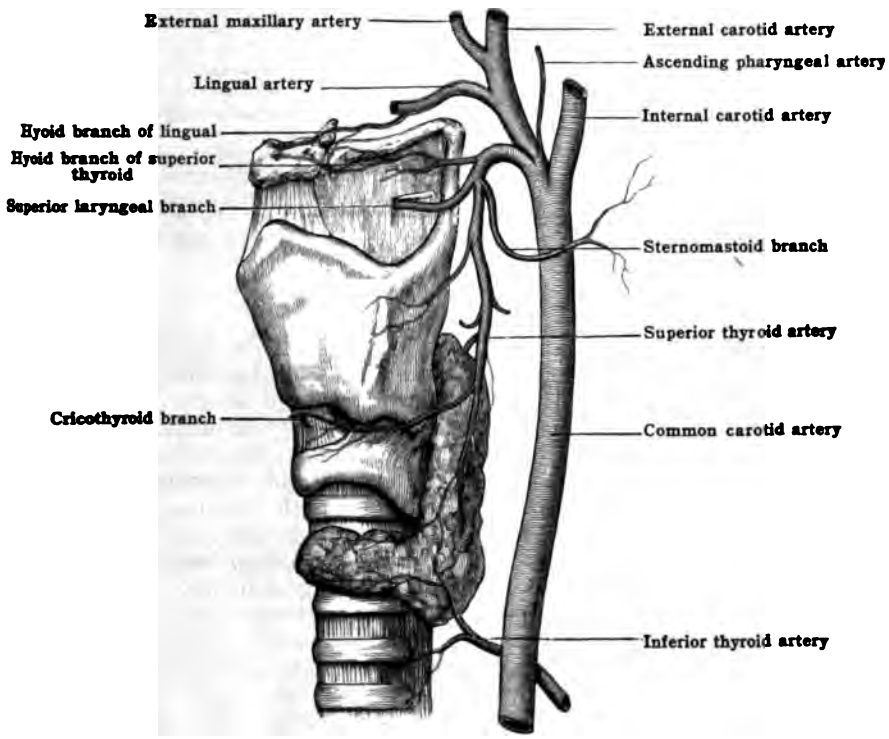
ganglion and adjacent lymph-nodes, as well as the pharynx, soft palate, ear, cranial nerves, and meninges.

The **pharyngeal** branches [rami pharyngei] supply the superior and middle constrictor muscles and the mucous membrane lining them. These vessels anastomose with branches of the superior thyroid. One branch (the **palatine**) passes over the upper edge of the superior constrictor to the soft palate and its muscles. This branch follows a course similar to that taken by the ascending palatine artery, and when the latter is small may take its place. It generally gives off small twigs to the auditory (Eustachian) tube and tonsil. The **inferior tympanic** artery [a. tympanica inferior] accompanies the tympanic branch of the glossopharyngeal nerve through the tympanic canaliculus into the tympanum, and anastomoses with the other tympanic arteries. The **posterior meningeal** artery [a. meningea posterior] is distributed to the membranes of the brain. Some twigs pass with the jugular vein through the jugular foramen into the cranium, and supply the dura mater in the posterior fossa of the skull. Others occasionally reach the same fossa through the hypoglossal (anterior condyloid) canal in company with the hypoglossal nerve; while others pass through the cartilage of the lacerated foramen and supply the middle fossa of the skull.

2. THE SUPERIOR THYROID ARTERY

The **superior thyroid** artery [a. thyreoidea superior] (figs. 488, 491) arises from the front of the external carotid a little above the origin of that vessel, and, coursing forward, medially, and then downward, in a tortuous manner, supplies

FIG. 491.—SCHEME OF LEFT SUPERIOR THYROID ARTERY. (Walsham.)



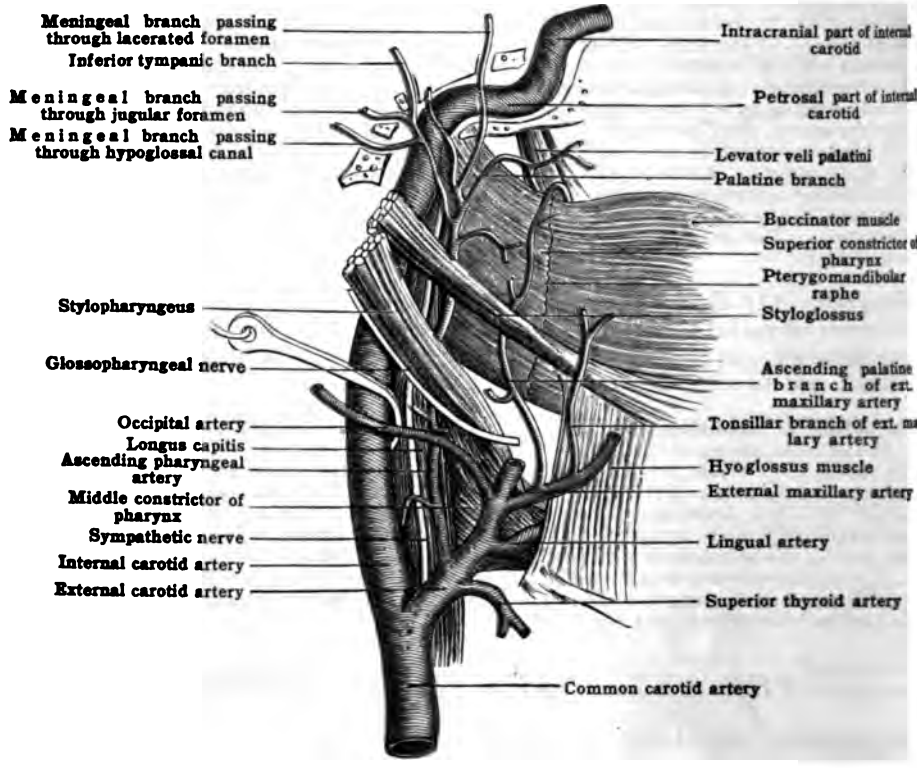
the depressor muscles of the hyoid bone, the larynx, the thyroid gland, and the lower part of the pharynx. The artery at first runs forward and a little upward, just beneath the greater cornu of the hyoid bone. In this part of its course it lies in the superior carotid triangle, and is quite superficial, being covered only with the integument, fascia, and platysma. It next turns downward, and passes beneath the omohyoid, sternohyoid, and sternothyroid muscles, and ends at the upper part of the thyroid gland in the terminal glandular branches. The superior thyroid vein passes beneath the artery on its way to the internal jugular vein. The superior thyroid is the artery most commonly divided in cases of suicidal wounds of the throat.

yngeal branch of the vagus nerve, a portion of the parotid gland, and the stylohyoid ligament. It measures about 6.5 cm. ($2\frac{3}{5}$ in.) in length.

Relations.—**In front,** in addition to the skin, superficial fascia, platysma, and deep fascia, it has the hypoglossal nerve, the lingual, common facial and posterior facial veins, the posterior belly of the digastric and stylohyoid muscles, the superior cervical lymphatic glands, branches of the facial nerve, and the parotid gland. The sternomastoid also overlaps it in the natural state of the parts. **Behind,** it is in relation with the internal carotid, from which it is separated by the styloglossus and stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, the stylohyoid ligament, and the parotid gland. The superior laryngeal nerve crosses behind both the external and internal carotid arteries. **Medially,** it is in relation with the hyoid bone, the pharyngeal wall, the ramus of the mandible, the stylomandibular ligament which separates it from the submaxillary gland, and the parotid gland. **Laterally,** in the first part of its course, it is in contact with the internal carotid artery.

The branches of the external carotid are usually given off in the following order, from below upward:—(1) Ascending pharyngeal; (2) superior thyroid; (3) lingual; (4) external maxillary (facial); (5) sternocleidomastoid; (6) occipital; (7) posterior auricular; (8) superficial temporal; (9) internal maxillary.

FIG. 490.—RIGHT ASCENDING PHARYNGEAL ARTERY. (Walsham.)
The internal carotid artery is hooked aside.



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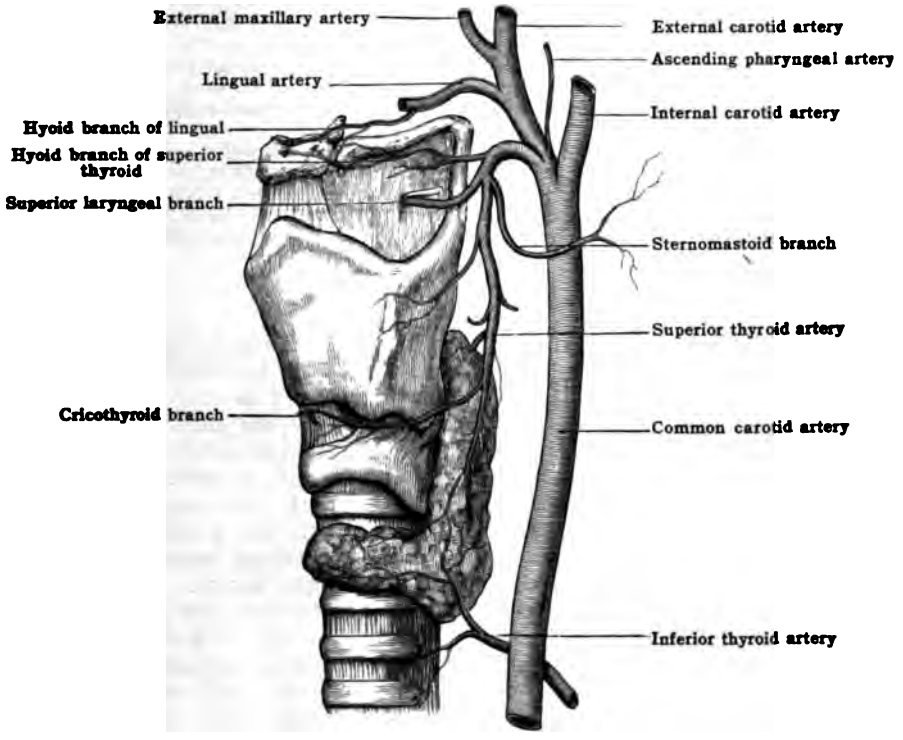
The **superior thyroid** artery [a. thyreoidea superior] (figs. 488, 491) arises from the front of the external carotid a little above the origin of that vessel, and, coursing forward, medially, and then downward, in a tortuous manner, supplies

FIG. 491.—SCHEME OF LEFT SUPERIOR THYROID ARTERY. (Walsham.)



the depressor muscles of the hyoid bone, the larynx, the thyroid gland, and the lower part of the pharynx. The artery at first runs forward and a little upward, just beneath the greater cornu of the hyoid bone. In this part of its course it lies in the superior carotid triangle, and is quite superficial, being covered only with the integument, fascia, and platysma. It next turns downward, and passes beneath the omohyoid, sternohyoid, and sternothyroid muscles, and ends at the upper part of the thyroid gland in the terminal glandular branches. The superior thyroid vein passes beneath the artery on its way to the internal jugular vein. The superior thyroid is the artery most commonly divided in cases of suicidal wounds of the throat.

Branches of the Superior Thyroid Artery

The named **branches of the superior thyroid artery** are:—(1) The hyoid; (2) the sternomastoid; (3) the superior laryngeal; (4) the cricothyroid; (5) anterior; (6) posterior; and (7) glandular.

(1) The **hyoid** branch [ramus hyoideus] is usually a small twig which passes along the lower border of the hyoid bone, lying on the thyrohyoid membrane under cover of the thyrohyoid and sternohyoid muscles. It supplies the infrahyoid bursa and the thyrohyoid muscle, and anastomoses with its fellow of the opposite side, and with the hyoid branch of the lingual. When the latter artery is small, the hyoid branch of the superior thyroid is usually comparatively large, and *vice versa*.

(2) The **sternomastoid** branch [ramus sternocleidomastoideus] (fig. 491) courses downward and backward across the carotid sheath, and entering the sternomastoid supplies the middle portion of that muscle. It gives off slender twigs to the thyrohyoid, sternohyoid, and omohyoid muscles, and the platysma and integuments covering it. At times the vessel arises directly from the external carotid. It lies usually somewhere in the upper part of the incision for tying the common carotid above the omohyoid muscle.

(3) The **superior laryngeal** artery [a. laryngea superior] (fig. 491) passes medially beneath the thyrohyoid muscle, and, perforating the thyrohyoid membrane along with the internal branch of the superior laryngeal nerve, supplies the intrinsic muscles and mucous lining of the larynx. Its further distribution within the larynx is given with the description of that organ. This branch sometimes arises from the external caroid direct. It may enter the larynx by passing through a foramen in the thyroid cartilage.

(4) The **cricothyroid** [ramus cricothyreoideus] passes across the cricothyroid membrane immediately beneath the lower border of the thyroid cartilage. It anastomoses with its fellow of the opposite side, and usually sends a small branch through the membrane into the interior of the larynx. Occasionally a considerable twig descends over the cricoid cartilage to enter the isthmus of the thyroid gland. The cricothyroid has, however, frequently been seen of comparatively large size—once as large as the radial, and crossing the membrane obliquely. In order to avoid injuring the cricothyroid artery in the operation of laryngotomy, it is usual, if the operation has to be done in a hurry to make the incision through the cricothyroid membrane in a transverse direction, and as near to the cricoid cartilage as possible.

(5) The **anterior** branch [ramus anterior] is the terminal branch supplying the isthmus and the neighboring part of the lateral lobe of the thyroid gland.

(6) The **posterior** branch [ramus posterior], also terminal, supplies the posterior part of the lateral lobe, and sends branches to the inferior constrictor of the pharynx and to the esophagus. It anastomoses with the ascending branches of the inferior thyroid artery.

(7) The **glandular** branches [rami glandulares] are the ultimate twigs, arising from the anterior and posterior terminal branches, for the supply of the thyroid gland.

3. THE LINGUAL ARTERY

The **lingual** artery [a. lingualis] (fig. 492) arises from the front of the external carotid, between the superior thyroid and external maxillary (facial) arteries, often as a common trunk with the latter vessel, and nearly opposite or a little below the greater cornu of the hyoid bone. It may, for purposes of description, be divided into three portions: the **first,** or **oblique,** extends from its origin to the posterior edge of the hyoglossus muscle; the **second,** or **horizontal,** lies beneath the hyoglossus; the **third,** or **ascending,** beneath the tongue. The **first** or **oblique portion** is situated in the superior carotid triangle, and is superficial, being covered merely by the integument, platysma, and deep fascia. Here it lies on the middle constrictor muscle and superior laryngeal nerve. After ascending a short distance, it curves downward and forward beneath the hypoglossal nerve, and, in the **second part of its course,** runs horizontally along the upper border of the hyoid bone, beneath the hyoglossus, by which it is separated from the hypoglossal nerve and its vena comitans, and the posterior belly of the digastric and the stylohyoid muscles. In this part of its course it lies successively on the middle constrictor of the pharynx and the genioglossus, covered by the hyoglossus muscle. In the **third part of its course** it ascends tortuously, usually beneath the anterior margin of the hyoglossus, to the lower surface of the tongue, and is thence continued to the tip of that structure lying between the lingualis and the genioglossus muscles. From the anterior edge of the hyoglossus to its termination it is covered only by the mucous membrane of the lower surface of the tongue. The lingual artery is accompanied by small venæ comitantes.

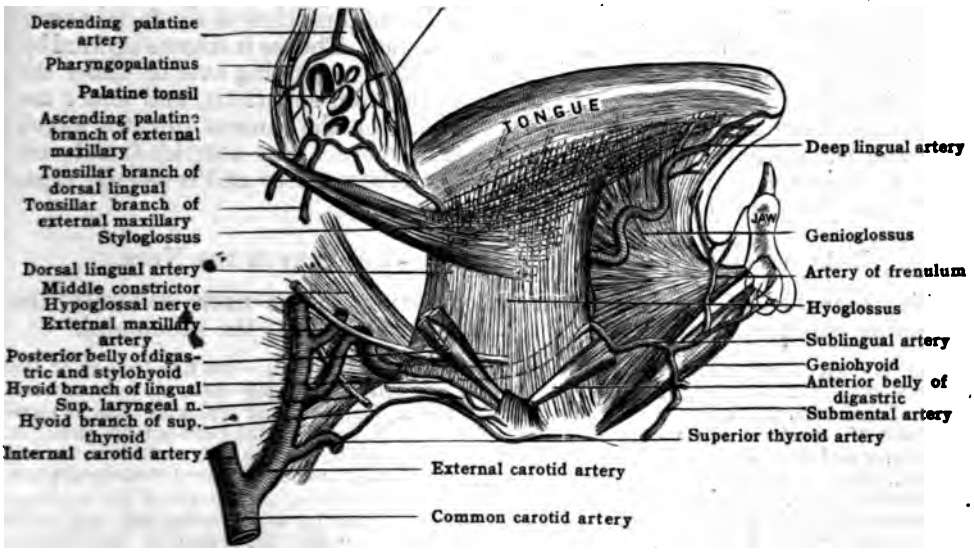
Branches of the Lingual Artery

The named **branches of the lingual artery** are:—(1) The hyoid; (2) the dorsal lingual; (3) the sublingual; and (4) the deep lingual (ranine).

(1) **The hyoid branch** [ramus hyoideus] (fig. 492) is a small vessel which arises from the first part of the lingual, and courses along the upper border of the hyoid bone, superficial to the hyoglossus, but beneath the insertion of the posterior belly of the digastric and the stylohyoid. It anastomoses with its fellow of the opposite side, and with the hyoid branch of the superior thyroid artery, and supplies the contiguous muscles.

(2) **The dorsalis linguæ** (fig. 492) arises from the second portion of the lingual artery, usually under cover of the posterior edge of the hyoglossus muscle. It ascends to the back of the dorsum of the tongue, and, dividing into branches, supplies the mucous membrane on each side of the V formed by the vallate papillæ. It also supplies the palatine arches (pillars) and the tonsil, where it anastomoses with the other faucial and tonsillar arteries. Instead of a single artery, as above described, there may be several small vessels running directly to the parts mentioned. The artery anastomoses in the mucous membrane by very small branches with the vessel of the opposite side; but the anastomosis is so minute that when one lingual artery is injected the injection merely passes across to the opposite side at the tip of the tongue; and when the tongue is divided accurately in the middle line, as in the removal of one-half of that organ, practically no hemorrhage occurs.

FIG. 492.—SCHEME OF THE RIGHT LINGUAL ARTERY. (Walsham.)



(3) **The sublingual artery** [a. sublingualis] (fig. 492) usually comes off from the lingual at the anterior margin of the hyoglossus. It passes beneath the mylohyoid to the sublingual gland, which it supplies, and finally it usually anastomoses with the submental artery, a branch of the external maxillary (facial). It also supplies branches to the side of the tongue, and gives off a terminal twig, which anastomoses beneath the mucous membrane of the floor of the mouth (to which it also gives twigs) with the artery of the opposite side. The artery of the frenulum is usually derived from this vessel (fig. 492).

(4) **The deep lingual** [a. profunda linguæ] or ranine artery, the termination of the lingual, courses forward beneath the mucous membrane, on the lower surface of the tongue, to the tip. It lies upon the lateral side of the genioglossus, between that muscle and the inferior lingualis, and is accompanied by the lingual vein and terminal branch of the lingual nerve. It follows a very tortuous course, so that it is not stretched when the tongue is protruded. Branches are given off from it to the contiguous muscles and mucous membrane. Near the tip of the tongue it communicates with its fellow of the opposite side.

4. THE EXTERNAL MAXILLARY (FACIAL) ARTERY

The external maxillary or facial artery [a. maxillaris externa] (figs. 488, 493) arises immediately above the lingual from the fore part of the external carotid, at times as a common trunk with the lingual. It courses forward and upward in a tortuous manner to the mandible, and, passing over the body of that bone at the anterior edge of the masseter muscle, winds obliquely upward and forward over the face to the medial angle of the eye, where it anastomoses, under the name of the **angular artery,** with the dorsal nasal branch of the ophthalmic. It is usually described as having two portions—the cervical and the facial.

The cervical portion (fig. 493) ascends tortuously from its origin from the external carotid upward and forward beneath the posterior belly of the digas-

tric and beneath the stylohyoid muscle and the hypoglossal nerve. Then, making a turn, it runs horizontally forward for a short way beneath the jaw, either imbedded in, or lying under the submaxillary gland with the mylohyoid and styloglossus beneath it. On leaving the cover of the gland it forms a loop passing first downward and then upward over the lower border of the jaw immediately in front of the masseter muscle, where it is superficial, being merely covered by the integument and platysma.

Here it can be felt beating, and can be readily compressed. In the above course it lies in the posterior part of the submaxillary triangle, and, in addition to the structures already mentioned as crossing it, is covered by the skin, superficial fascia, and platysma, and by one or two submaxillary lymphatic nodes. The vein is separated from the artery by the submaxillary gland, the posterior belly of the digastric muscle, the stylohyoid muscle, and the hypoglossal nerve.

The **facial portion** (fig. 493) of the external maxillary artery ascends tortuously forward toward the angle of the mouth, passing under the platysma (risorius), the zygomatic muscle, the zygomatic head of the quadratus labii superioris (zygomaticus minor), and the zygomatic and buccal branches of the facial nerve. It here lies upon the jaw and the buccinator muscle. Thence it courses upward by the side of the nose toward the medial angle of the eye, passing over or under the infraorbital and angular heads of the quadratus labii superioris, and under the infraorbital branches of the facial nerve. It lies on the caninus (levator anguli oris) and the infraorbital branches of the fifth nerve. The anterior facial vein takes a straighter course than the external maxillary artery and is usually separated from the latter by the zygomatic muscle.

Branches of the External Maxillary Artery in the Neck

The **branches of the external maxillary artery in the neck** are:—(1) The ascending palatine; (2) the tonsillar; (3) the glandular; (4) the submental.

(1) **The ascending palatine** [a. palatina ascendens] (figs. 492, 493).—**the first branch of the** external maxillary, but often a distinct branch of the external carotid—**ascends between the** internal and external carotids, and then between the styloglossus **and stylopharyngeus muscles**, and on reaching the wall of the pharynx is continued upward **between the superior** constrictor and internal pterygoid muscles toward the base of the skull **as high as the levator veli** palatini, where it divides into two branches, a palatine and a tonsillar. **One of these branches, the palatine,** passes with the levator veli palatini over the curved upper **margin of the superior** constrictor to the soft palate. It anastomoses with its fellow of the **opposite side and with** the descending palatine branch of the internal maxillary, also with **the ascending pharyngeal,** which often to a great extent supplies the place of this artery. The other **branch, the tonsillar,** supplies the tonsil and the auditory (Eustachian) tube, anastomosing **with the tonsillar branch** of the external maxillary (facial) and ascending pharyngeal arteries. **The ascending palatine** artery supplies the muscles between which it runs on its way to the **palate.**

(2) The **tonsillar** branch [ramus tonsillaris] (fig. 493) ascends **between the styloglossus and** internal pterygoid muscles to the level of the tonsil, where it perfo**rates the superior constrictor** muscle of the pharynx, and ends in the tonsil, anastomosing with **the tonsillar branch of the** ascending palatine and with the other tonsillar arteries (fig. 492). **It gives branches also to the** root of the tongue.

(3) The **glandular** branches [rami glandulares] are distributed **to the submaxillary gland** as the artery is passing through or beneath that structure. **A small twig from one of these** branches usually supplies the submaxillary (Wharton's) duct.

(4) The **submental** artery [a. submentalis] (fig. 493) comes **off from the external maxillary** as the latter vessel lies under cover of the submaxillary gland, **and, passing forward on the** mylohyoid muscle between the base of the jaw and the anterior belly of **the digastricus, supplies** these structures and the overlying platysma and integuments. **It anastomoses with the sub**lingual artery.

Branches of the External Maxillary Artery on the Face

From the **lateral** or **concave** side of the artery **are given off branches which** supply the masseter muscle and anastomose with the **masseteric and buccinator** branches of the internal maxillary artery, the transverse **facial artery, and the** infraorbital arteries.

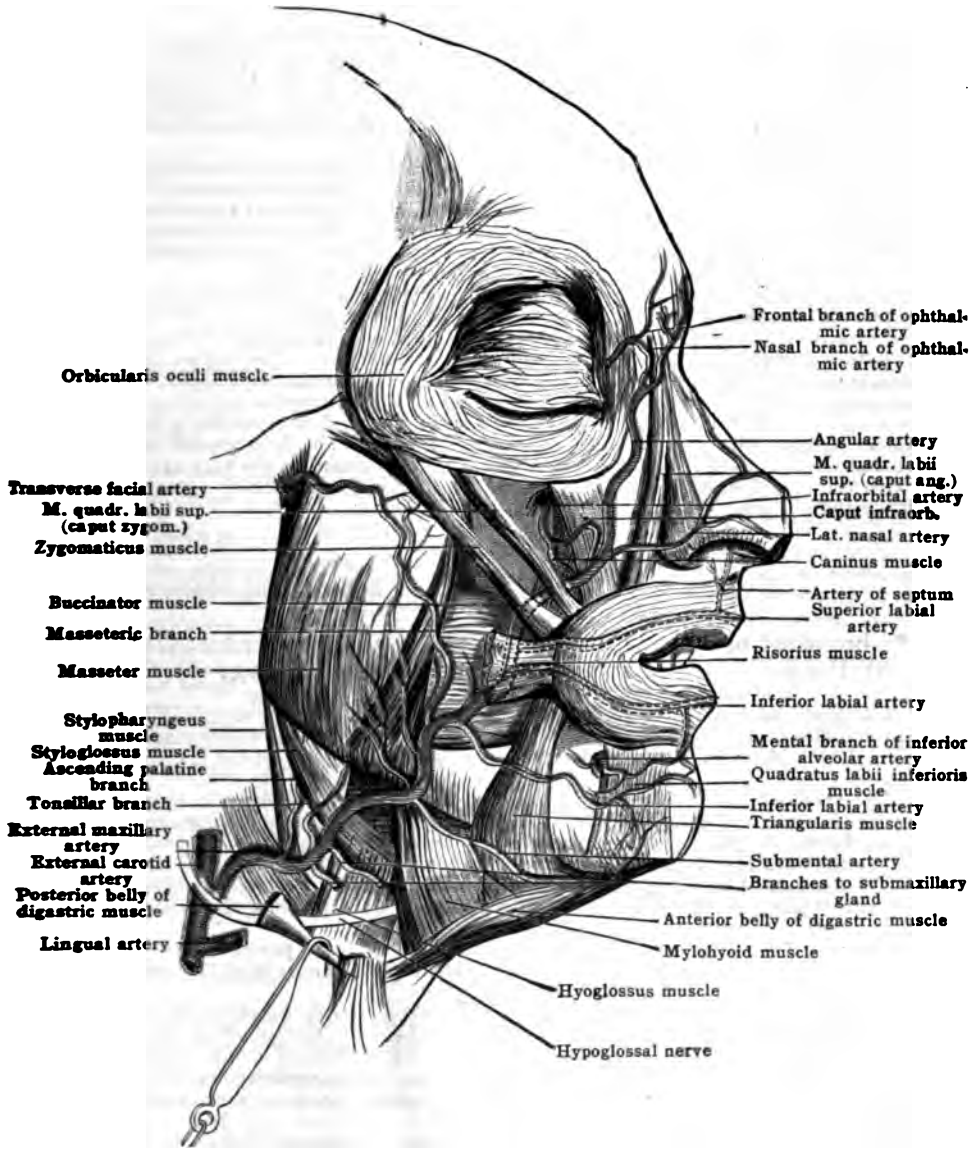
From the **medial** or **convex** side the following larger **and named vessels are** given off:—(1) The inferior labial; (2) the superior labial; **and (3) the angular.**

(1) The **inferior labial** artery [a. labialis inferior] arises at the **angle of the mouth (fig. 493)** and runs in the lower lip within the substance of the orbicularis oris, **close to the mucous mem**brane. It anastomoses with the artery of the other side. **Frequently an additional branch** passes from the external maxillary to the lower lip.

(2) The **superior labial** artery [a. labialis superior] arising from the external maxillary higher [illegible] the inferior (fig. 493), passes forward beneath the zygomaticus, and then, like the inferior [illegible], courses tortuously along the lower margin of the upper lip between the orbicularis oris and [illegible] mucous membrane, about 1.2 cm. (½ in.) from the junction of the mucous membrane and [illegible] skin. It is usually larger than the inferior labial. It anastomoses with its fellow of the [illegible]osite side, and gives off a small artery to the septum—**arteria septi nasi.** Compression of [illegible] vessel will sometimes control hemorrhage from the nose.

(3) The **angular** artery [a. angularis] (fig. 493) is the terminal branch of the external max[illegible]ry. It supplies the nose and anastomoses at the medial angle of the eye with the dorsal nasal [illegible]nch of the ophthalmic. It lies to the medial side of the lacrimal sac and supplies that [illegible]ecture and the lower part of the orbicularis oculi, beneath which a branch anastomoses with [illegible] infraorbital artery.

FIG. 493.—RIGHT EXTERNAL MAXILLARY ARTERY AND BRANCHES. (Walsham.)



5. THE STERNOCLEIDOMASTOID ARTERY

The **sternocleidomastoid** artery [a. sternocleidomastoidea] arises from the posterior side of the external carotid at the point where the carotid is crossed by the digastric muscle. It is distributed to the sternocleidomastoid muscle, and is frequently represented by one *of the muscular* branches of the occipital artery.

6. THE OCCIPITAL ARTERY

The **occipital** artery [a. occipitalis] (fig. 494) is usually a vessel of considerable size. It comes off from the posterior part of the external carotid opposite the external maxillary (facial), or else a little higher than that vessel. It then runs upward and backward to the interval between the mastoid process of the temporal bone and transverse process of the atlas, and, after running horizontally backward in a groove on the mastoid portion of the temporal bone, again turns upward, and ends by ramifying in the scalp over the back of the skull, extending as far forward as the vertex.

The vessel may be divided into three parts—viz., that anterior to the sternomastoid muscle; that beneath the sternomastoid; and that posterior to the sternomastoid.

In the **first part of its course** the occipital artery is covered by the integument and fascia, and is more or less overlapped by the posterior belly of the digastric muscle, the parotid gland, and posterior facial (temporomaxillary) vein. It is crossed by the hypoglossal nerve as the latter winds forward over the carotid vessels to reach the tongue. It successively crosses in front of the internal carotid artery, the hypoglossal nerve, the vagus nerve, the internal jugular vein, and the spinal accessory nerve.

In the **second part of its course** it sinks deeply beneath the digastric muscle into the interval between the mastoid process of the temporal bone and the transverse process of the atlas. It is here covered by the sternomastoid, splenius capitis, and longissimus capitis muscles and by the origin of the digastric; and lies, first on the rectus capitis lateralis, which separates it from the vertebral artery, then in a groove, the occipital groove, on the mastoid portion of the temporal bone, and then on the insertion of the superior oblique muscle.

In the **third part of its course** it enters the triangular interval formed by the diverging borders of the splenius capitis and the superior nuchal line of the occipital bone. Here it lies beneath the integuments and the aponeurosis uniting the occipital attachments of the sternomastoid and trapezius, and rests upon the semispinalis capitis (complexus) just before the insertion of that muscle into the occipital bone. In company with the greater occipital nerve, it perforates the aponeurosis, or less often the posterior belly of the epicranius (occipitofrontalis), and follows roughly, but in a tortuous course, the line of the lambdoid suture, lying between the integument and the cranial aponeurosis. In the scalp it divides into several large branches, which ramify over the back of the skull and reach as far forward as the vertex. They anastomose with the corresponding branches of the opposite side, and with the posterior auricular and the superficial temporal arteries.

Branches of the Occipital Artery (Fig. 494)

The branches of the occipital artery are:—(1) The muscular; (2) the meningeal; (3) the auricular; (4) the mastoid; (5) the descending; (6) the occipital.

(1) The **muscular** branches [rami musculares] (fig. 494) supply the sternocleidomastoid and adjacent muscles. One of these branches may take the place of the sternomastoid branch of the external carotid. The hypoglossal nerve then, as a rule, loops around it instead of around the occipital.

(2) The **meningeal** branches [rami meningei] (fig. 494), one or more in number, are long slender vessels which leave the occipital artery as it crosses the internal jugular vein and, ascending along the vessel, pass with it through the jugular or hypoglossal foramen, and are distributed to the dura mater lining the posterior fossa of the skull.

(3) The **auricular** branch [ramus auricularis] ascends over the mastoid process to the back of the ear, and supplies the auricle. It sometimes takes the place of the posterior auricular artery (fig. 494).

(4) The **mastoid** branch [ramus mastoideus] is a small twig that passes into the skull through the mastoid foramen, supplying the dura mater, the diploë, the walls of the transverse sinus, and the mastoid cells.

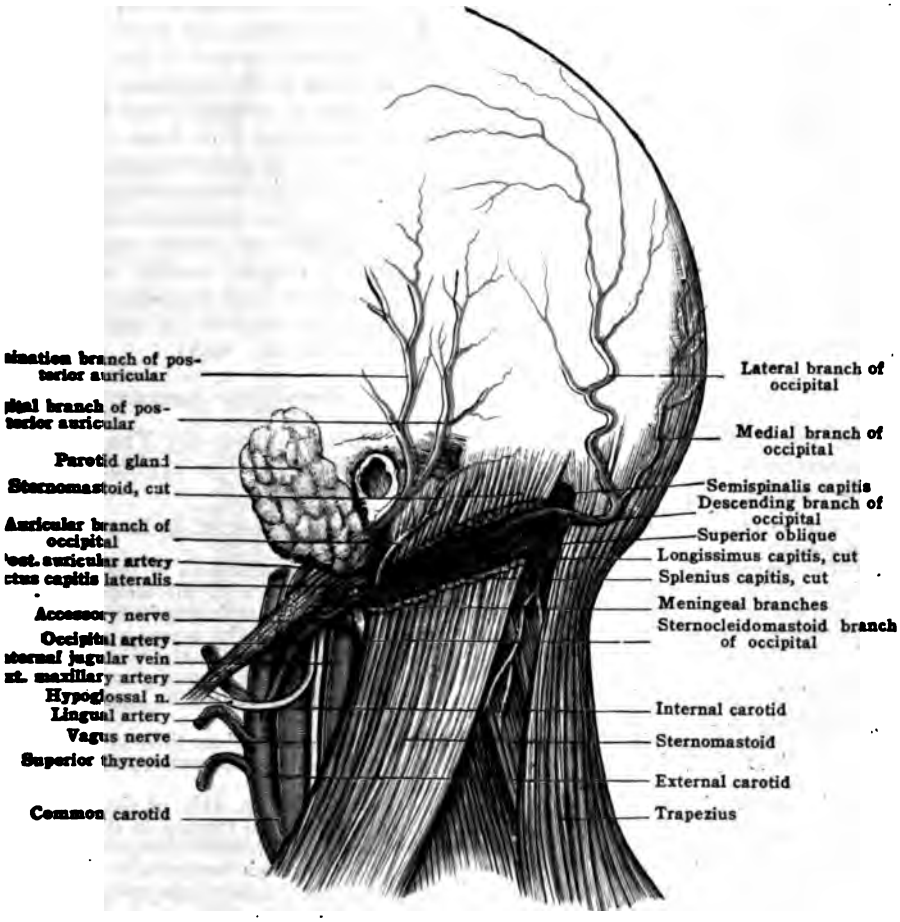
(5) The **descending** or **princeps cervicis** [ramus descendens] (fig. 494), the largest of the branches of the occipital, arises from that artery just before it emerges from beneath the splenius, and, descending for a short distance between the splenius and semispinalis capitis (complexus), divides into a superficial and a deep branch. The **superficial branch** perforates the splenius, supplies branches to the trapezius, and anastomoses with the ascending branch of the transverse cervical artery. The **deep branch** passes downward between the semispinalis capitis (complexus) and colli, and anastomoses with the deep cervical branch of the costocervical trunk and with branches of the vertebral. The anastomoses between the above-mentioned arteries form important collateral channels after ligature of the common carotid and subclavian arteries (fig. 489).

(6) The **occipital** or **terminal** branches [rami occipitales] (fig. 494), usually two in number, named from their position medial and lateral, ramify over the scalp, and have already been described. The medial branch generally gives off a twig which enters the parietal foramen (parietal artery) and is distributed to the dura mater. The occipital artery may also give off the stylomastoid, the posterior auricular, or the ascending pharyngeal arteries.

7. THE POSTERIOR AURICULAR ARTERY

he posterior auricular artery [a. auricularis posterior] (fig. 494) arises from osterior part of the external carotid artery, usually immediately above the rior belly of the digastric, about the level of the tip of the styloid process. sionally it arises under cover of the digastric, quite close to, or as a common k with, or as a branch of, the occipital. It courses upward and backward in arotid gland to the notch between the margin of the external acoustic meatus the mastoid process, where it divides into branches. In this course it rests he styloid process, crosses the accessory nerve, and is crossed by the facial e.

FIG. 494.—LEFT OCCIPITAL AND POSTERIOR AURICULAR ARTERIES. (Walsham.)



BRANCHES OF THE POSTERIOR AURICULAR ARTERY

he branches of the posterior auricular artery are:—(1) the stylomastoid; (2) auricular; (3) the occipital (fig. 494).

he posterior auricular also gives branches to the parotid gland and the adjacent muscles, ly, the posterior belly of the digastric, the stylohyoid, and auricularis posterior (retrahens n).

) **The stylomastoid artery** [a. stylomastoidea] comes off from the posterior auricular r just before it reaches the notch between the margin of the external acoustic meatus he mastoid process, and, following the facial nerve upward, enters the stylomastoid fora- in the temporal bone. In the facial canal (aqueduct of Fallopius) it gives off the following d twigs:—(*a*) **meatal,** to the external acoustic meatus; (*b*) **mastoid** [rami mastoidei], to astoid cells and tympanic antrum; (*c*) **stapedic** [ramus stapedius], which runs forward to tapedius muscle; (*d*) **posterior tympanic** [a. tympanica posterior], which anastomoses with nterior tympanic branch of the internal maxillary, forming with it in the fetus a vascular around the membrana tympani; (*e*) **vestibular,** to the vestibule and semicircular canals; *f*) **terminal,** a *small twig which leaves the facial* canal (by the hiatus) with the great super-

ficial petrosal nerve, and anastomoses with the superior petrosal branch of the middle meningeal artery.

(2) The **auricular** branch [ramus auricularis] passes upward behind the ear and beneath the auricularis posterior (retrahens aurem), supplying the medial surface of the pinna and adjacent skin. It anastomoses with the posterior branch of the superficial temporal artery. The branches to the pinna not only supply the back of that structure, but some perforate the cartilage, and others turn over its free margin to supply the lateral surface; there they anastomose with the anterior auricular branches from the temporal.

(3) The **occipital** branch [ramus occipitalis] passes upward and backward, crossing the aponeurotic insertion of the sternomastoid muscle. It gives a branch to the posterior belly of the epicranius (occipitofrontalis), and anastomoses with the occipital artery.

8. THE SUPERFICIAL TEMPORAL ARTERY

The **superficial temporal** artery [a. temporalis superficialis] (fig. 488), is the smaller of the two terminal divisions of the external carotid, though apparently the direct continuation of that vessel. It arises opposite the neck of the mandible and, under cover of the parotid gland, passes upward in the interval between the condyle and the external acoustic meatus to the zygoma, lying on the capsule of the temporomandibular joint. Thence it ascends over the posterior zygomatic root and the temporal aponeurosis for about 4 or 5 cm. ($1\frac{1}{2}$ or 2 in.), and there divides into frontal and parietal branches. It is surrounded by a dense plexus of sympathetic nerves, and is accompanied by the auriculotemporal nerve, which lies beneath and generally a little behind it. It is crossed by the temporal and zygomatic branches of the facial nerve, and by the auricularis anterior (attrahens aurem) muscle. As it crosses the zygoma it can be readily felt pulsating immediately in front of the auricle, and in this situation can be compressed against the bone. It is here quite superficial, being merely covered by the integuments and a delicate prolongation from the cervical fascia (fig. 488).

Branches of the Superficial Temporal Artery

The **branches of the superficial temporal** artery are:—(1) The parotid; (2) the transverse facial; (3) the anterior auricular; (4) the zygomatico-orbital; (5) the middle temporal; (6) the frontal; (7) the parietal.

(1) The **parotid** branches [rami parotidei] are small twigs given off in the substance of the parotid gland.

(2) The **transverse facial** [a. transversa faciei] is the largest branch of the temporal. It sometimes arises from the external carotid as a common trunk with the temporal. It is at first deeply seated in the substance of the parotid gland, but soon emerging from the upper part of the anterior border of the gland, courses transversely across the masseter muscle about a finger's breadth below the zygoma. The parotid duct runs below it, and the zygomatic (infraorbital) branches of the facial nerve above it. It supplies the parotid gland, the masseter muscle, and the skin of the face, and anastomoses with the infraorbital, the buccal, and the external maxillary (facial) arteries.

(3) The **anterior auricular** branches [rami auriculares anteriores] are three or four in number and supply the tragus, the pinna, and the lobule of the ear, and to some extent the external acoustic meatus.

(4) The **zygomatico-orbital** artery [a. zygomaticoorbitalis] (fig. 448), at times a branch of the deep temporal, passes forward along the upper border of the zygoma in the fat between the superficial and deep layers of the temporal aponeurosis, and, after giving branches to the orbicularis oculi, sends one or more twigs into the orbit through foramina in the zygomatic (malar) bone to anastomose with the lacrimal and palpebral branches of the ophthalmic.

(5) The **middle temporal** artery [a. temporalis media] (fig. 497), arises just above the zygoma, and, perforating the temporal aponeurosis and temporal muscle, ascends on the squamous portion of the temporal bone, and anastomoses with the posterior deep temporal artery.

(6) The **frontal** or **anterior terminal** branch [ramus frontalis] ramifies tortuously in an upward and forward direction over the front part of the skull. It lies first between the skin and temporal fascia and then between the skin and epicranial aponeurosis. It supplies the anterior belly of the epicranius (occipitofrontalis) and the orbicularis oculi muscles, and anastomoses with the supraorbital and frontal branches of the ophthalmic, and with the corresponding artery of the opposite side. The secondary branches given off from this vessel to the scalp run from before backward.

(7) The **parietal** or **posterior terminal** branch [ramus parietalis] ramifies on the side of the head between the skin and temporal fascia. Its branches anastomose, in front with the anterior terminal branch; behind, with the posterior auricular and occipital arteries; and above, across the vertex of the skull, with the corresponding artery of the opposite side.

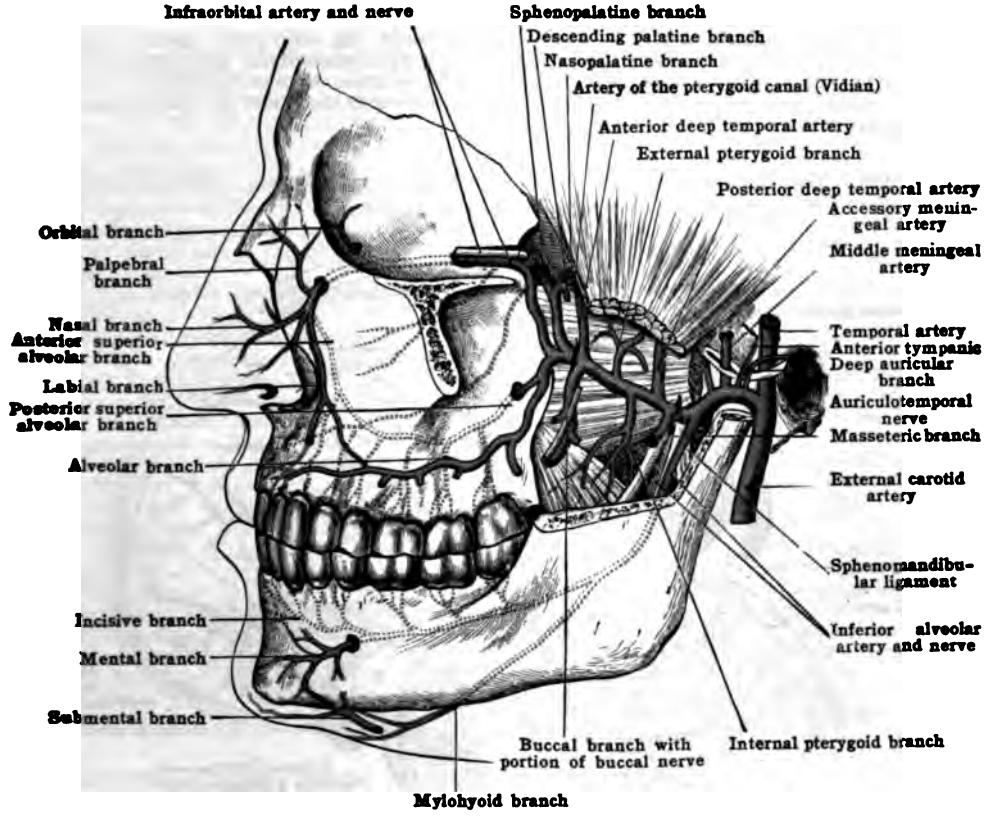
9. THE INTERNAL MAXILLARY ARTERY

The **internal maxillary** artery [a. maxillaris interna] (fig. 495) is the larger of the two terminal divisions of the external carotid. It arises opposite the neck of

mandible in the substance of the parotid gland, and, passing first between the mandible and the sphenomandibular ligament and then between the external and internal pterygoid muscles, sinks deeply into the pterygopalatine (sphenomaxillary) fossa, and there breaks up into its terminal branches. It is divided for description into three portions: mandibular, pterygoid, and pterygopalatine.

(1) In the **first part of its course** (the **mandibular portion**) the artery lies between the neck of the mandible and the sphenomandibular ligament, taking a horizontal course forward, nearly parallel to and a little below the auriculotemporal nerve and the external pterygoid muscle. It is here embedded in the parotid gland, and usually crosses in front of the inferior alveolar (dental) nerve.

FIG. 495.—LEFT INTERNAL MAXILLARY ARTERY. (Walsham.)



(2) In the **second part of its course** (the **pterygoid portion**) the artery may be placed superficial or deep to the external pterygoid muscle. In the first case it passes between the two pterygoid muscles and the ramus of the jaw, and then turns upward over the lateral surface of the external pterygoid, medial to the temporal muscle, to reach the interval between the two heads of the external pterygoid, and sinks into the pterygopalatine fossa. In the second case it passes medially to the external pterygoid, and is covered by that muscle till it reaches the interval between its two heads, where, forming a projecting loop, it turns into the pterygopalatine fossa.

(3) In the **third part of its course** (the **pterygopalatine portion**) the artery lies in the pterygopalatine fossa beneath the maxillary division of the fifth nerve and in close relationship with the sphenopalatine (Meckel's) ganglion, and there breaks up into its terminal branches.

BRANCHES OF THE INTERNAL MAXILLARY ARTERY

The branches of the internal maxillary artery are:—

(A) **From the first part:**—(1) The deep auricular; (2) the anterior tympanic; (3) the middle meningeal; *(4) the inferior* alveolar (dental); (5) the accessory

meningeal (sometimes). All these vessels pass through bony or cartilaginous canals.

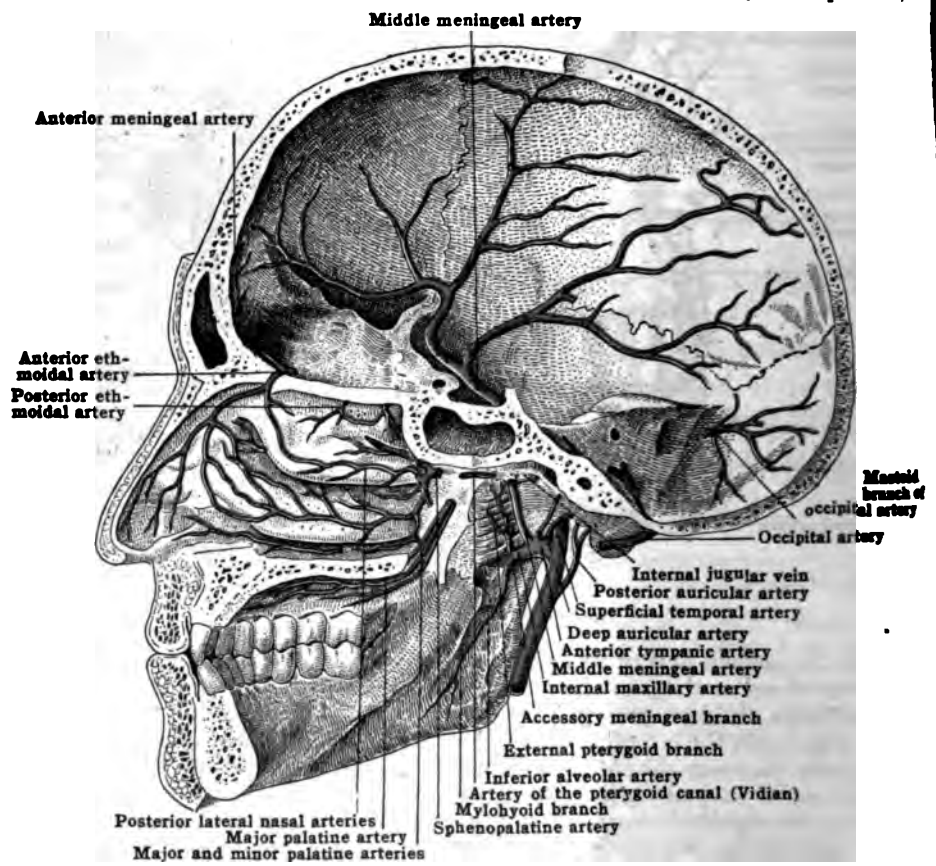
(B) **From the second part:**—(1) The masseteric; (2) the posterior deep temporal; (3) the pterygoid; (4) the buccal; and (5) the anterior deep temporal. All these branches supply muscles.

(C) **From the third part:**—(1) The posterior superior alveolar (dental); (2) the infraorbital; (3) the descending palatine; (4) the a. canalis pterygoidei or Vidian; and (5) the sphenopalatine. All these branches pass through bony canals.

Branches of the First Part of the Internal Maxillary Artery

(1) The **deep auricular** artery [a. auricularis profunda] (fig. 495) passes upward in the substance of the parotid gland behind the capsule of the temporomandibular joint, and, perforating the bony or cartilaginous wall of the external acoustic meatus, supplies the skin of that passage and the membrana tympani. It at times gives a branch to the joint as it passes behind the temporomandibular articular capsule.

Fig. 496.—The Middle Meningeal Artery within the Skull. (After Spalteholz.)



(2) The **anterior tympanic** artery [a. tympanica anterior] is a long slender vessel, which runs upward behind the condyle of the jaw to the petrotympanic (Glaserian) fissure, through which it passes to the interior of the tympanum. Here it supplies the lining membrane of that cavity and anastomoses with the other tympanic arteries, forming with the posterior tympanic branch of the stylomastoid artery a vascular circle around the membrana tympani. This circle is more distinct in the fetus than in the adult.

(3) The **middle meningeal** artery [a. meningea media] is the largest branch of the internal maxillary artery. It comes off from the vessel as it lies between the sphenomandibular ligament and the ramus of the jaw, and under cover of the external pterygoid passes directly upward to the foramen spinosum, through which it enters the interior of the cranium. In this part of its course it is crossed by the chorda tympani nerve; and just before it enters the foramen *embraced by the* two heads of origin of the auriculotemporal nerve (fig. 495).

The trunk of the mandibular division of the fifth nerve, as it emerges from the foramen vale, lies in front of the artery. As the artery passes upward it is surrounded by filaments of he sympathetic nerve, and is accompanied by two veins. On entering the skull it ramifies etween the bone and dura mater, supplying both structures. It at first ascends for a short istance in a groove on the greater wing of the sphenoid, and then divides into two branches, an nterior and a posterior.

The **anterior branch** passes upward, in the groove on the greater wing of the sphenoid, on to the parietal bone at its anterior and inferior angle; at this spot the groove becomes deepened and often bridged over by a thin plate of bone, being converted for 6 to 12 mm. (¼ to ½ in.) or more into a distinct canal. The situation of the artery is here indicated on the exterior of the skull by a spot 3.7 cm. (1½ in.) behind, and about 2.5 cm. (1 in.) above, the zygomatic process of the frontal bone. The anterior branch is continued along the anterior border of the parietal bone nearly as far as the superior sagittal sinus, and gives off in its course, but especially posteriorly, large branches which ramify in an upward and backward direction in grooves on the parietal bone (fig. 496).

The **posterior branch** passes backward over the squamous portion of the temporal bone; and thence on to the parietal bone, behind the anterior branch. This branch and its collaterals extend upward as far as the sagittal sinus, and backward as far as the transverse (lateral) sinus.

In addition to its terminal anterior, and terminal posterior branches, the middle meningeal gives off:—(*a*) **Ganglionic** branches to the semilunar (Gasserian) ganglion and its sheath of dura mater. (*b*) **A superficial petrosal** branch [ramus petrosus superficialis], which enters the hiatus of the facial canal in company with the large superficial petrosal nerve and anastomoses with the terminal branch of the stylomastoid artery. (*c*) **A superior tympanic** artery [a. tympanica superior], which enters the canal for the tensor tympani, and supplies that muscle. (*d*) An **orbital** or **lacrimal** branch, which enters the orbit at the outermost part of the superior orbital (sphenoidal) fissure, or sometimes through a minute foramen, just lateral to that fissure, and anastomoses with the lacrimal branch of the ophthalmic; (*e*) **Anastomotic** or **perforating** branches which pierce the greater wing of the sphenoid bone, and anastomose with the deep temporal arteries.

(4) The **inferior alveolar** artery [a. alveolaris inferior] (fig. 495), arising from the internal maxillary as it lies between the sphenomandibular ligament and neck of the jaw, courses downward to the mandibular foramen, which it enters in company with, and a little behind and lateral to, the inferior alveolar nerve. It then passes along the canal in the interior of the bone, giving off branches to the molar, premolar, and canine teeth. On reaching the mental foramen it divides into two branches, the incisive and the mental. The incisive continues its course in the bone, supplies branches to the incisor teeth, and anastomoses with the artery of the opposite side. The **mental** branch [ramus mentalis] passes through the mental foramen in company with the mental branch of the inferior alveolar (dental) nerve, and emerges on the chin under cover of the quadratus labii inferioris. It anastomoses above with the inferior labial (coronary), and below with the submental, and also with the inferior labial. Near its origin the artery gives off (*a*) **a lingual** or **gustatory** branch which accompanies and supplies the lingual nerve, and ends in the mucous membrane of the mouth; and, just before it enters the mandibular (dental) foramen in the lower jaw, (*b*) **mylohyoid** branch [ramus mylohyoideus], which accompanies the nerve of that name along the groove in the lower jaw, and after supplying the mylohyoid muscle, anastomoses with the sublingual and submental arteries.

(5) **The accessory or small meningeal** branch [ramus meningeus accessoria] arises either from the internal maxillary a little in front of the middle meningeal, or as a branch of the latter itself. It passes upward along the course of the mandibular division of the fifth nerve, and, entering the skull through the foramen ovale, is distributed to the semilunar (Gasserian) ganglion, to the walls of the cavernous sinus and to the dura mater in the neigborhood.

Branches of the Second Part of the Internal Maxillary Artery

The branches of the second portion of the internal maxillary all supply muscles. They are: —(1) The masseteric; (2) the posterior deep temporal (3) the pterygoid ; (4) the buccal; and (5) the anterior deep temporal.

(1) The **masseteric** artery [a. masseterica] comes off from the internal maxillary as the latter is passing from between the neck of the jaw and the sphenomandibular ligament. It passes, with the masseteric nerve through the mandibular (sigmoid) notch in the mandible and supplies the masseter muscle. Some filaments perforate the muscle and anastomose with the transverse facial and with the masseteric branches of the external maxillary (facial).

(2) The **posterior deep temporal** artery [a. temporalis profunda posterior] arises, as a rule, from the internal maxillary in common with the masseteric, or a little beyond that branch. It passes upward beneath the temporal muscle in a slight groove on the anterior margin of the squamous portion of the temporal bone, supplying the temporal muscle, the pericranium and the external layer of the bone. It anastomoses with the other temporal arteries.

(3) The **pterygoid** branches [rami pterygoidei] are short trunks which pass into and supply the internal and external pterygoid muscles.

(4) The **buccal** artery [a. buccinatoria] (fig. 495) courses forward and downward with the buccal nerve to the buccinator muscle, lying in close contact with the medial side and anterior margin of the tendon of the temporal muscle and coronoid process of the lower jaw. It supplies the buccinator muscle and mucous membrane of the mouth, and anastomoses with the external maxillary (facial), transverse facial, and infraorbital arteries.

(5) The **anterior deep temporal** artery [a. temporalis profunda anterior] ascends beneath the temporal muscle in a slight groove on the greater wing of the sphenoid bone. It supplies the muscle, pericranium, and subjacent bone, and gives off small branches which pass through

minute foramina in the zygomatic (malar) bone. Some of these last branches enter the orbit and anastomose with the lacrimal artery; others emerge on the face and anastomose with the transverse facial artery.

Branches of the Third Part of the Internal Maxillary Artery

The branches of the third part of the internal maxillary artery, like those of the first part, all pass through bony canals. They are the following:—(1) The posterior superior alveolar (dental); (2) the infraorbital; (3) the descending palatine; (4) the artery of the pterygoid canal (Vidian); and (5) the sphenopalatine.

(1) The **posterior superior alveolar (dental)** artery [a. alveolaris superior posterior] arises from the internal maxillary as the latter is passing into the pterygopalatine (sphenomaxillary) fossa, and descends in a tortuous manner in a groove on the back of the body of the maxilla. It gives off branches to the maxillary sinus, to the molar and premolar teeth, the gums, and to the buccinator muscle.

(2) The **infraorbital** artery [a. infraorbitalis] arises from the internal maxillary, generally as a common trunk with posterior alveolar (dental). It then passes forward and a little upward through the pterygopalatine (sphenomaxillary) fossa; then forward in company with the infraorbital branch of the fifth nerve, first along the groove, and then through the canal in the orbital plate of the maxilla; and finally, emerging on the face at the infraorbital foramen, under cover of the quadratus labii superioris, is distributed to the structures forming the upper lip, the lower eyelid, the lacrimal sac, and the side of the nose. It anastomoses with the superior labial (coronary) and angular branches of the external maxillary (facial), with the nasal and lacrimal branches of the ophthalmic, and with the transverse facial. It gives off small branches supplying the fat of the orbit and the inferior rectus and inferior oblique muscles. The **anterior superior alveolar** branch [a. alveolaris superior anterior] passes downward through a groove in the anterior wall of the maxilla, together with the anterior alveolar branch of the infraorbital nerve, and supplies branches to the incisor and canine teeth and the mucous membrane of the maxillary sinus. It has also **nasal** branches which pass through the foramina in the nasal process of the maxilla.

(3) The **descending palatine** artery [a. palatina descendens] descends in the pterygopalatine canal with the anterior palatine branch of the sphenopalatine ganglion. On emerging on the palate at the greater (posterior) palatine foramen, it divides into the following branches —(*a*) The **major palatine** artery [a. palatina major], which courses forward in the mucoperiosteum at the junction of the hard palate with the alveolar process as far as the incisive (anterior palatine) foramen, where it anastomoses with the sphenopalatine artery; and (*b*) **minor palatine** arteries [aa. palatinæ minores], which pass backward and downward into the soft palate, contributing to the supply of that structure, and anastomosing with the ascending palatine artery. After the operation for cleft palate, serious hemorrhage occasionally occurs from the major palatine artery. The foramen is situated a little behind, and medial to, the last molar tooth, and almost immediately in front of the hamular process (fig. 496).

(4) The **arteria canalis pterygoidei or Vidian** artery is a long slender branch which passes backward through the pterygoid (Vidian) canal in company with the nerve of the same name into the cartilage of the lacerated foramen. It gives off branches which supply the roof of the pharynx, and anastomose with the ascending pharyngeal and sphenopalatine arteries; also a branch which is distributed to the auditory (Eustachian) tube; and one which enters the tympanum, and anastomoses with the other tympanic arteries.

(5) The **sphenopalatine** [a. sphenopalatina], the terminal branch of the internal maxillary, passes with the nasopalatine branch of the sphenopalatine ganglion from the pterygopalatine (sphenomaxillary) fossa into the nose through the sphenopalatine foramen. Crossing the roof of the nose in the mucoperiosteum, it passes on to the septum, and then runs forward and downward in a groove on the vomer toward the incisive (anterior palatine) foramen, where it anastomoses with the major palatine artery, which enters the nose through the lateral compartment of that foramen (the canal of Stenson). In this course it gives off branches to the roof and contiguous portions of the pharynx, and to the sphenoidal cells. It has also **posterior lateral nasal** branches [aa. nasales post. laterales], which ramify over the nasal conchæ (turbinate bones) and lateral walls of the nose, and give twigs to the ethmoidal and frontal sinuses and the lining membrane of the maxillary sinus; and **posterior septal** branches [aa. nasales post. septi], which run upward and forward, giving small twigs to the mucous membrane covering the upper part of the septum, and which pass through the cribriform plate of the ethmoid and anastomose with the ethmoidal arteries (perforating or meningeal branches).

THE INTERNAL CAROTID ARTERY

The **internal carotid** artery [a. carotis interna] (figs. 497 and 498) arises with the external carotid at the bifurcation of the common carotid, opposite the upper border of the thyroid cartilage, on a level with the fourth cervical vertebra. It is at first placed a little laterally to the external carotid, but as it ascends in the neck the external carotid becomes more superficially placed, in front of the internal. The internal carotid passes up the neck, in front of the transverse processes of the upper cervical vertebræ, lying upon the longus capitis (rectus capitis ant. major), to the carotid foramen, thence through the carotid canal in the petrous portion of the temporal bone. It makes at first a forward and medial

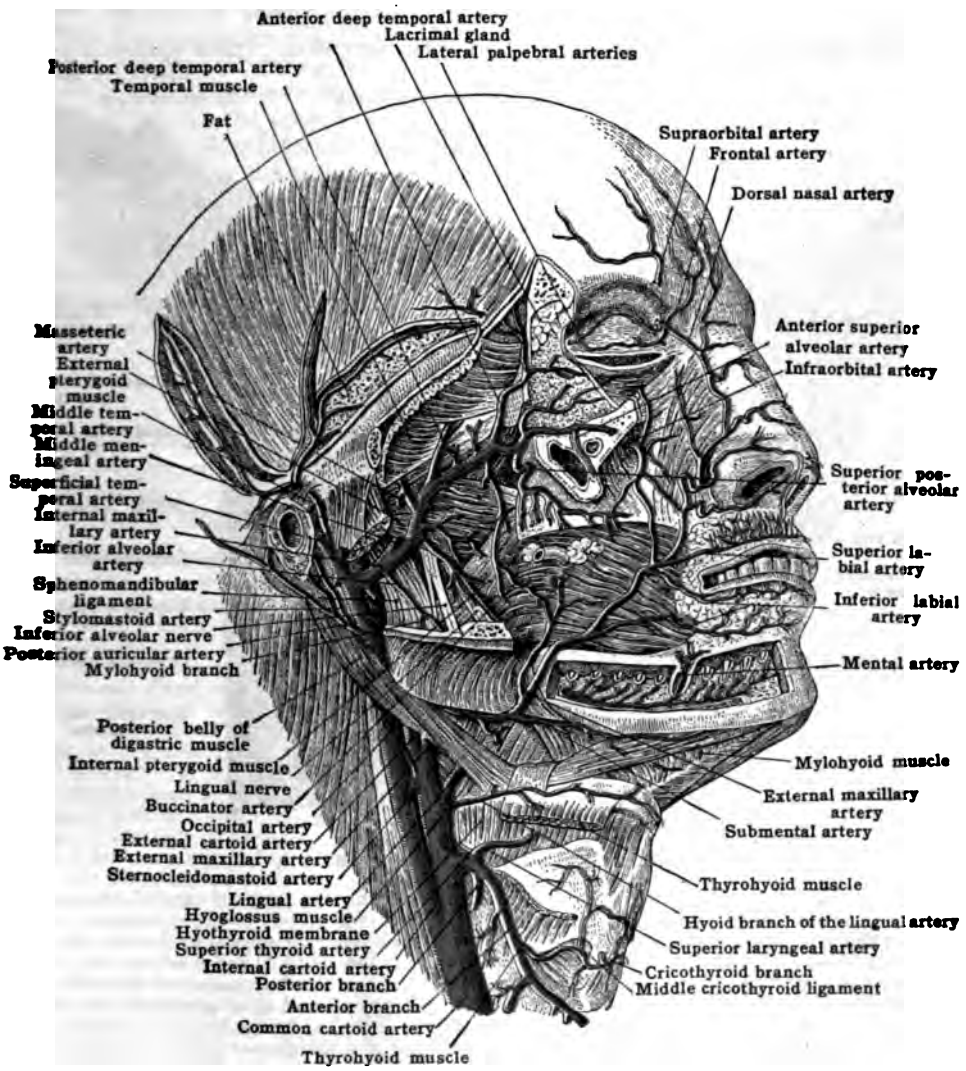
turn and then a second turn upward, and enters the cranium through the foramen lacerum. Within the cranium, it makes a sigmoid curve on the side of the body of the sphenoid bone, and terminates, after perforating the dura mater, by dividing opposite the anterior clinoid process, in the lateral fissure (fissure of Sylvius), into the anterior and middle cerebral arteries.

In its course up the neck it often forms one or more curves, especially in old people. Between the internal and the external carotids, at their angle of divergence, is situated the carotid body or gland [glomus caroticum].

1. The Cervical Portion

Relations.—In the neck (fig. 497) the artery is at first comparatively superficial, having in front of it, as it lies in the superior carotid triangle, the skin, superficial fascia, platysma and

Fig. 497.—The Carotid Arteries. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



deep fascia, and the overlapping edge of the sternomastoid muscle. Higher up, as it sinks beneath the parotid gland, it becomes deeply placed, and is crossed by the posterior belly of the digastric and stylohyoid muscles, the hypoglossal nerve, and the occipital and posterior auricular arteries. Still higher it is separated from the external carotid artery, which here gets in front of it, by the styloglossus and stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, and by the stylohyoid ligament.

Behind, it lies upon the longus capitis (rectus capitis anticus major), which separates it from the transverse processes of the three upper cervical vertebræ, on the superior cervical

ganglion of the sympathetic nerve, and on the vagus nerve. Near the base of the skull, the hypoglossal, vagus, glossopharyngeal, and accessory nerves cross obliquely behind it, and separate it from the internal jugular vein, which, as the artery is about to enter the carotid canal, also forms one of its posterior relations.

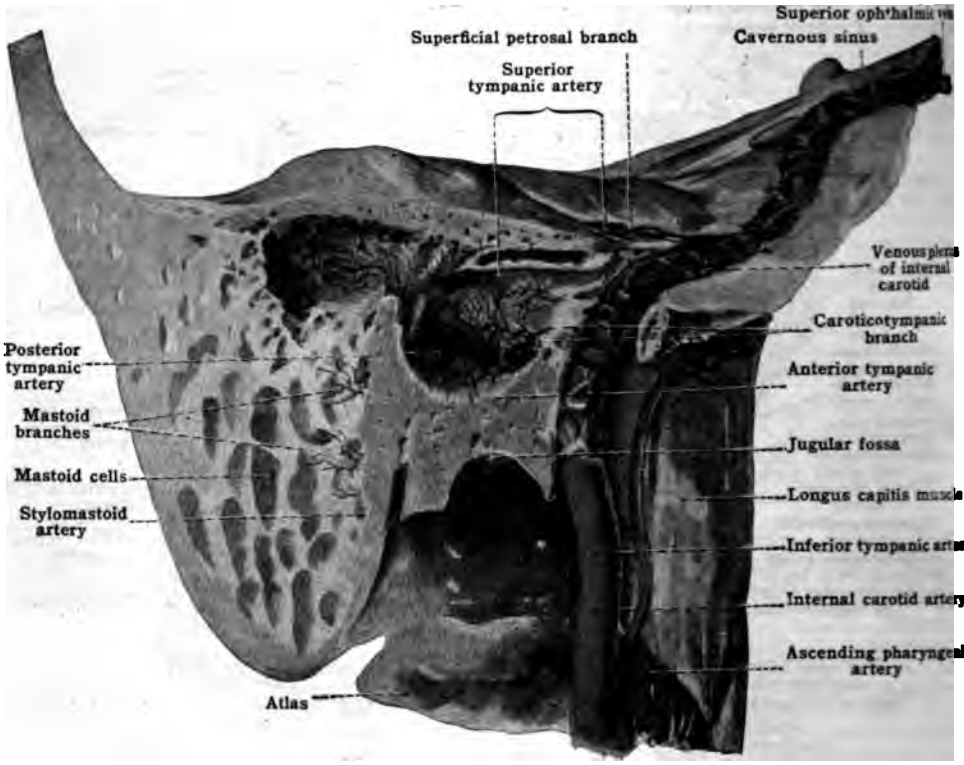
On its **lateral side** are the internal jugular vein and vagus nerve.

On its **medial side** it is in relation with the pharynx, the superior constrictor muscle separating it from the tonsil. The ascending pharyngeal and ascending palatine arteries, and the auditory (Eustachian) tube and levator veli palatini muscles, are also medial to it.

2. The Petrosal Portion

The **petrosal portion** (fig. 498) is situated in the carotid canal in the petrous portion of the temporal bone. It is here separated from the walls of the canal by a prolongation downward of the dura mater. In this part of its course it first ascends in front of the tympanum and cochlea of the internal ear; it then turns forward and medially, lying a little to the medial side of and behind the auditory (Eustachian) tube, and enters the cranial cavity by turning upward through the foramen lacerum, lying upon the lingula of the sphenoid bone. In this part of its course it is accompanied by the ascending branches from the superior cervical ganglion of the sympathetic. These form a plexus about the artery, but are situated chiefly on its lateral side. It is also surrounded by a number of small veins, which receive tributaries from the tympanum and open into the cavernous sinus and internal jugular vein.

Fig. 498.—The Internal Carotid Artery in the Canal. (After Spalteholz.)



3. The Intracranial Portion

On entering the cranium through the foramen lacerum, the **internal carotid first ascends** upon the medial side of the lingula along the lateral part of the **body of the sphenoid. It then** follows the carotid sulcus forward and slightly downward along the **medial wall of the cavernous** sinus (fig. 498). Here it has the sixth nerve immediately lateral to it, **and is covered by the lining membrane of the sinus.** Again turning upward, it pierces the **dura mater on the medial side** of the anterior clinoid process, and passes between the second **and third nerves to the anterior** perforated substance. At the medial end of the lateral (Sylvian) **fissure it pierces the arachnoid** and divides into its two terminal branches, the anterior and middle **cerebral. As it lies in the** foramen lacerum the artery is crossed on its lateral side by the **great superficial petrosal nerve** as the latter goes to join the great deep petrosal from the carotid **plexus to form the nerve of** the pterygoid canal (Vidian).

Branches of the Internal Carotid Artery

The **cervical portion** has no branches. The **petrosal portion gives off the** caroticotympanic. The **branches of the intracranial portion are:—(2) ophthal-**

[illegible]ic; (3) posterior communicating; (4) choroid; (5) anterior cerebral; (6) middle [illegible]erebral.

As the internal carotid artery lies on the medial side of the cavernous sinus, it also gives off [illegible]he following small branches—branches to the walls of the cavernous sinus, to the pituitary body, [illegible]e the semilunar (Gasserian) ganglion and to the dura mater. These anastomose with anterior [illegible]branches of the middle meningeal.

1. THE CAROTICOTYMPANIC ARTERY

The **caroticotympanic** enters the tympanum through a small foramen in the posterior wall of the carotid canal, and contributes its quota to the blood-supply of that cavity. It anastomoses with the tympanic branches of the stylomastoid, internal maxillary, and middle meningeal arteries.

2. THE OPHTHALMIC ARTERY

The **ophthalmic** artery (fig. 499) arises from the internal carotid immediately below the anterior clinoid process just as the latter vessel is passing through the dura mater. Entering the orbit through the optic foramen below and laterally to the optic nerve, it at once perforates the sheath of dura mater which is prolonged through the optic foramen on both artery and nerve. It then runs in a gentle curve with a lateral convexity below the optic nerve and lateral rectus, being here crossed by the nasociliary (nasal) nerve. Turning forward and upward, it passes over the optic nerve, to its medial side. Thence it runs obliquely beneath the superior rectus in front of the nasociliary (nasal) nerve under the lower border of the superior oblique, but above the medial rectus, and continues its course under the pulley for the superior oblique and reflected tendon of that muscle to the medial palpebral region, where it divides into the frontal and dorsal nasal branches.

Branches of the Ophthalmic Artery

The **branches of the ophthalmic artery** are:—(1) the lacrimal; (2) the supra-orbital; (3) the central artery of the retina; (4) the muscular; (5) the ciliary; (6) the posterior ethmoidal; (7) the anterior ethmoidal; (8) the medial palpebral; (9) the frontal; and (10) the dorsal nasal.

(1) **The lacrimal artery** [a. lacrimalis], is usually the first and often the largest branch of the ophthalmic. It arises between the superior and lateral rectus on the lateral side of the optic nerve from the ophthalmic, soon after that vessel has entered the orbit. At times it is given off from the ophthalmic, or from the middle meningeal artery outside the orbit, and then usually passes into that cavity through the superior orbital (sphenoidal) fissure. It runs forward along the lateral wall of the orbit with the lacrimal nerve, above the upper border of the lateral rectus, to the lacrimal gland, which it supplies. In this course it furnishes the following branches:—(*a*) **Recurrent,** one or more branches which pass backward through the superior orbital (sphenoidal) fissure, and anastomose with the lacrimal branch of the middle meningeal artery. The anastomosis is sometimes of large size, and then takes the chief share in the formation of the lacrimal artery. (*b*) **Muscular** branches, distributed chiefly to the lateral rectus. (*c*) **Zygomatic branches**—small twigs, which pass through the zygomatico-orbital (malar) canals, and anastomose with the orbital branch of the middle temporal, and with the transverse facial on the cheek. (*d*) **Lateral palpebral** arteries [aa. palpebrales laterales] which are distributed to the upper and lower eyelids and to the conjunctiva. (*e*) **Ciliary.** See Ciliary Arteries below.

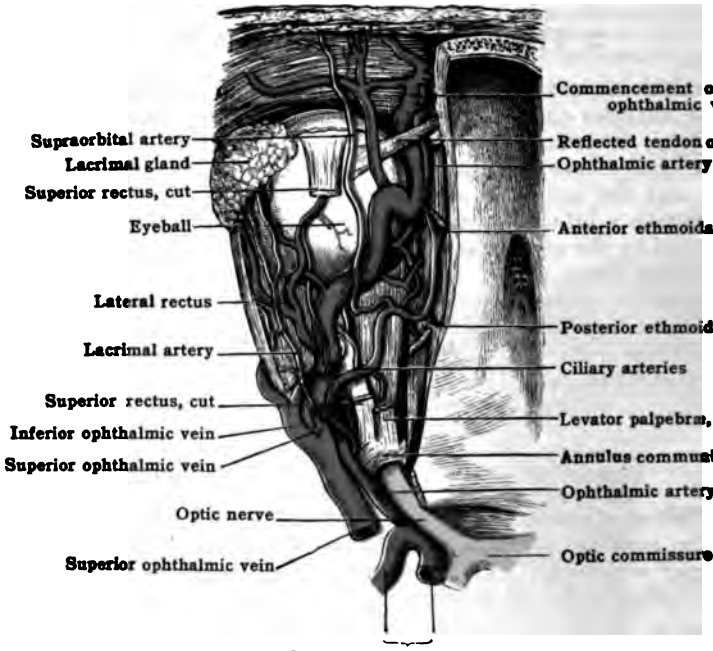
(2) **The supraorbital artery** [a. supraorbitalis] usually arises from the ophthalmic as the latter vessel is about to cross over the optic nerve. Passing upward to the medial side of the superior rectus and levator palpebræ, it runs along the upper surface of the latter muscle with the frontal nerve in the orbital fat, but beneath the periosteum, to the supraorbital notch. On emerging on the forehead beneath the orbicularis oculi, it divides into a superficial and a deep branch, the former ramifies between the skin and epicranius (occipitofrontalis), the latter between the epicranius and the pericranium. Both branches anastomose with the anterior branches of the superficial temporal, the angular branch of the external maxillary (facial), and the transverse facial artery. The branches of the supraorbital are:—(*a*) **periosteal,** to the periosteum of the roof of the orbit; (*b*) **muscular,** to the levator palpebræ and superior rectus; (*c*) **diploic,** given off as the artery is passing through the supraorbital notch and, entering a minute foramen at the bottom of the notch, is distributed to the diploë and frontal sinuses; (*d*) **trochlear,** to the pulley of the superior oblique; (*e*) **palpebral,** to the upper eyelid.

(3) **The arteria centralis retinæ,** a small but constant branch, comes off from the ophthalmic close to the optic foramen, and, perforating the optic nerve about 6 mm. (¼ in.) behind the globe, runs forward (in the substance of the nerve) to the eyeball, supplying the retina. Its further description is given in the section on the Eye.

(4) The **muscular** branches [rami musculares] are very variable in their origin an bution. They may be roughly divided into superior and inferior sets. Those of the set supply the superior oblique, the levator palpebræ, and superior rectus. The infer forward, between the optic nerve and the inferior rectus, supplying that muscle, the rectus, and the inferior oblique. From the muscular branches are given off the anterio arteries. (See CILIARY ARTERIES.)

(5) The **ciliary arteries** are divided into three sets:—The **short posterior**, the **long p** and the **anterior**. (i) The **short posterior** [aa. ciliares posteriores breves], five or six in n come off chiefly from the ophthalmic as it is crossing the optic nerve. They run forwar the nerve, dividing into twelve or fifteen small vessels, which perforate the sclerotic the entrance of the optic nerve, and are distributed to the choroid coat. (ii) The **long p** ciliary arteries [aa. ciliares posteriores longæ], usually two, sometimes three, in number, from the ophthalmic on either side of the optic nerve, and run forward with the short c

FIG. 499.—THE LEFT OPHTHALMIC ARTERY AND VEIN, VIEWED FROM ABOVE



the sclerotic. On piercing the sclerotic, they course forward, one on either side of th between the sclerotic and the choriod to the ciliary processes and iris. Their further tion is given under the anatomy of the EYE. (iii) The **anterior ciliary arteries** [aa. ci teriores] are derived from the muscular branches and from the lacrimal. They run to along the tendons of the recti, forming a zone of radiating vessels beneath the con Some of them, the **episcleral arteries** [aa. episclerales], perforate the sclerotic abou (¼ in.) behind the cornea, and supply the iris and ciliary processes. It is these vessel enlarged and congested in iritis, forming the circumcorneal zone of redness so charac that disease. They then differ from the tortuous vessels of the conjunctiva in that straight and parallel. The remainder constitute the **anterior conjunctival arteries** junctivales anteriores].

(6) The **posterior ethmoidal** artery [a. ethmoidalis posterior] (fig. 499) runs me tween the superior oblique and medial rectus, and, leaving the orbit by the posterior canal, together with the posterior ethmoidal branch of the nasociliary (nasal) ner the posterior ethmoidal cells, whence it passes through a transverse slit-like apertur the sphenoid bone and cribriform plate of the ethmoid bone into the cranium. It gi ethmoidal branches to the posterior ethmoidal cells; (*b*) **meningeal branches to the d** lining the cribriform plate; and (*c*) **nasal** branches, which pass through the cribriform the superior meatus and upper nasal conchæ, and anastomose with the nasal branch sphenopalatine artery (fig. 496).

(7) The **anterior ethmoidal** artery [a. ethmoidalis anterior] (figs. 496, 499), a larg than the posterior ethmoidal, arises in front of the latter, passes medially between th oblique and medial rectus, and, leaving the orbit through the anterior ethmoidal cana pany with the anterior ethmoidal nerve, enters the cranial cavity. After running a tance beneath the dura mater on the cribriform plate of the ethmoidal bone, it passe nose through the horizontal slit-like aperture by the side of the crista galli. Its branch passes along the groove on the under surface of the nasal bone, and emerges on between the bone and lateral cartilage, terminating in the skin of that organ. It giv following branches in its course:—(i) **Ethmoidal**, to the anterior ethmoidal cells; (ii

ngeal artery, [a. meningea anterior] to the dura mater of the anterior fossa; (iii) nasal hes to the middle meatus and anterior part of the nose; (iv) frontal branches to the frontal ss; (v) cutaneous, or terminal branches to the skin of the nose.

i) The medial palpebral arteries [aa. palpebrales mediales] arise either separately or by a mon trunk from the ophthalmic artery opposite the pulley for the superior oblique. They one above and one below, the medial palpebral ligament and then skirt along the upper and r eyelids respectively, near the free margin between the palpebral tarsi and the orbicularis le, and form a superior and an inferior tarsal arch [arcus tarseus superior, inferior] by bomosing with the lateral palpebral branches of the lacrimal. The upper medial palpebral y anastomoses with the supraorbital artery and orbital branch of the temporal artery; the r with the infraorbital, the angular branch of the external maxillary (facial), and the trans- facial arteries. A branch from the lower palpebral artery passes with the ductus naso- malis as far as the inferior meatus. Small twigs, the posterior conjunctival arteries [aa. nctivales posteriores], are also given to the caruncula lacrimalis and conjunctiva.

9) The frontal artery [a. frontalis] the upper of the terminal branches of the ophthalmic, es the superior tarsus at the medial angle of the orbit, passes upward over the frontal bone ath the orbicularis oculi, supplies the structures in its neighborhood. It anastomoses its fellow of the opposite side, with the supraorbital, and with the anterior division of the rficial temporal artery.

10) The dorsal nasal [a. dorsalis nasi], the lower of the terminal branches of the ophthalmic, s the orbit at the medial angle by perforating the tarsus above the medial palpebral liga- t. It then descends along the dorsum of the nose, beneath the integuments, and anasto- s with the angular and lateral nasal branches of the external maxillary (facial). It gives lacrimal branch as it crosses the lacrimal sac.

3. THE POSTERIOR COMMUNICATING ARTERY

The **posterior communicating** artery [a. communicans posterior] (fig. 500) s from the internal carotid just before the division of that vessel into the rior and middle cerebral arteries; occasionally it arises from the middle bral.

t is as a rule a slender vessel which runs backward over the optic tract and pedunculus ori along the side of the hippocampal gyrus to join the posterior cerebral. At times, how- it is of considerable size, and contributes chiefy to form the posterior cerebral, the portion e latter vessel between the basilar and posterior communicating being then as a rule reduced mere rudiment. It gives off the following branches:—(*a*) the **hippocampal**, to the gyrus at name; and (*b*) the **middle thalamic**, to the optic thalamus.

4. THE CHOROID ARTERY

The **choroid** artery [a. chorioidea] is a small but constant vessel which arises rule from the back part of the internal carotid just laterally to the origin of the erior communicating.

passes backward on the optic tract and the pedunculus cerebri, at first lying parallel to and e lateral side of the posterior communicating artery. It then dips under the edge of the ate gyrus and, entering the choroid fissure at the lower end of the inferior cornu of the l ventricle, ends in the choroid plexus and supplies the hippocampus and fimbria.

5. THE ANTERIOR CEREBRAL ARTERY

The **anterior cerebral** artery [a. cerebri anterior] (figs. 500, 503), one of the inal branches into which the internal carotid divides in the lateral fissure ire of Sylvius), supplies a part of the cortex of the frontal and parietal lobes e brain and a small part of the basal ganglia. It passes at first anteriorly and ially across the anterior perforated substance between the olfactory and optic es to the longitudinal fissure where it approaches its fellow of the opposite side communicates with it by a short transverse trunk, about five mm. long, rn as the **anterior communicating** artery [a. communicans anterior] (fig. 500). ard from this point it runs side by side with its fellow in the longitudinal re round the genu of the corpus callosum; then, turning backward, it continues g the upper surface of that commissure, and, after giving off large branches to rontal and parietal lobes, anastomoses with the posterior cerebral artery.

6. THE MIDDLE CEREBRAL ARTERY

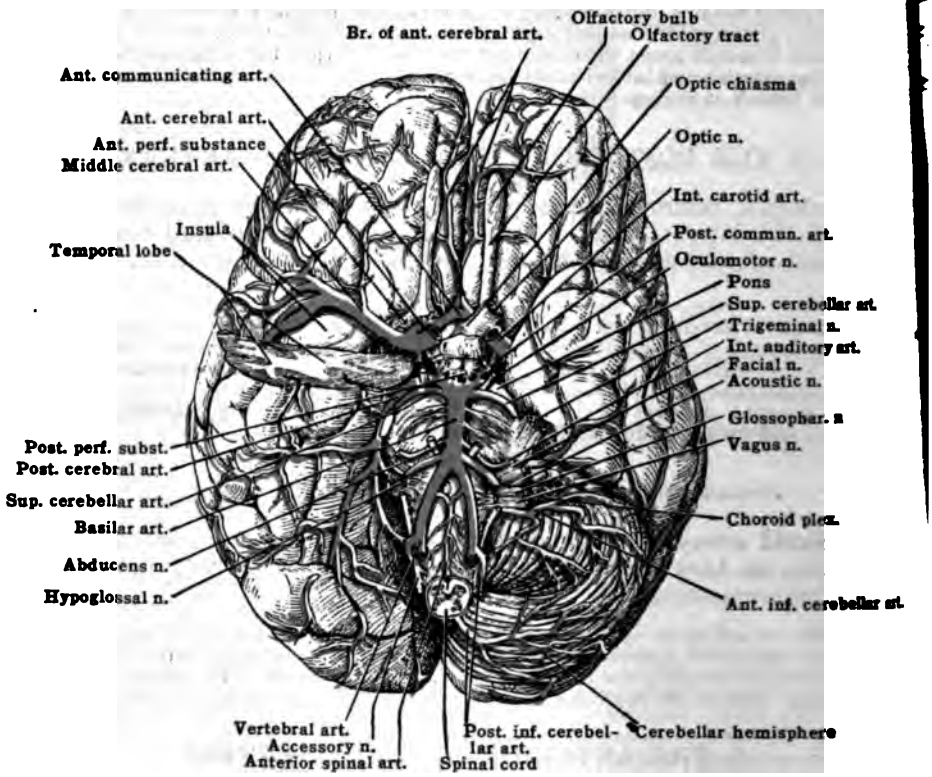
The **middle cerebral** artery [a. cerebri media] (figs. 500, 504), the larger of the inal divisions of the internal carotid, supplies the basal ganglia and a part of

the cortex of the frontal and parietal lobes. It passes obliquely upward and lateralward into the lateral (Sylvian) fissure, and opposite the insula divides into cortical branches.

Circulus Arteriosus

The four arteries which supply the brain, namely, the two internal carotid arteries and the two vertebrals (which unite to form the basilar), form a remarkable anastomosis at the base of the brain known as the circle of Willis [circulus arteriosus (Willisi)]. This so-called circle, which has really the form of a heptagon, is formed, **in front,** by the anterior communicating artery uniting the anterior cerebral arteries of opposite sides; **laterally,** by the internal carotids and the posterior communicating arteries stretching between these and the posterior cerebrals; **behind,** by the two posterior cerebrals diverging from the bifurcation of the basilar artery (fig. 500).

Fig. 500.—The Arteries at the Base of the Brain.



The free anastomosis between the two internal carotid and the two vertebral arteries serves to equalize the flow of blood to the various portions of the brain. Should one or more of the arteries entering into the formation of the circle be temporarily or permanently obstructed, blood would be transmitted to the deprived part through some of the collateral arteries. Thus, if one carotid or one vertebral were obstructed, the parts supplied by that vessel would receive their blood through the circle from the remaining pervious vessels. One vertebral artery alone has indeed been found equal to the task of carrying sufficient blood for the supply of the brain after ligature of both the carotids and the other vertebral artery. Further, the circulus arteriosus is the only medium of communication between the ganglionic or central and the peripheral or cortical branches of the cerebral arteries, and between the various ganglionic branches themselves. The ganglionic and the cortical branches form separate and distinct systems, and do not anastomose with each other; the ganglionic arteries, moreover, are so-called end-vessels, and do not anastomose with the neighboring ganglionic branches. The three cerebral arteries, anterior, middle, and posterior may be regarded as branches of the circulus arteriosus (circle of Willis). (For details concerning the distribution of the cerebral arteries see p. 602.)

THE SUBCLAVIAN ARTERY

The **subclavian artery** on the right side [a. subclavia **dextra**] arises at the bifurcation of the innominate opposite the upper limit of the right sternoclavicular articulation. On the left side it arises from the arch of the aorta, and, as far as the *medial border* of the scalenus anterior, is situated deeply in the chest.

beyond the medial border of the scalenus anterior the artery has the same rela- s on both sides. It courses from this point beneath the clavicle in a slight e across the root of the neck to the lateral border of the first rib, there to end ie axillary artery. Thus the course of the artery in the neck will be indicated a line drawn from the sternoclavicular joint in a curve with its convexity ard to the middle of the clavicle. The height to which the artery rises in the : varies. It is perhaps most commonly about 1.2 cm. (½ in.) above the clav-

If the curved line above mentioned is drawn to represent part of the cir- ference of a circle having its center at a point on the lower margin of the icle 3.7 cm. (1½ in.) from the sternal end of that bone, the line of the artery be sufficiently well indicated for all practical purposes. In its course the ry arches over the dome of the pleura and gains the groove on the upper ace of the first rib by passing between the scalenus anterior and medius mus- . The artery is accompanied by the subclavian vein, the latter vessel lying ront of the scalenus anterior, anterior to the artery, and on a slightly lower ie. .

The subclavian artery is divided into three portions—as it lies medial to, pos- or to, or lateral to, the scalenus anterior muscle.

THE FIRST OR THORACIC PORTION OF THE LEFT SUBCLAVIAN ARTERY

The left subclavian artery [a. subclàvia sinistra] (fig. 501) arises from the left of the arch of the aorta. The first part of the left subclavian is consequently ger than the first part of the right, which arises at the bifurcation of the ominate artery. The artery at its origin is situated deeply in the thorax, as it arises from the aorta is on a plane posterior to and a little to the left of thoracic portion of the left common carotid. It first ascends almost vertically at the root of the neck curves laterally over the apex of the left pleura and to the interval between the anterior and middle scalene muscles. Beyond medial border of the scalenus anterior—that is, in the second and third ions of its course—its relations are similar to those of the right subclavian ry.

elations.—In front the left subclavian artery is covered by the left pleura and lung, and superficially by the sternothyroid, sternohyoid, and sternomastoid muscles. It is crossed le above its origin by the left innominate vein, and higher in the neck near the scalenus ior by the internal jugular, vertebral, and subclavian veins. The phrenic nerve crosses rtery medially to the scalenus anterior, and then descends parallel with it, but on an ior plane, to cross the arch of the aorta. The vagus nerve descends parallel with the y between it and the left common carotid, coming into contact with its anterior surface before crossing the arch of the aorta. The left cervical cardiac nerves of the sympathetic descend in front of it on their way to the cardiac plexus. The left *ansa subclavia* also loops ont of the subclavian artery. The left common carotid is situated anteriorly and to its The thoracic duct arches over the artery just medially to the scalenus anterior, to y its contents into the confluence of the internal jugular and subclavian veins (fig. 486). ehind and somewhat medial to it are the esophagus, thoracic duct, inferior cervical gang- of the sympathetic, longus colli muscle, and vertebral column. To some extent it is over- d posteriorly by the left pleura and lung. On its right side are the trachea and the rent (laryngeal) nerve, and, higher up, the esophagus and thoracic duct. On its left side he left pleura and lung.

Branches.—The vertebral, internal mammary, and thyrocervical trunk roid axis) usually arise from the first portion on the left side. (See p. 673.)

THE FIRST PORTION OF THE RIGHT SUBCLAVIAN ARTERY

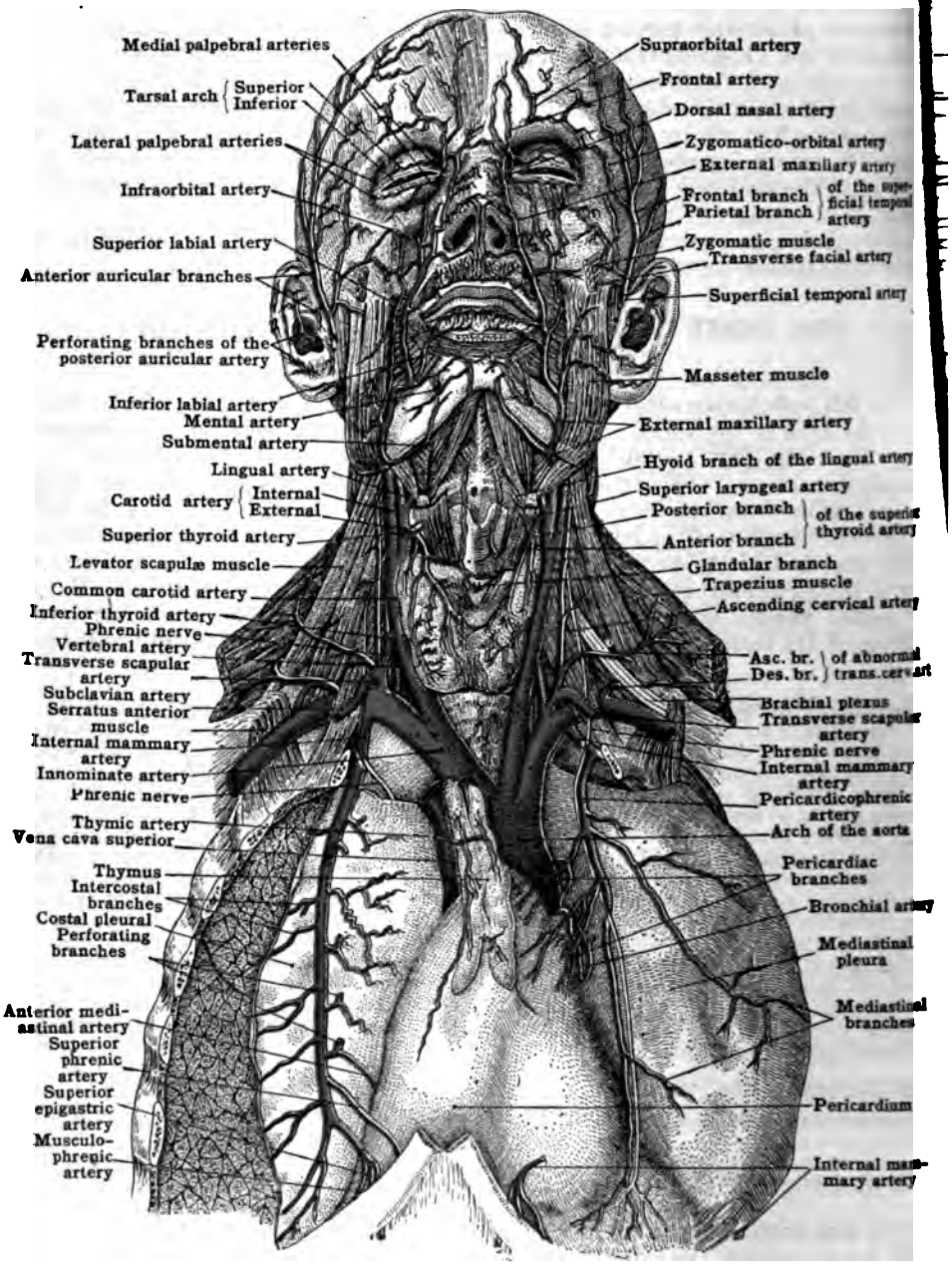
The first portion of the right subclavian artery (fig. 501) extends from its origin ie bifurcation of the innominate, behind the upper margin of the right sterno- icular joint, upward and laterally in a gentle curve over the apex of the right and pleura to the medial border of the scalenus anterior. It measures about . (1¼ in.). In this course it ascends in the neck a variable distance above the icle, deeply placed and surrounded by important structures.

elations.—In front it is covered by the integument, the superficial fascia, the platysma, nterior layer of the deep fascia, the clavicular origin of the sternomastoid, the sternohyoid sternothyroid muscles, and the deep cervical fascia. It is crossed by the commencement

of the innominate, by the internal jugular, and by the vertebral veins; and, in a mediolateral direction, by the vagus and phrenic nerves, and the superior cardiac branches of the sympathetic nerve. A loop of the sympathetic nerve itself also crosses the artery, and forms with the trunk of the sympathetic a ring around the vessel known as the **ansa subclavia** (annulus of Vieussens).

Behind, but separated from the artery by a cellular interval, are the longus colli muscle, the transverse process of the seventh cervical or first thoracic vertebra, the main chain of the

FIG. 501.—THE SUBCLAVIAN ARTERY. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



sympathetic nerve, the inferior cardiac nerves, the recurrent (laryngeal) nerve, and the apex of the right lung and pleura.

Below, it is in contact with the pleura and lung and the loop of the recurrent (laryngeal) nerve, which winds round the artery from the vagus and ascends behind it to the larynx. The subclavian vein is below the artery and on an anterior plane.

Branches.—The vertebral, internal mammary, superficial cervical, and thyro-cervical trunk (thyroid axis) arise from this part of the vessel on the right side.

Not uncommonly a small aberrant artery also takes origin from this portion of the artery descends to the left behind the esophagus to join a branch of the aorta opposite the third urth thoracic vertebra. This vessel is probably the remains of the right dorsal aorta.

THE SECOND PORTION OF THE SUBCLAVIAN ARTERY

The second portion of the subclavian artery lies behind the scalenus anterior scle. It measures about 2 cm. (¾ in.) in length and here reaches highest in the ck. The subclavian vein is separated from the artery by the scalenus anterior, d lies on a lower and anterior plane (fig. 507).

Relations.—**In front** it is covered by the skin, superficial fascia, platysma, anterior layer deep fascia, the clavicular origin of the sternomastoid, posterior layer of deep fascia, and the scalenus anterior. The phrenic nerve—which, in consequence of its oblique course idially downward, crosses a portion of both the first and second part of the subclavian—is arated from the second portion by the scalenus anterior muscle, as is also the subclavian in which courses on a somewhat lower plane. **Behind** the artery are the apex of the pleura d lung, and a portion of the scalenus medius; also the scalenus minimus (partially or entirely rous, known as Sibson's fascia, see. p. 389). **Above** is the brachial plexus. **Below** are the ura and lung.

One branch only—the costocervical trunk (superior intercostal)—is, as a le, given off from this portion of the subclavian; occasionally the transverse rvical or the descending branch of the transverse cervical (posterior scapular tery) arises from it.

THE THIRD PORTION OF THE SUBCLAVIAN ARTERY

The third portion of the subclavian artery extends from the lateral margin of scalenus anterior muscle to the lateral border of the first rib. It is more superal than either the first or second portion and is in relation with less important uctures. It is the longest of the three portions of the subclavian artery, and in a triangle—the subclavian triangle—bounded by the sternomastoid, the ohyoid, and the clavicle (fig. 488).

As a rule it gives off no branches. The descending branch of the transverse cervical artery es from it sometimes however, in which case the ascending branch arises from the thyrorical trunk. (See fig. 501.)

Relations.—**In front** it is covered by skin, superficial fascia, platysma and the supraclavicular ves of the cervical plexus; the anterior layer of deep fascia which descends from the omoid to the clavicle; and the posterior layer of deep fascia which descends from the omohyoid the first rib and passes over the scalenus anterior and phrenic nerve. Between the two ers of fascia is a variable amount of cellular tissue and fat, and running in this is the transse scapular (suprascapular) artery. The subclavian is crossed by this artery unless the arm rawn well downward. Close to the lateral margin of the sternomastoid, the external jugu- vein pierces the fascia, and crosses the subclavian artery to open into the subclavian vein. this vein lies between the two layers of fascia, it receives on its lateral side the transverse pular (suprascapular), transverse cervical, and other veins of the neck, which together form lexus of large veins in front of the artery. The nerve to the subclavius, and, when present, accessory branch from this nerve to the phrenic, also here cross in front of the artery. In y muscular subjects the clavicular head of the sternomastoid may be larger than usual, and such a case will form one of the coverings of the artery.

Behind, the artery is in contact with the scalenus medius, and with the lower trunk of the achial plexus.

Below, the artery rests in the posterior of the two grooves on the upper surface of the first

Above is the brachial plexus of nerves and the posterior belly of the omohyoid muscle. e trunk formed by the fifth and sixth cervical nerves is also above the artery, but on a somet anterior plane. The seventh cervical nerve is close to the vessel, and has been mistaken the artery in the application of a ligature.

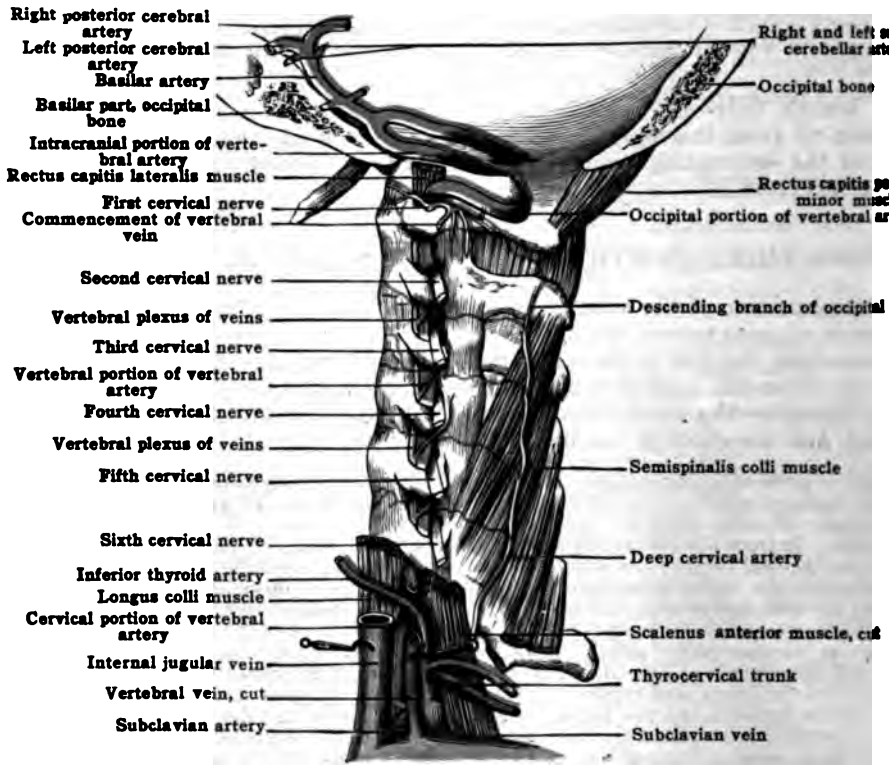
The branches of the subclavian artery will be described in the following der:—(1) The vertebral artery; (2) the thyrocervical trunk; (3) the internal ammary artery; (4) the costocervical trunk.

1. THE VERTEBRAL ARTERY

The vertebral artery [a. vertebralis] (fig. 502) the first, largest, and most conant branch, arises from the upper and posterior part of the first portion of the bclavian; on the right side, about 2 cm. (¾ in.) from the origin of the latter ves-

sel from the innominate, on the left side, from the most prominent part of the arch of the subclavian, close to the medial edge of the scalenus anterior muscle. It first ascends vertically to the foramen transversarium of the sixth cervical vertebra, and, having passed through that foramen and those of the next succeeding cervical vertebræ as high as the epistropheus (axis), it turns laterally and then ascends to reach the foramen in the transverse process of the atlas; after passing through that foramen it turns backward behind the articular process, lying in the groove on the posterior arch of the atlas. It next pierces the posterior occipitoatlantoid membrane and the dura mater, and enters the cranium through the foramen magnum. Here it passes upward, at first lying by the side of the medulla, then in front of that structure, and terminates at the lower portion of the pons by anastomosing with the vertebral of the opposite side to form the basilar

FIG. 502.—THE LEFT VERTEBRAL ARTERY. (Walsham.)
The internal jugular and vertebral veins are hooked aside to expose the artery.



The vertebral artery may be divided for purposes of description into four parts: the **first,** or **cervical,** extending from its origin to the transverse process of the sixth cervical vertebra; the **second,** or **vertebral,** situated in the foramina transversaria; the **third,** or **occipital,** contained in the suboccipital triangle; and the **fourth,** or **intracranial,** within the cranium.

The first or cervical portion.—The artery here lies between the scalenus anterior and longus colli muscles. In front it is covered by the vertebral and internal jugular veins, and is crossed by the inferior thyroid artery, and on the left side, in addition, by the thoracic duct, which runs over it mediolaterally. Behind, the artery lies on the transverse process of the seventh cervical vertebra and the sympathetic nerve. To its medial side is the longus colli. To its lateral side is the scalenus anterior. It gives off as a rule no branch in this part of its course. Occasionally, however, a small branch passes into the foramen transversarium of the seventh cervical vertebra.

The second or vertebral portion.—As the artery passes through the foramina transversaria, it is surrounded by a plexus of veins and by branches of the sympathetic nerve. The cervical nerves lie behind it. Between the transverse processes it is in contact with the intertransverse muscles.

The third or occipital portion.—The artery here lies in the suboccipital triangle, bounded by the superior oblique, inferior oblique, and rectus capitis posterior major muscles. As it winds round the groove on the atlas, it has the rectus capitis lateralis, the articular process, the posterior occipitoatlantoid membrane in front of it; the superior oblique, the rectus

apitis posterior major, and the semispinalis capitis (complexus) **behind** it. Separating it **om the arch of the atlas**, is the first cervical or suboccipital nerve.

The **fourth** or **intracranial portion** extends from the aperture in the dura mater to the **ower** border of the pons, where it pierces the arachnoid and unites with its fellow to form the **asilar** artery. It here winds round from the side to the front of the medulla, lying in the **ertebral** groove on the basilar part of the occipital bone. In this course it passes beneath **the** first process of the ligamentum denticulatum, and between the hypoglossal nerve in front, **and** the anterior roots of the suboccipital nerve behind.

Branches of the Vertebral Artery

The first part of the vertebral artery gives no branches. The second and third parts give off *muscular* branches to the semispinalis and posterior recti and oblique muscles. The second part also gives off five or six, (1) Spinal branches. The fourth part gives off the following: (2) Posterior meningeal; (3) posterior spinal; (4) anterior spinal; and (5) posterior inferior cerebellar.

(1) The **spinal** branches [rami spinales] run through the intervertebral foramina into the **vertebral canal**, and there divide into two branches: one of which ramifies on the backs of **the bodies of the cervical vertebræ**; while the other runs along the spinal nerves, supplies the **cord** and its membranes, and anastomoses with the arteries above and below.

(2) The **meningeal** [ramus meningeus] is a small branch given off as the vertebral artery pierces the dura mater to enter the cranium. It supplies the bone and dura mater of the posterior fossa of the skull, and anastomoses with the posterior meningeal branches derived from the occipital and ascending pharyngeal arteries. It gives branches to the falx cerebelli.

(3) The **posterior spinal** artery [a. spinalis posterior] runs downward obliquely along the side of the medulla to the back of the cord, down which it passes behind the roots of the spinal nerves, being reinforced by spinal branches accompanying these nerves, in the neck, the thoracic, and in the lumbar region. It can be traced as low as the end of the spinal cord.

(4) The **anterior spinal** artery [a. spinalis anterior] comes off from the vertebral a little below its termination in the basilar artery. Descending with a medial slant in front of the medulla, it unites on a level with the foramen magnum with its fellow of the opposite side. The single vessel thus formed runs downward in front of the spinal cord beneath the pia mater as far as the termination of the cord, being reinforced by the spinal branches on the way down. The spinal arteries are described in detail with the anatomy of the spinal cord.

(5) The **posterior inferior cerebellar** [a. cerebelli inferior posterior] (fig. 500)—the largest branch of the vertebral—arises from that vessel just before it joins its fellow to form the basilar artery. At times it may come off from the basilar itself. It runs, at first laterally across the restiform body between the origin of the vagus and hypoglossal nerves, and, descending toward the vallecula, there divides into two branches, medial and lateral. (*a*) The *medial branch* runs backward between the vermis and the lateral hemisphere of the cerebellum. It supplies the vermis, and anastomoses with the artery of the opposite side, and with the superior vermian of the superior cerebellar. (*b*) The *lateral branch* runs laterally and, ramifying over the under surface of the cerebellar hemisphere, supplies its cortex and anastomoses along its lateral margin with the superior cerebellar arteries.

From the undivided trunk of the posterior inferior cerebellar artery branches are given to the **medulla oblongata**, supplying the choroid plexus and the fourth ventricle.

THE BASILAR ARTERY

The **basilar artery** [a. basilaris] is formed by the confluence of the right and left vertebral arteries, which meet at an acute angle at the lower border of the pons. It runs forward and upward in a slight groove in the middle line of the pons, and divides at the upper border of that structure at the level of the tentorial notch into the two posterior cerebral arteries, which take part in the formation of the circle of Willis (fig. 500).

Branches of the Basilar Artery

The branches of the basilar artery are:—(1) Pontine; (2) internal auditory; (3) anterior inferior cerebellar; (4) superior cerebellar; (5) posterior cerebral.

(1) The **pontine** branches [rami ad pontem] are numerous small vessels which come off at **right angles** on either side of the basilar artery, and, passing laterally over the pons, supply that **structure** and adjacent parts of the brain.

(2) The **internal auditory** artery [a. auditiva interna], a long slender vessel, accompanies **the auditory** nerve into the internal acoustic meatus (figs. 500, 555). It here lies between the **facial and auditory nerves**, and at the bottom of the meatus passes into the internal ear, and **anastomoses with the other auditory** arteries. (See INTERNAL EAR.)

(3) The **anterior inferior cerebellar** [a. cerebelli inferior anterior] arises from the basilar **soon after its origin, passes** laterally and backward across the pons, and then over the brachium **pontis to the front part** of the under surface of the cerebellum. It anastomoses with the **posterior inferior cerebellar** artery (fig. 500).

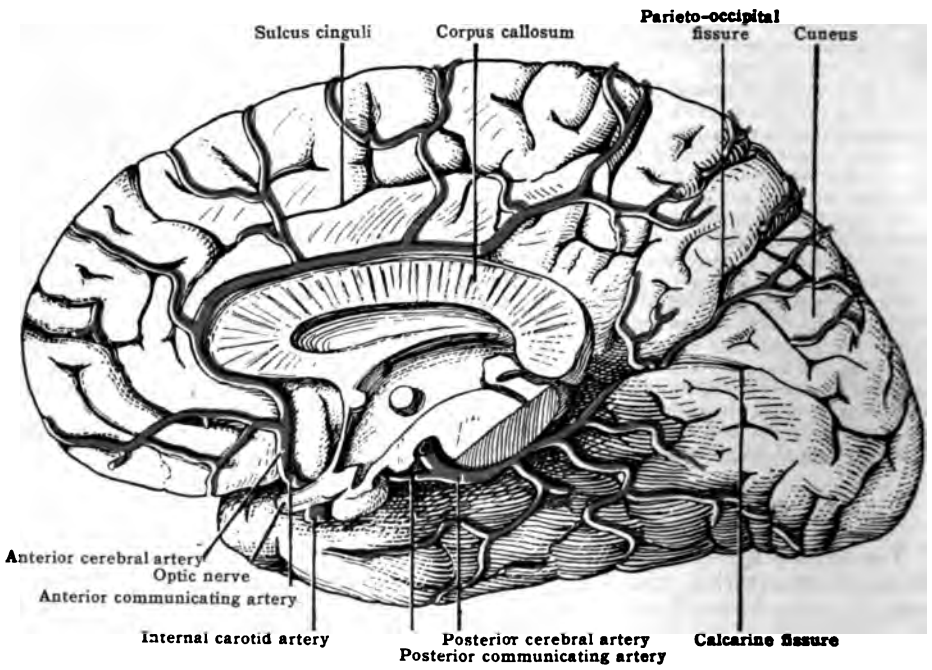
(4) The **superior cerebellar** [a. cerebelli superior] comes off from the basilar immediately behind its bifurcation into the posterior cerebral arteries. It courses laterally and backward over the pons, in a curve roughly corresponding to that of the posterior cerebral artery, from which it is separated by the third cranial nerve; but, soon sinking into the groove between the pons and the pedunculus cerebri, it curves round the latter onto the upper surface of the cerebellum, lying nearly parallel to the fourth nerve. Here it divides into two branches, medial and lateral. (*a*) The *medial branch* courses backward along the superior vermis, anastomosing with its fellow of the opposite side, and, at the posterior notch of the cerebellum, with the inferior vermian branch of the posterior inferior cerebellar artery. (*b*) The *lateral* runs to the circumference of the cerebellum, anastomosing with the lateral branch of the inferior posterior cerebellar artery.

Branches are given off from the main trunk of the superior cerebellar artery, or from its medial branch to the anterior velum (valve of Vieussens), the corpora quadrigemina, the pineal body, and the choroid plexus.

(5) The **posterior cerebral** arteries [aa. cerebri posteriores] are the two terminal branches into which the basilar bifurcates at the upper border of the pons, immediately behind the posterior perforated substance. Each artery runs at first laterally and a little forward across the pedunculus cerebri immediately in front of the third nerve, which separates it from the superior cerebellar artery. After receiving the posterior communicating artery, which runs backward from the internal carotid, the posterior cerebral turns backward onto the lower surface of the cerebral hemisphere, where it breaks up into branches for the supply of the temporal and occipital lobes.

The **branches of the posterior cerebral artery** are described below in connection with those of the other cerebral arteries.

FIG. 503.—THE ARTERIES OF THE MEDIAL SURFACE OF THE BRAIN. (After Spalteholz.)



DISTRIBUTION OF THE CEREBRAL ARTERIES

Although the brain receives its blood supply from two distinct sources, namely, from the internal carotids and from the vertebrals, it is convenient to consider together the distribution of the various cerebral branches derived from these stems. The formation of the circulus arteriosus (circle of Willis) and the origin of the anterior, middle and posterior cerebral arteries have already been described (pp. 595, 596). The detailed distribution of these vessels will now be considered. In general, their branches may be divided into *central* or *ganglionic* and *peripheral* or *cortical*.

The **anterior cerebral artery** has but a limited central distribution. It gives off a few inconstant branches which enter the anterior perforated substance and supply the anterior end of the caudate nucleus. One or two of these run to the corpus callosum and septum pellucidum. The **anterior communicating** branch is a transverse trunk which connects the two arteries and thereby completes the circulus arteriosus in front. It lies in front of the optic chiasm, and varies considerably in length and size. It may give off some of the branches to the anterior perforated substance. The **cortical branches** supply the gyrus rectus, the olfactory lobe and a part of the orbital gyri on the ventral surface. On the medial surface branches supply the cortex as far back as the parieto-occipital fissure. These branches are given off as the artery

round the corpus callosum and some of them curve over onto the lateral surface and he superior and middle temporal convolutions. Branches from the anterior cerebral lso supply the corpus callosum (fig. 503).

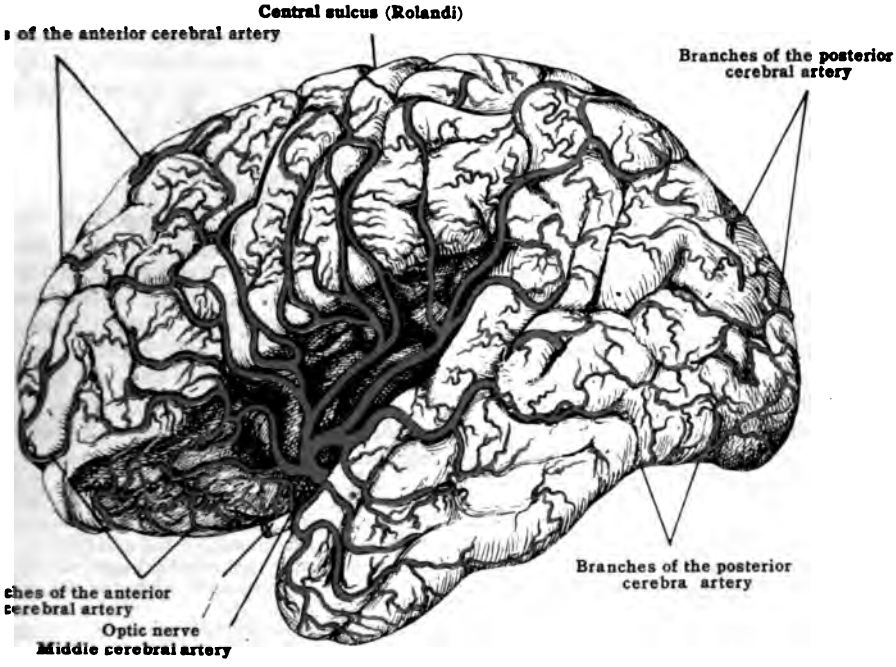
middle cerebral artery gives off most of the branches to the basal ganglia and supplies ter part of the lateral surface of the brain. It runs through the lateral fissure (fissure ns) (fig. 504). The *branches* of the middle cerebral include the following:

central branches are:—(i) The **caudate,** two or three small branches, which arise from lial aspect of the artery and pass through the medial part of the floor of the lateral fissure of Sylvius) to the head of the caudate nucleus. (ii) The **anterolateral** are numerous rteries which pass through the anterior perforated substance and supply the caudate (except its head), the internal capsule, and part of the optic thalamus. (iii) The **ostriate,** a larger branch of the anterolateral set, passes through a separate aperture in ral part of the anterior perforated substance, runs upward between the lenticular nucleus, t supplies, and the external capsule, perforates the internal capsule, and terminates in the nucleus. It has been so frequently found ruptured in apoplexy that it is called by t the 'artery of cerebral hemorrhage.' (iv) Sometimes a more or less distinct branch, **enticulo-optic,** is distributed to the lateral and hinder portion of the lenticular nucleus lateral portion of the optic thalamus.

cortical branches come off opposite the insula. They supply the insula, the inferior gyri, the central gyri (anterior and posterior), the parietal lobules, superior and infe- supramarginal, angular, and superior temporal gyri.

posterior cerebral give off both central and cortical branches. The **central branches posteromedial,** posterior choroid, and the posterolateral. The **posteromedial** enter the r perforated substance and supply the medial portion of the optic thalamus, and the

4.—The Arteries of the Lateral Surface of the Brain. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)


Central sulcus (Rolandi)
of the anterior cerebral artery
Branches of the posterior cerebral artery
Branches of the posterior cerebra artery
ches of the anterior cerebral artery
Optic nerve
Middle cerebral artery

f the third ventricle; the **posterior choroid** pass through the transverse fissure to the tela idea (velum interpositum) and chorioid plexus; the **posterolateral** run to the posterior f the optic thalamus and give branches to the cerebral peduncles and the corpora gemina.

e cortical branches of the posterior cerebral supply the entire occipital lobe and all of the ral lobe except the superior temporal gyrus (fig. 503).

regard to the cerebral arteries in general it may be said that there is no anastomosis en the cortical and central branches, the two forming distinct and separate systems. rtical may or may not anastomose with each other, but the communication between the oring cortical branches is seldom sufficient to maintain the nutrition of an area when sel that normally supplies it is obstructed. The central branches are so-called end- and do not anastomose with each other. Hence obstruction of the middle cerebral leads to softening of the area supplied by its central branches, but not always to softening region supplied by its cortical branches. Indeed, the cortical region may escape com-, although the central area is irreparably disorganized. The gross anastomosis of the ior cerebral with the anterior cerebral arteries through the circulus arteriosus has already lescribed (p. 596). To sum up the distribution of the cerebral arteries, the branches of are divided into the central, or ganglionic and the peripheral or cortical. The central

branches arise at the commencement of the cerebral arteries about the circulus arterio the cortical are derived chiefly from the termination of these vessels.

(A) The **central branches** are divided into four sets—two medial and two la The **two medial** are—(1) The **anteromedial,** which arise from the anterior cerebral anterior communicating, and supply the fore end of the caudate nucleus, and (2) the **medial,** which arise from the posterior cerebral and supply the medial part of the optic and neighboring wall of the third ventricle. 2. The **two lateral** are:—(1) The **ante** arise from the middle cerebral, and, passing through the anterior perforated substanc the lenticular nucleus, the posterior part of the caudate nucleus, the internal and capsules, and the lateral part of the optic thalamus. (2) The **posterolateral** arise posterior cerebral, and supply the hinder part of the optic thalamus, the pedunculus cer the corpora quadrigemina.

(B) The **cortical branches** ramify in the pia mater, giving off branches to the cort stance, some of which extend through it to the underlying white substance.

It will be seen that the middle cerebral supplies the somesthetic area of the co also supplies the cortical auditory center, and, in part, the higher visual center. The cerebral supplies only a small part of the somesthetic area, namely, the part of the l that occupies the paracentral lobule and the highest part of the anterior central gyr posterior cerebral supplies the visual path from the middle of the tract backward, and vision center in the occipital lobe. It supplies also the corpora quadrigemina and the part of the internal capsule.

The branches which supply the cerebellum and brain stem are described in connect the vertebrals on page 601.

2. THE THYROCERVICAL TRUNK

The **thyrocervical trunk** [truncus thyreocervicalis] or **thyroid axis** aris the upper and front part of the subclavian artery, usually opposite the i mammary, and near the medial margin of the scalenus anterior. It is thick trunk, and divides almost immediately into three radiating bra namely, the **inferior thyroid,** the **transverse scapular,** and the **transverse** figs. 489, 501). It may give off also the **ascending cervical.**

THE INFERIOR THYROID ARTERY

The **inferior thyroid** artery [a. thyreoidea inferior] is the largest of th branches into which the thyrocervical trunk (thyroid axis) divides, a arise in a common trunk with the transverse scapular, or as a direct branc subclavian. It ascends tortuously passing medially in front of the v artery, the recurrent (laryngeal) nerve and the longus colli muscle, and the common carotid and the sympathetic nerve or its middle cervical g to the thyroid gland, where it anastomoses with the superior thyroid art the inferior thyroid of the opposite side.

The branches of the inferior thyroid artery are:—(1) Muscular; (2) eso and pharyngeal; (3) tracheal; (4) inferior laryngeal; (5) glandular; and cending cervical.

(1) The **muscular** branches supply the scalenus anterior, longus colli, sternohyoid thyroid, and omohyoid muscles, and the inferior constrictor muscle of the pharynx.

(2) The **esophageal and pharyngeal** branches [rami œsophagei et pharyngei] of th thyroid artery supply the esophagus and pharynx and anastomose with the othe supplying those structures.

(3) The **tracheal** branches [rami tracheales] ramify on the trachea, where they an with the tracheal branches of the superior thyroid and bronchial arteries.

(4) The **inferior laryngeal** artery [a. laryngea inferior] passes along the trachea to of the cricoid cartilage in company with the recurrent (laryngeal) nerve. It enters t beneath the inferior constrictor. Its further distribution in that organ is descri LARYNX.

(5) The **glandular** branches [rami glandulares] supply the thyroid gland.

(6) The **ascending cervical** artery [a. cervicalis ascendens] (figs. 489, 501) is given the thyrocervical trunk or from the inferior thyroid as that vessel is passing beneath th sheath. It ascends between the scalenus anterior and the longus capitis (rectus capiti major), lying parallel and medial to the phrenic nerve and behind the internal jug It anastomoses with the vertebral, ascending pharyngeal, and occipital arteries, and branches to the deep muscles of the neck [rami musculares], to the spinal canal [rami and to the phrenic nerve. Two veins accompany the ascending cervical artery and e innominate vein.

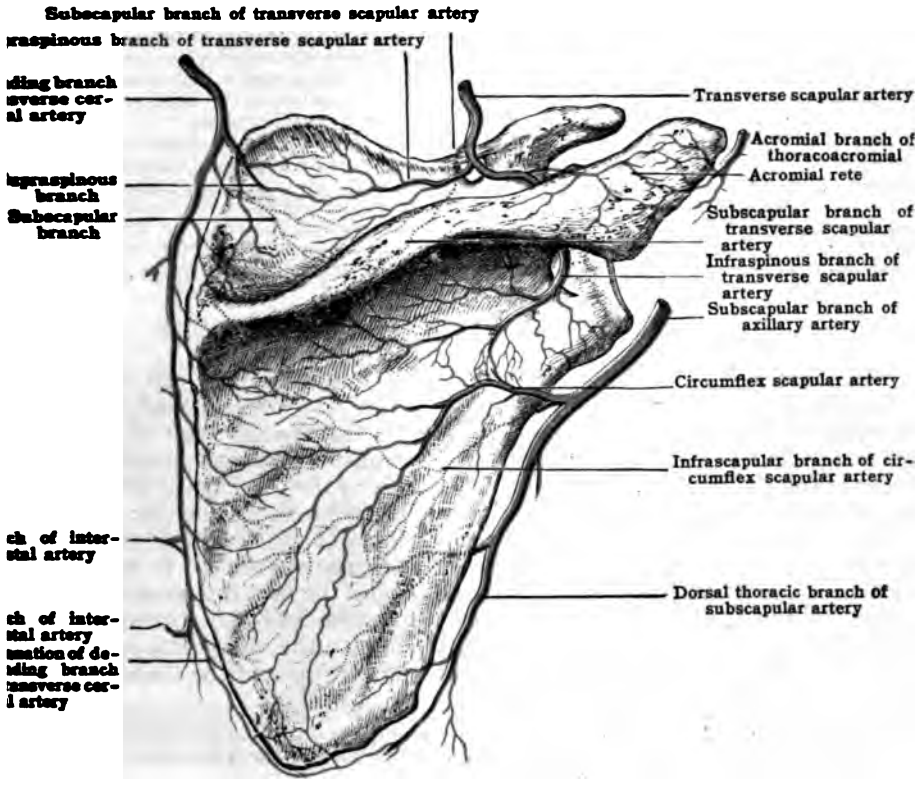
THE TRANSVERSE SCAPULAR ARTERY

The **transverse scapular** or suprascapular [a. transversa scapulæ] arter laterally across the root of the neck, lying first beneath the sternomast

n the subclavian triangle behind the clavicle and subcalvius muscle. At teral angle of this space it is joined by the suprascapular nerve, sinks th the posterior belly of the omohyoid, and passes over the ligament bridge scapular notch, the nerve passing through the notch (fig. 505). It then es in the supraspinous fossa of the scapula, and, winding downward round ne of the spine over the neck of the scapula, enters the infraspinous fossa, erminates by anastomosing with the circumflex (dorsal) scapular artery, he descending branch of the transverse cervical (posterior scapular) artery.

it lies under cover of the sternomastoid muscle, it crosses the phrenic nerve and the ns anterior; and as it courses through the subclavian triangle, it is separated by the cervical which descends from the omohyoid to the first rib, from the subclavian artery and brachial of nerves. It is one of the chief vessels by which the collateral circulation is carried on igature of the subclavian in the third part of its course. At the lateral part of the sub- triangle it is covered by the trapezius, and after passing over the transverse scapular nt it pierces the supraspinous fascia and passes beneath the supraspinatus muscle, rami- between it and the bone. In the infraspinous fossa it lies between the infraspinatus and ne. The artery is accompanied by two veins.

505.—Scheme of Anastomoses of the Right Scapular Arteries. (Walsham.)



he branches of the transverse scapular are:—(1) the nutrient, to the clavicle; (2) the mial [ramus acromialis] to the arterial rete or plexus on the acromial process, to reach h it pierces the trapezius; (3) the articular, to the acromioclavicular joint and shoulder-; (4) the subscapular, given off as the artery is passing over the transverse scapular ment, descends to the subscapular fossa between the subscapularis and the bone, and tomoses with the infrascapular branch of the circumflex (dorsal) scapular artery, and with ubscapular and transverse cervical arteries; (5) the supraspinous branches, which ramify he supraspinous fossa, and supply the supraspinatus muscle and the periosteum, and the ient artery to the bone; (6) the infraspinous branches, which ramify in a similar way in infraspinous fossa, giving off twigs to the infraspinatus muscle, the periosteum, and the

THE TRANSVERSE CERVICAL ARTERY

The transverse cervical artery [a. transversa colli], somewhat larger than the sverse scapular (suprascapular), runs like the latter vessel laterally across oot of the neck, but on a slightly higher transverse plane, and a little above the

clavicle. At its origin from the thyrocervical trunk (thyroid axis) it lie the sternomastoid; on leaving the cover of this muscle, it crosses the upp of the subclavian triangle, lying here only beneath the platysma and c fascia; further laterally, it passes beneath the anterior margin of the trape omohyoid muscle, and at the lateral margin of the levator scapulæ divide descending (posterior scapular) and an ascending (superficial cervical) l In this course it crosses the phrenic nerve, the scalenus anterior, the b plexus, and the scalenus medius. Sometimes it passes between the cord brachial plexus.

The **branches of the transverse cervical artery** are:—(1) a descendin terior scapular); and (2) an ascending (or superficial) cervical. The d ing branch occasionally arises from the third portion of the subclavian ar

(1) The **descending branch, or posterior scapular** [ramus descendens] the apparent c tion of the transverse cervical artery, begins at the lateral border of the levator scap continuing its course beneath this muscle to the medial angle of the scapula, turns d and skirts along the vertebral border of the bone, between the serratus anterior (mu front and the levator scapulæ and rhomboideus minor and major behind, to the inferi where it anastomoses with the subscapular artery. It gives off the following branc **Supraspinous**, which ramifies between the supraspinous muscle and the trapezius, a branches through the muscle into the fossa, to anastomose with the transverse scapula (*b*) **Infraspinous** branches, one or more of which enter the infraspinous fossa, and an with the circumflex (dorsal) scapular. (*c*) **Subscapular** branches, which enter the sul fossa, and anastomose with the branches of the transverse scapular and subscapular (*d*) **Muscular** branches, to the muscles between which it runs and to the latissimus dorsi branches anastomose with muscular branches of the intercostal arteries.

(2) The **ascending branch** or **superficial cervical artery** [r. ascendens], smaller descending branch, ascends under the anterior margin of the trapezius, lying upon th scapulæ and splenius muscles. It supplies branches to the trapezius, levator scap splenius muscles, and the posterior chain of lymphatic glands. It anastomoses superficial ramus of the descending branch of the occipital between the splenius a spinalis capitis (complexus). It is accompanied by two veins. This artery may aris from the thyrocervical trunk, or from the third part of the subclavian artery.

3. THE INTERNAL MAMMARY ARTERY

The **internal mammary** artery [a. mammaria interna] (figs. 501, 506) c from the lower part of the first portion of the subclavian, usually oppo thyrocervical trunk (thyroid axis), close to the medial edge of the s anterior. It descends with a slight inclination forward and medialward cover of the clavicle, and enters the thorax behind the cartilage of the first thence passes down behind the cartilages of the next succeeding ribs, about (½ in.) from the lateral margin of the sternum, to the sixth interspace, divides into the **superior epigastric** and the **musculophrenic.** It is acco by two veins, which unite into one trunk behind the first intercostal mus passes to the medial side of the artery to open into the correspondi innominata, or occasionally on the right side into the vena cava superic artery may be divided into two portions, the *cervical* and the *thoracic.*

The **cervical portion** is covered by the sternomastoid muscle, subclavian vein, an jugular vein, and is crossed obliquely, in the lateromedial direction, by the phrenic r rests upon the pleura and courses around the upper part of the innominate vein. no branch from this part of the artery.

The **thoracic portion** lies behind the cartilages of the six upper ribs, and in the i between the ribs has in front of it the pectoralis major and the internal intercost and external intercostal ligaments. Behind, it is in contact above with the pleura separated from it lower down by slips of the transversus thoracis (triangularis ste the left side, the artery between the fourth and sixth ribs may be said to be in th mediastinum, the pleura here forming a notch for the heart. In the first, second, spaces the artery, if wounded, can easily be tied; but in the fourth space the opera tended with more difficulty. The remaining spaces are so narrow that a portion of th would have to be removed to expose the vessel.

The **branches of the internal mammary artery** (fig. 501) are:—(1) T cardiophrenic; (2) the anterior mediastinal and thymic; (3) the bronc the pericardiac; (5) the sternal; (6) the anterior intercostals; (7) the per (8) the lateral costal; (9) the superior epigastric; and (10) the musculop

(1) The **pericardiophrenic** artery [a. pericardiophrenica], is a long slender ves comes off from the internal mammary just after it has entered the chest, and desc the phrenic nerve, at first between the pleura and innominate vein; then (on the r

...een the pleura and the vena cava superior; and lastly, between the pleura and the peri-...um to the diaphragm, where it anastomoses with the other diaphragmatic arteries. It ... branches both to the pleura and pericardium.

(2) The anterior mediastinal and thymic arteries [aa. mediastinales anteriores et thymicæ] ... off irregularly from the internal mammary. They are of small size, and supply the con-...ive tissue, fat, and lymphatics in the superior and anterior mediastina and the remains of ... thymus gland.

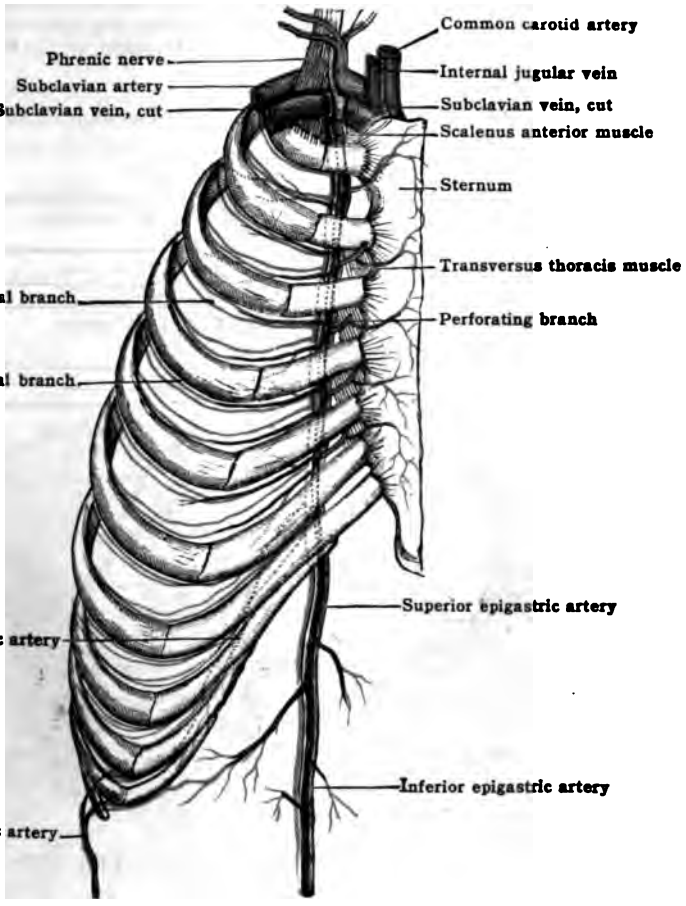
(3) The bronchial branches [rami bronchiales] are often wanting. When present they are ...plied to the bronchi and the lower part of the trachea.

(4) The pericardiac branches are distributed to the anterior surface of the pericardium.

(5) The sternal branches [rami sternales] enter the nutrient foramina in the sternum, and ...o supply the transversus thoracis (triangularis sterni).

(6) The anterior intercostal branches [rami intercostales] (figs. 507, 518)—two in each of ... five or six upper intercostal spaces—run laterally from the internal mammary artery, ...ng the lower border of the rib above and the upper border of the rib below, and anastomose

FIG. 506.—THE RIGHT INTERNAL MAMMARY ARTERY. (Walsham.)



with the corresponding anterior and collateral branches of the aortic intercostals. The pair of branches for each intercostal space sometimes arises by a common trunk. The branches lie at first between the internal intercostal muscles and the pleura; afterward between the external and internal intercostal muscles. They supply the contiguous muscles, the pectoralis major, and the ribs.

(7) The perforating or anterior perforating branches [rami perforantes]—five or six in number, one corresponding to each of the five or six upper spaces—come off from the front of the internal mammary, and, perforating the internal intercostal muscles, pass forward between the costal cartilages to the pectoralis major, which they supply [*rami musculares*]. The terminal twigs perforate the muscle close to the sternum, and are distributed to the integument [*rami cutanei*]. The second, third, and fourth perforating supply the medial and deep surfaces of the mammary gland, and become greatly enlarged during lactation [*rami mammarii*].

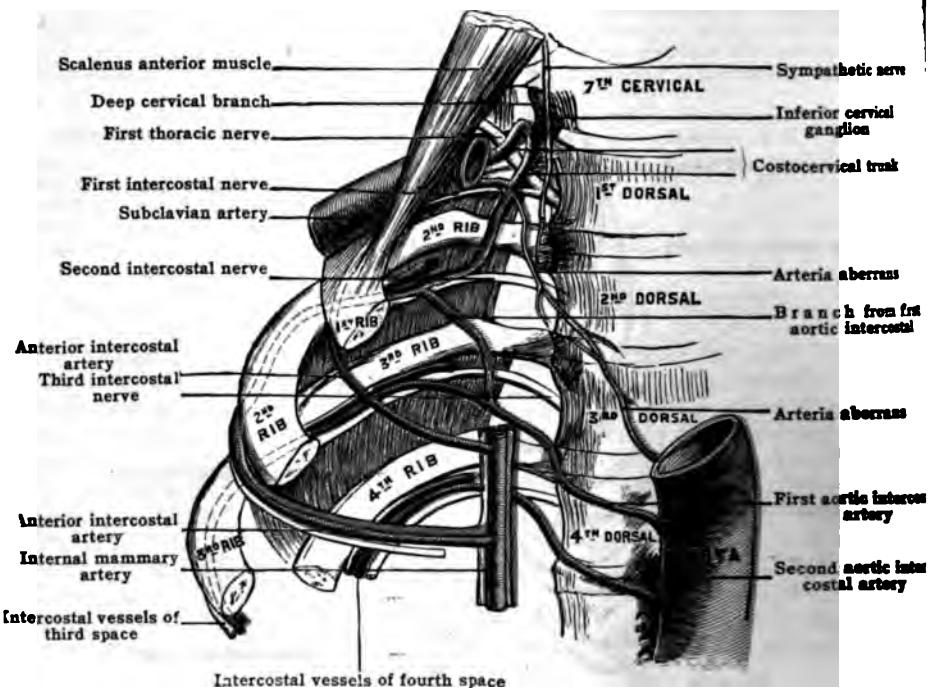
(8) The lateral costal branch [ramus costalis lateralis] is given off close to the first rib, and descends behind the ribs laterally to the costal cartilages. It anastomoses with the upper intercostal arteries. This vessel is often of insignificant size, or absent.

(9) The superior epigastric artery [a. epigastrica superior] (fig. 506), or medial terminal branch of the internal mammary artery, leaves the thorax behind the seventh costal cartilage

by passing through the costoxiphoid space in the diaphragm. It is the direct prolongation of the internal mammary downward. In the abdomen it descends behind the rectus muscle between its posterior surface and its sheath, and, lower, entering the substance of the muscle anastomoses with the inferior epigastric, a branch of the external iliac. It gives off the following small branches:—(*a*) The **phrenic**, to the diaphragm; (*b*) the **xiphoid**, which crosses in front of the xiphoid cartilage, and anastomoses with the artery of the opposite side; (*c*) the cutaneous, which perforate the anterior layer of the sheath of the rectus and supply the integument; (*d*) the **muscular**, to the rectus muscle, some of which perforate the rectus sheath laterally, and are distributed to the oblique muscles; (*e*) the **hepatic** (on the right side only), which passes up the falciform ligament to the liver, and anastomose with the hepatic artery; (*f*) the perforating, which perforate the posterior layer of the sheath of the rectus, and ramify on the peritoneum.

(10) The **musculophrenic** artery [a. musculophrenica], or **lateral terminal branch** of the internal mammary artery, skirts laterally and downward behind the costal cartilages of the false ribs along the costal attachments of the diaphragm, which it perforates opposite the ninth rib. It terminates, much reduced in size, at the tenth or eleventh intercostal space by anastomosing with the ascending branch of the deep circumflex iliac artery. It gives off in its course the following small branches:—(*a*) the **phrenic** for the supply of the diaphragm; (*b*) the **anterior intercostals**, two in number for each of the lower five or six intercostal spaces, which are distributed like those to the upper spaces, already described, and anastomose like them with the corresponding anterior branches of the lower aortic intercostals; (*c*) the **muscular** for the supply of the oblique muscles of the abdomen.

FIG. 507—THE RIGHT COSTOCERVICAL TRUNK. (Walsham.)



4. THE COSTOCERVICAL TRUNK

The **costocervical trunk** [truncus costocervicalis] (figs. 489, 507) is a short stem which arises usually from the back part of the second portion of the subclavian artery, behind the scalenus anterior on the right side, but commonly just medial to that muscle on the left side. Its course is upward and backward above the dome of the pleura and then downward to the thorax, before ending which it divides into its two terminal branches.

The **branches of the costocervical trunk** are:—(1) the superior intercostal and (2) the deep cervical.

(1) The **superior intercostal** [a. intercostalis suprema] (fig. 507) continues the direction of the costocervical trunk, passing downward into the thorax in front of the neck of the first rib. It sometimes terminates opposite the first intercostal space by becoming the first intercostal artery. Usually, however, it is prolonged downward over the neck of the second rib and supplies the second intercostal space in addition. It communicates with the highest aortic intercostal artery. As it crosses the neck of the first rib the superior intercostal lies upon the vena side of the first intercostal nerve and to the lateral side of the superior thoracic ganglion of sympathetic. The branches to the first and second intercostal spaces resemble in course

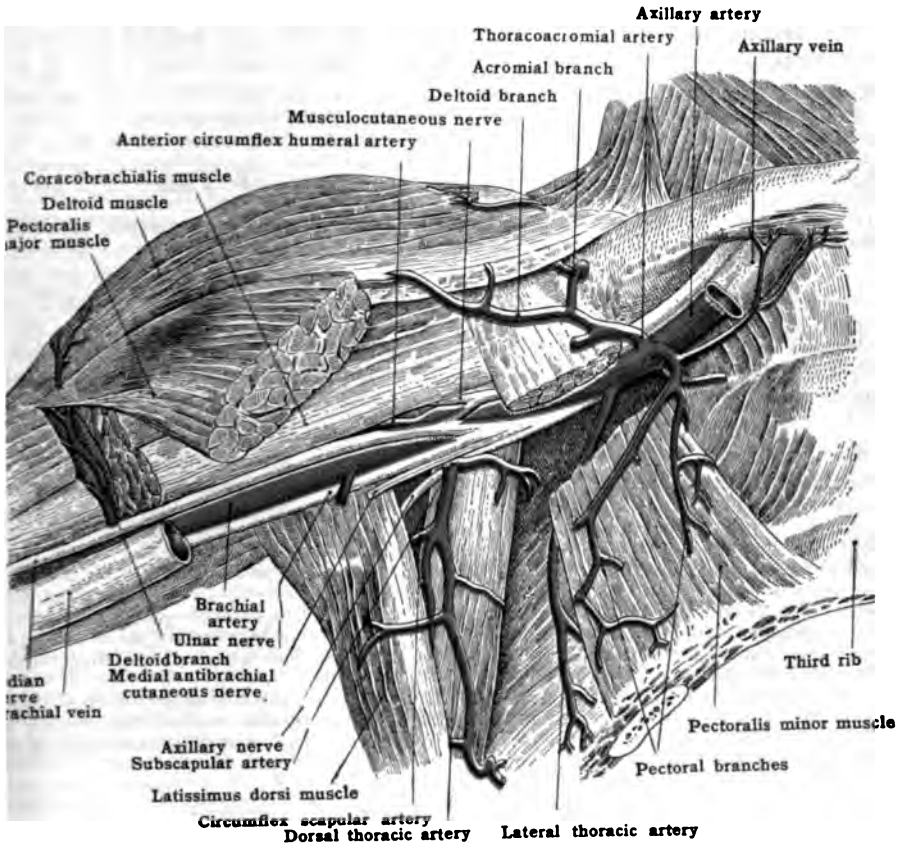
ution the succeeding intercostals derived from the thoracic aorta (see p. 625). Like the **intercostals** they give off **dorsal** [rr. dorsales] and **spinal branches** [rr. spinales]. An **arteria ima**, when present, arises from the medial side of the right superior intercostal, or from **ght** subclavian itself. It descends as a slender vessel into the thorax, passing downward **edially** behind the esophagus as far as the third or fourth thoracic vertebra, where in **cases** it anastomoses with a similar slender branch arising from the aorta below the liga**ım** arteriosum. This anastomosis represents the remains of the embryonic right dorsal

) **The deep cervical** artery [a. cervicalis profunda] passes directly backward, first between **venth** and eighth cervical nerves, and then between the transverse process of the seventh **al** vertebra and the neck of the first rib, having the body of the seventh cervical vertebra **medial** side, and the intertransverse muscle to its lateral side. It then turns upward **groove** between the transverse and spinous processes of the cervical vertebræ lying upon **emispinalis** colli and covered by the semispinalis capitis (complexus). Between these **les** it anastomoses with the deep branch of the descending branch (princeps cervicis) of **ecipital** artery. It gives off a spinal branch which enters the vertebral canal through **ıtervertebral** foramen with the eighth cervical nerve.

THE AXILLARY ARTERY

'he term axillary is applied to that portion of the main arterial stem of the **·r** limb that passes through the axillary fossa. The **axillary** artery [a. axillaris] 508) therefore is continuous with the subclavian above and with the brachial

FIG. 508.—THE AXILLARY ARTERY. (After Spaltcholz.)



w. It extends from the lateral border of the first rib to the lower edge of the **s** major muscle, and has the shoulder-joint and the neck of the humerus to **ateral** side. When the arm is placed close to the side of the body, the artery **ıs** a gentle curve with its convexity upward; but when the arm is carried out **ı** the side at right angles to the trunk in the ordinary dissecting position, the **els** takes a nearly straight course, which will then be indicated by a line drawn **ı** the middle of the clavicle to the groove on the medial side of the coraco-

in length.

Relations.—In front it is covered by the skin, superficial fascia, the lower part of th ysma, the deep fascia, the pectoralis major, the coracoclavicular (costocoracoid) fascia, th clavius muscle and by the clavicle when the arm hangs down by the side. The cephal thoracoacromial veins and the lateral anterior thoracic nerve, and the axillary lymphatic cross over it. A layer of the deep cervical fascia which has passed under the clavi descends in front of it.

Behind, it rests upon the first intercostal space and first intercostal muscle, the first tion and sometimes a portion of the second digitation of the serratus anterior (magnus) and a part of the second rib. The long thoracic nerve, on its way to the serratus a muscle, passes behind it. To its **lateral side,** and somewhat on a higher plane, are the the brachial plexus. To its **medial side,** and on a slightly anterior plane, is the axillar The medial anterior thoracic nerve courses between the vein and the artery.

The Second Part of the Axillary Artery

The **second part of the axillary artery** (fig. 508) lies behind the pec minor deep in the axilla. It measures 3 cm. (a little more than 1 in.) in l

Relations.—In front, in addition to the pectoralis minor, it is covered by the p major and the integument. **Behind** it is separated by a considerable interval, containi connective tissue and fat, from the subscapularis muscle; the posterior cord of the plexus lies immediately behind it. To the **medial side,** but separated from the artery medial cord of the brachial plexus, is the axillary vein. To the **lateral side** is the latera the brachial plexus, and at some little distance the coracoid process.

It is thus seen that the second portion of the axillary artery is surrounded on thr by the cords of the brachial plexus.

The Third Part of the Axillary Artery

The **third part of the axillary artery** (fig. 508) extends from the lower of the pectoralis minor to the lower border of the teres major. Its upper l deeply placed within the axilla, beneath the lower edge of the pectoralis muscle, but its lower half is not covered anteriorly by muscle. It m about 7.5 cm. (3 in.) in length.

Relations.—In front it has, in addition to the skin and superficial fascia, the p major above, and lower down the deep fascia of the arm. It is crossed obliquely by th root of the median nerve and by the lateral brachial vena comitans. **Behind,** it lie sively upon the subscapularis, the latissimus dorsi, and teres major muscles. From named muscle it is separated at first by a considerable mass of fat and cellular tissu radial (musculospiral) and axillary (circumflex) nerves intervene between the artery muscles. On its **lateral side** it is separated from the bone by the coracobrachialis, by w partly overlapped, this muscle and the short head of the biceps serving as a guide to th in ligature. For a part of its course it has also the musculocutaneous nerve and th

1. The **superior thoracic** [a. thoracalis suprema] is variously given off either directly from the axillary artery, or by a trunk common to it and to the thoracoacromial (see fig. 508). It passes behind the axillary vein across the first intercostal space, supplying the intercostal muscles and the upper portion of the serratus anterior, and anastomoses with the intercostal arteries. At times it sends a branch between the pectoralis major and minor, which then, as a rule, takes the place of the pectoral branch of the thoracoacromial.

2. The **thoracoacromial** or acromiothoracic axis [a. thoracoacromialis] arises from the first part of the axillary just above the upper border of the pectoralis minor. It is a short trunk, and, coming off from the front of the artery, pierces the coracoclavicular fascia, and then divides into three or four small branches, named from their direction:—(*a*) the acromial; (*b*) the deltoid; (*c*) the pectoral, and (*d*) the clavicular.

(*a*) The **acromial** branch [r. acromialis] passes laterally across the coracoid process, frequently through the deltoid muscle, which it supplies, and to the acromion. Here it forms by anastomosing with the anterior and posterior circumflex and transverse scapular (suprascapular) arteries, the so-called acromial rete, or plexus of vessels on the surface of the acromion (fig. 505).

(*b*) The **deltoid** branch [r. deltoideus] runs downward with the cephalic vein in the interval between the pectoralis major and the deltoid, and, supplying lateral offsets to these muscles and the adjacent integument, anastomoses with the anterior and posterior circumflex humeral arteries.

(*c*) The **pectoral** branch [r. pectoralis] passes between the pectoralis major and minor muscles, both of which it supplies. In the female, the branches which perforate the pectoralis major are often of large size, and supply the superimposed mammary gland.

(*d*) The **clavicular** branch passes upward beneath the clavicle, supplies the subclavius muscle, and anastomoses with the transverse scapular artery.

3. The **lateral thoracic** artery [a. thoracalis lateralis] descends along the lower border of the pectoralis minor, under cover of the pectoralis major, to the chest wall. It supplies both pectoral muscles and the serratus anterior (magnus), sends branches around the lower border of the pectoralis major to the mammary gland, and terminates in the intercostal muscles by anastomosing with the aortic intercostals and the internal mammary. It also furnishes branches to the lymph-nodes of the axillary fossa. The branches to the mammary gland in the female are often of large size.

4. The **subscapular** artery [a. subscapularis] is the largest branch of the axillary. It arises opposite the lower border of the subscapularis, and runs in a downward and medial direction along the anterior border of that muscle under cover of the latissimus dorsi. It supplies the subscapularis, teres major, latissimus dorsi, and serratus anterior (magnus) muscles, and gives branches to the nodes in the axillary fossa. It is accompanied by two veins, which usually unite and then receive the circumflex (dorsal) scapular vein, and open as a single vein of large size either into the axillary or at the confluence of the medial brachial vena comitans with the basilic vein.

About 2.5 or 3.7 cm. (1 or 1½ in.) from its origin, the subscapular artery divides into two end branches, (1) the circumflex (dorsal) scapular, and (2) the dorsal thoracic.

(1) The **circumflex scapular** artery [a. circumflexa scapulæ], or dorsal scapular, arising from the subscapular, usually at the point above mentioned, passes backward through the triangular space bounded by the subscapularis above, the teres major below, and the long head of the triceps laterally, and then between the teres minor and the axillary border of the scapula, which it commonly grooves. It thus reaches the infraspinous fossa, where, under cover of the infraspinatus, it anastomoses with the transverse scapular (suprascapular) artery and the descending branch of the transverse cervical (posterior scapular) (fig. 505). As it passes through the triangular space, it gives off a ventral branch which ramifies between the subscapularis and the bone, supplying branches to the subscapularis, to the scapula, and to the shoulder-joint. A second branch is often given off near the triangular space and passes downward between the teres major and teres minor, supplying both muscles (fig. 509).

(2) The **dorsal thoracic** artery [a. thoracodorsalis] continues in the course of the subscapular as far as the angle of the scapula, where it anastomoses with the circumflex scapular, the descending branch of the transverse cervical (posterior scapular), the lateral thoracic, and intercostal arteries.

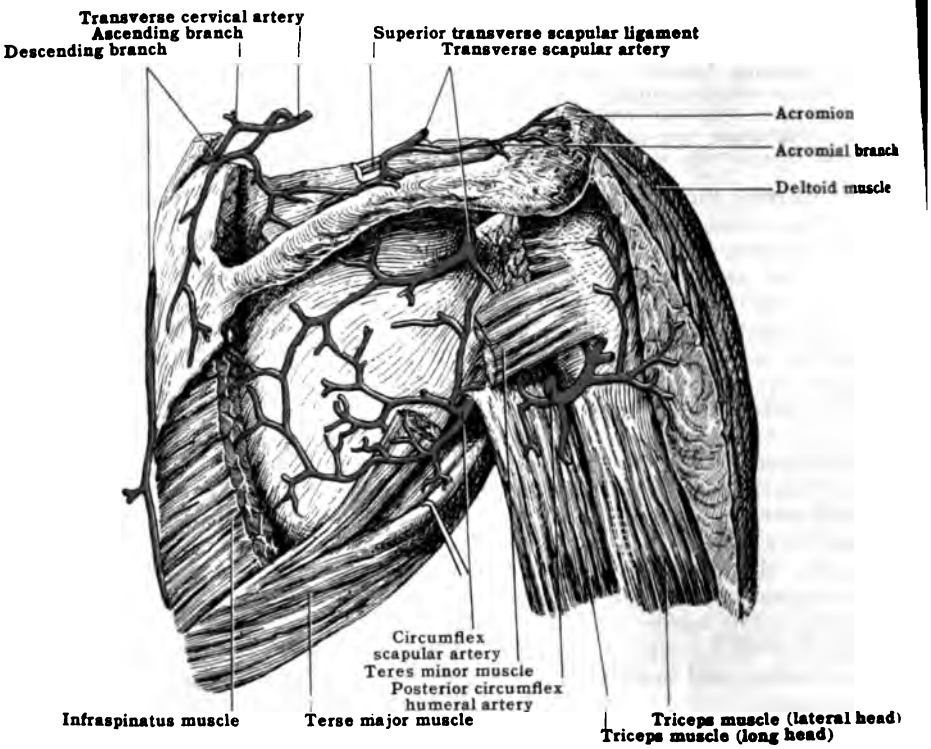
5. The **anterior circumflex humeral** artery [a. circumflexa humeri anterior], usually quite a small vessel, comes off from the lateral side of the axillary artery, generally opposite the posterior circumflex. It passes beneath the coracobrachialis and short and long heads of the biceps, winding transversely round the

front of the surgical neck of the humerus, across the intertubercular (bicipital) groove, and anastomoses with the posterior circumflex and thoracoacromial arteries. It gives off the following small branches:

(*a*) The **bicipital** or ascending, which runs up the intertubercular groove to supply the long tendon of the biceps and the shoulder-joint; and (*b*) a **pectoral** or descending branch, which runs downward along the insertion of the pectoralis major, and supplies the tendon of that muscle.

6. The **posterior circumflex humeral** artery [a. circumflexa humeri posterior] (fig. 509) arises from the posterior aspect of the axillary, just below the lower border of the subscapularis muscle. It passes through the quadrilateral space, bounded by the teres minor above, the latissimus dorsi and teres major below, the humerus laterally, and the long head of the triceps medially, and, winding round the back of the humerus beneath the deltoid, breaks up under cover of that muscle into a leash of branches, which for the most part enter its substance. The axillary (circumflex) nerve and two venæ comitantes run with it. It anastomoses with the anterior circumflex, the arteries on the acromion, and the profunda artery.

FIG. 509.—THE ARTERIES OF THE SHOULDER. (After Spalteholz.)



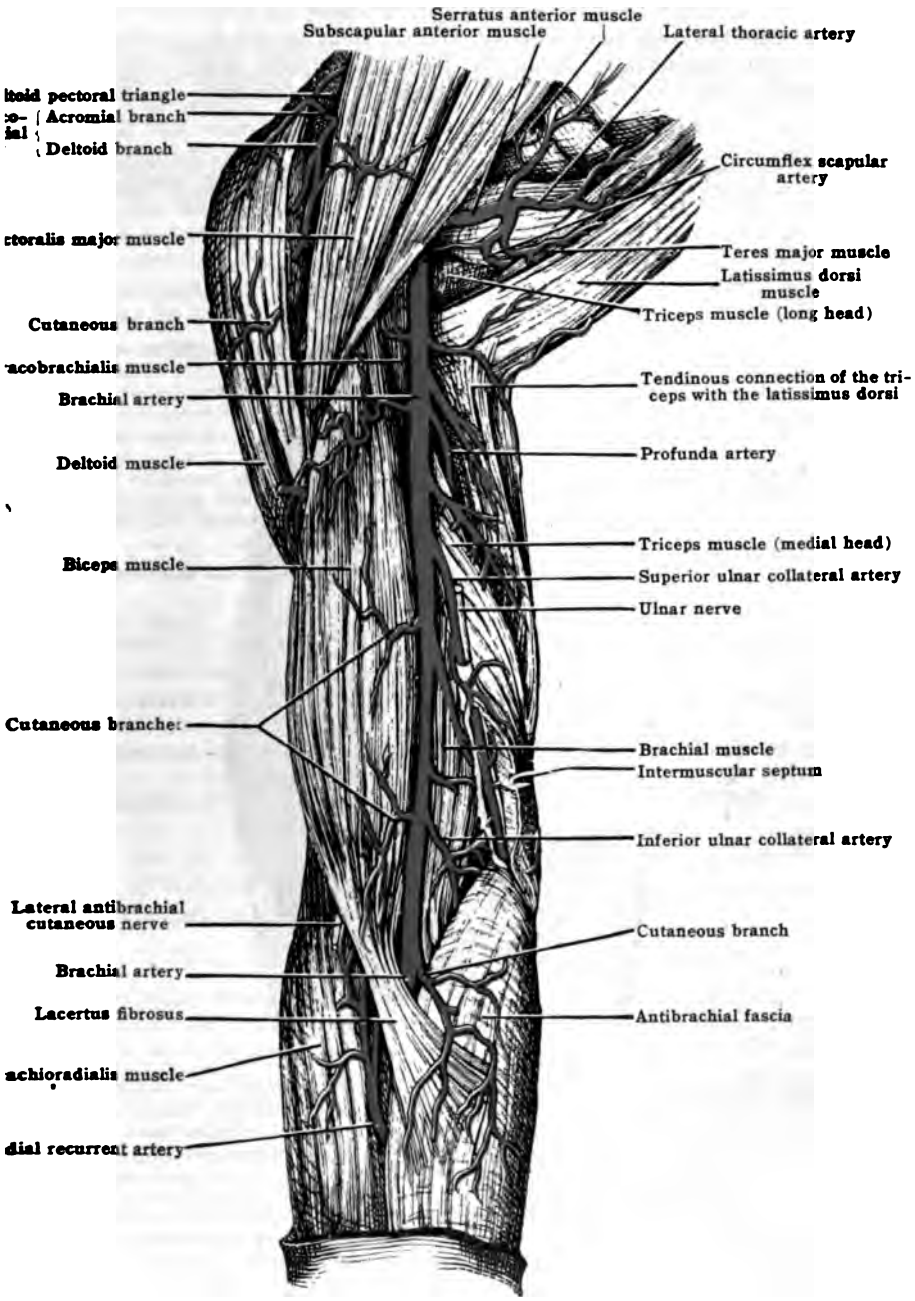
In addition to the leash of vessels to the deltoid, it gives off the following small branches —(*a*) **nutrient**, to the greater tuberosity of the humerus; (*b*) **articular**, to the back of the shoulder-joint; (*c*) **acromial**, to the plexus on the acromion; and (*d*) **muscular**, to the teres minor and long and short heads of the triceps. One or more of these branches to the triceps descend either between the lateral and long head or in the substance of that muscle, to anastomose with an ascending branch from the profunda artery. It is by means of this anastomosis that the collateral circulation is chiefly carried on when the axillary or the brachial artery is tied between the origins of the posterior circumflex and profunda arteries.

THE BRACHIAL ARTERY

The **brachial** artery [a. brachialis] (fig. 510), the continuation of the axillary extends from the lower border of the teres major to a little below the center of the crease at the bend of the elbow, where it divides, opposite the neck of the radius into the radial and ulnar arteries. The artery is at first medial to the humerus but as it passes down the arm it gradually gets in front of the bone, and at the

of the elbow it lies midway between the two epicondyles. Hence, in cong hemorrhage, the artery should be compressed laterally against the bone upper third, laterally and backward in its middle third, and directly back-

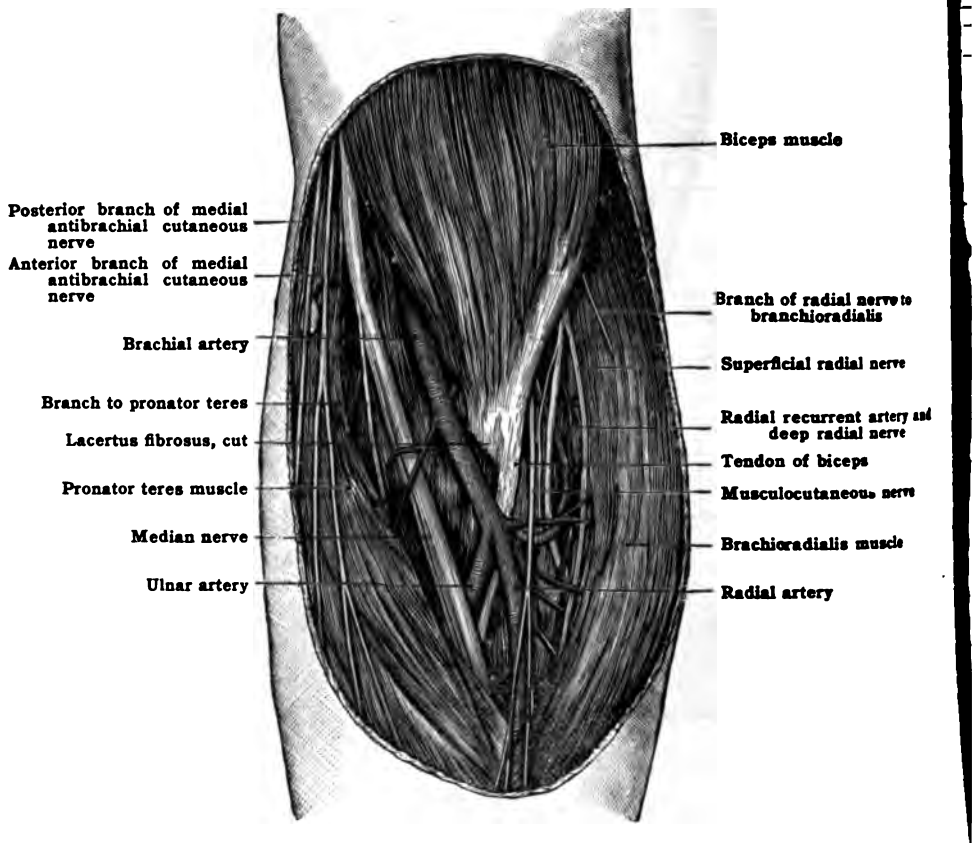
510.—The Brachial Artery. (After Toldt, 'Atlas of Human Anatomy,' Rebman London and New York.)



in its lower third. Throughout the greater part of its course the artery is ficial, being overlapped slightly on its lateral side by the coracobrachialis biceps muscles; but at the bend of the elbow it sinks deeply beneath the tus fibrosus of the biceps into the triangular interval (antecubital space)

between the brachioradialis and pronator teres, and at its bifurcation is more or less under cover of these muscles (fig. 511). The sheath of the brachial artery is closely incorporated with the fascia covering the biceps muscle. A line drawn from the groove on the medial side of the coracobrachialis and biceps muscles to a point midway between the epicondyles of the humerus will indicate its course. The brachial artery is accompanied by two veins which frequently communicate across it. In addition to the branches named below the artery gives off numerous muscular branches and, occasionally, the nutrient artery to the humerus. The muscular branches usually come off from the lateral side; one in particular, which supplies the biceps muscle, is frequently of large size.

FIG. 511.—THE BRACHIAL ARTERY AT THE BEND OF THE ELBOW, LEFT SIDE, FRONT VIEW
(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)



Relations.—**In front,** the artery is covered by the integument and superficial and deep fasciæ, and at the bend of the elbow by the lacertus fibrosus of the biceps, and in muscular subjects by the overlapping margins of the brachioradialis and pronator teres. In the middle third of the arm it is crossed obliquely from the lateral to the medial side by the median nerve, and at the bend of the elbow by the median cubital vein, the bicipital fascia intervening.

Behind, it lies successively on the long head of the triceps, from which it is separated by the radial (musculospiral) nerve and profunda artery, on the medial head of the triceps, on the insertion of the coracobrachialis, and thence to its bifurcation on the brachialis muscle.

Laterally the brachial artery is overlapped by the coracobrachialis above, and the muscular belly of the biceps below. The median nerve is in close contact with the lateral side of the artery in the upper third of its course, but in the middle third crosses the artery obliquely to gain the medial side. The tendon of the biceps lies laterally to the artery in its lower portion.

Medial to the artery in the upper part of its course are the medial antibrachial (internal) cutaneous and the ulnar nerves; the latter nerve, however, leaves the artery about the origin of the ulnar collateral (inferior profunda) branch, to pass, with that vessel, to the medial epicondyle. Lower down, the medial antibrachial cutaneous nerve also leaves the artery, by piercing the deep fascia. The median nerve is in close contact with the medial side of the artery in its lower third and at the bend of the elbow. The basilic vein is superficial to it, and a little to its medial side in the greater part of its course, but separated from it by the deep fascia. The brachial artery is accompanied by two or more venæ comitantes.

Branches of the Brachial Artery

The branches of the brachial artery are: (1) The profunda brachii; (2) the erior ulnar collateral (inferior profunda); (3) the inferior ulnar collateral astomotica magna); and (4) the terminal branches—the radial and ulnar ries.

(1) The Profunda Artery

The profunda brachii (superior profunda) is the largest branch of the brachial. rises from the medial and posterior aspect of the artery, a little below the infe- border of the tendon of the teres major. It at first lies to the medial side he brachial, but soon passes behind that vessel, and, sinking between the lial and long heads of the triceps with the radial (musculospiral) nerve, curves und the humerus in the groove for the nerve, lying between the bone and the ral head of the triceps. On reaching the lateral supracondyloid ridge of the nerus it perforates the lateral intermuscular septum, and, continuing forward ween the brachioradialis and brachialis to the front of the lateral epicondyle, s by anastomosing with the radial recurrent artery (figs. 510, 514). For stomoses, see fig. 1126.

It gives off the following branches:

(*a*) The **deltoid branch** [r. deltoideus] which may, however, arise from the brachial itself or n the superior ulnar collateral. It runs across the anterior surface of the humerus, under er of the coracobrachialis and biceps, and supplies the brachialis and deltoid.

(*b*) The **medial collateral artery** [a. collateralis media] runs in the substance of the medial d of the triceps as far as the elbow, where it often terminates in the articular rete.

(*c*) The **radial collateral artery** [a. collateralis radialis] arises about the middle of the upper ı. and runs behind the lateral intermuscular septum to the rete at the elbow-joint.

(*d*) A **nutrient humeral artery** [a. nutritia humeri], which may come from the brachial lf or from a muscular branch, enters a canal above and to the medial side of the sulcus for radial nerve.

(2) The Superior Ulnar Collateral Artery

The **superior ulnar collateral** artery [a. collateralis ulnaris superior] (inferior ofunda) arises from the medial side of the brachial, usually about the level of e insertion of the coracobrachialis, sometimes from a trunk common to it and the profunda brachii. It passes with the ulnar nerve medially and down- ırd through the medial intermuscular septum, and then along the medial head the triceps to the back of the medial epicondyle, where, under cover of the ep fascia and the origin of the flexor carpi ulnaris from the olecranon and dial epicondyle, it enters into the anastomoses around the elbow-joint. It quently supplies the nutrient artery to the humerus. It gives branches to the ceps, to the elbow-joint, and a branch which passes in front of the medial condyle to anastomose with the volar ulnar recurrent.

(3) The Inferior Ulnar Collateral Artery

The **inferior ulnar collateral** artery [a. collateralis ulnaris inferior] or anasto- tica magna arises from the medial side of the brachial, about 5 cm. (2 in.) above bifurcation into the radial and ulnar arteries, and, running medially and down- d across the brachialis, divides into two branches, a posterior and an anterior. **posterior** pierces the medial intermuscular septum, winds round the medial racondylar ridge of the humerus, and pierces the triceps, between which and bone it anastomoses with the articular branch of the profunda artery, and lesser extent with the interosseous recurrent, forming an arterial arch or rete ınd the upper border of the olecranon fossa. The **anterior** branch passes lially and downward between the brachialis and pronator teres, and anas- oses in front of the medial epicondyle, but beneath the pronator teres, with volar ulnar recurrent. From this branch a small vessel passes down behind medial epicondyle to anastomose with the dorsal ulnar recurrent and superior ır collateral arteries (fig. 514).

THE ULNAR ARTERY

The ulnar artery [a. ulnaris] (figs. 512 and 515), the larger of the two terminal ıches of the brachial, begins opposite the neck of the radius in the middle of the forearm. Thence through the proximal half of the forearm it runs

beneath the pronator teres and superficial flexor muscles, and, having reached the ulnar side of the forearm about midway between the elbow and the wrist, it passes directly downward, being merely overlapped by the flexor carpi ulnaris. Crossing the transverse carpal (anterior annular) ligament immediately to the radial side of the pisiform bone, it enters the palm, where it divides into two branches, which enter respectively into the formation of the superficial and deep volar arches. The artery is accompanied by two veins, which anastomose with each other by frequent cross-branches, and usually terminate in the brachial venæ comitantes. The ulnar nerve is at first some distance from the artery, but approaches the vessel at the junction of its proximal and middle thirds, and then lies close to its medial or ulnar side. The course of the artery in the distal two-thirds of the forearm is indicated by a line drawn from the front of the medial epicondyle to the radial side of the pisiform bone; and in the proximal third of the forearm by a line drawn in a gentle curve with its convexity to the medial side from 2.5 cm. (1 in.) below the center of the bend of the elbow to a point in the former line at the junction of its proximal and middle thirds. The artery throughout its course is best reached through the interval between the flexor carpi ulnaris and the flexor digitorum sublimis.

The relations of the artery will be given in detail in the forearm, and in the palm of the hand. The **relations in the forearm** are:

In front.—In the proximal half of the forearm the ulnar artery is deeply placed beneath the pronator teres, the flexor carpi radialis, the palmaris longus, and the flexor digitorum sublimis. In the distal half it is comparatively superficial, being merely overlapped above by the tendon of the flexor carpi ulnaris, while the last inch or so of the vessel is only covered as a rule by the skin and superficial and deep fasciæ. As the artery lies beneath the pronator teres, it is crossed from the medial to the lateral side by the median nerve, the deep head of origin of the muscle usually separating the nerve from the artery. The distal part of the artery is crossed by the palmar cutaneous branch of the ulnar nerve.

Behind.—For about 2.5 cm. (1 in.) of its course the artery lies upon the brachialis; but thence, as far as the transverse carpal (anterior annular) ligament, upon the flexor digitorum profundus, which separates it above from the interosseous membrane and bone, and at the wrist from the pronator quadratus. The artery is bound down to the flexor digitorum profundus by bands of fascia. To the **lateral side** in the distal two-thirds of its course is the flexor digitorum sublimis. To the **medial side** in the distal two-thirds is the flexor carpi ulnaris, the guide to the vessel. The ulnar nerve, as it enters the forearm from behind the medial epicondyle, is at first some distance from the artery, being separated from it in its proximal third by the flexor digitorum sublimis; but in its distal two-thirds is in close contact with the vessel on its ulnar side.

The **branches of the ulnar artery in the forearm** are: 1. The ulnar recurrent arteries. 2. The common interosseous. 3. Muscular. 4. Dorsal ulnar carpal. 5. Volar ulnar carpal.

1. The **ulnar recurrent** arteries [aa. recurrentes ulnares] are two, the volar, and dorsal. The *volar* is a small branch which arises from the medial side of the ulnar artery, or from the dorsal ulnar recurrent, and, running between the lateral edge of the pronator teres and the brachialis, anastomoses in front of the medial epicondyle with the inferior and superior ulnar collaterals. It supplies branches to the muscles between which it runs, and to the skin. The *dorsal*, larger than the volar, comes off from the medial side of the ulnar artery, either a little beyond the latter branch, or else as a common trunk with it, and, passing between the flexores digitorum sublimis and profundus, reaches the back of the medial epicondyle, where it lies with the ulnar nerve between the two heads of origin of the flexor carpi ulnaris. It supplies the contiguous muscles—the flexor carpi ulnaris, the palmaris longus, and the flexores digitorum sublimis and profundus—the elbow-joint, and the ulnar nerve, and anastomoses with the inferior and superior ulnar collaterals, and with the interosseous recurrent forming the so-called rete olecrani.

2. The **common interosseous** artery [a. interossea communis] is a short thick trunk 1.2 cm. ($\frac{1}{2}$ in.) or so in length, which comes off from the lateral and dorsal aspect of the ulnar artery about 2.5 cm. (1 in.) from its origin, and just before that artery is crossed by the median nerve. It passes backward and downward between the flexor pollicis longus and the flexor digitorum profundus, toward the triangular interval bounded by the upper border of the interosseous membrane, the oblique ligament, and the lateral border of the ulna, where it divides into the volar and dorsal interosseous arteries.

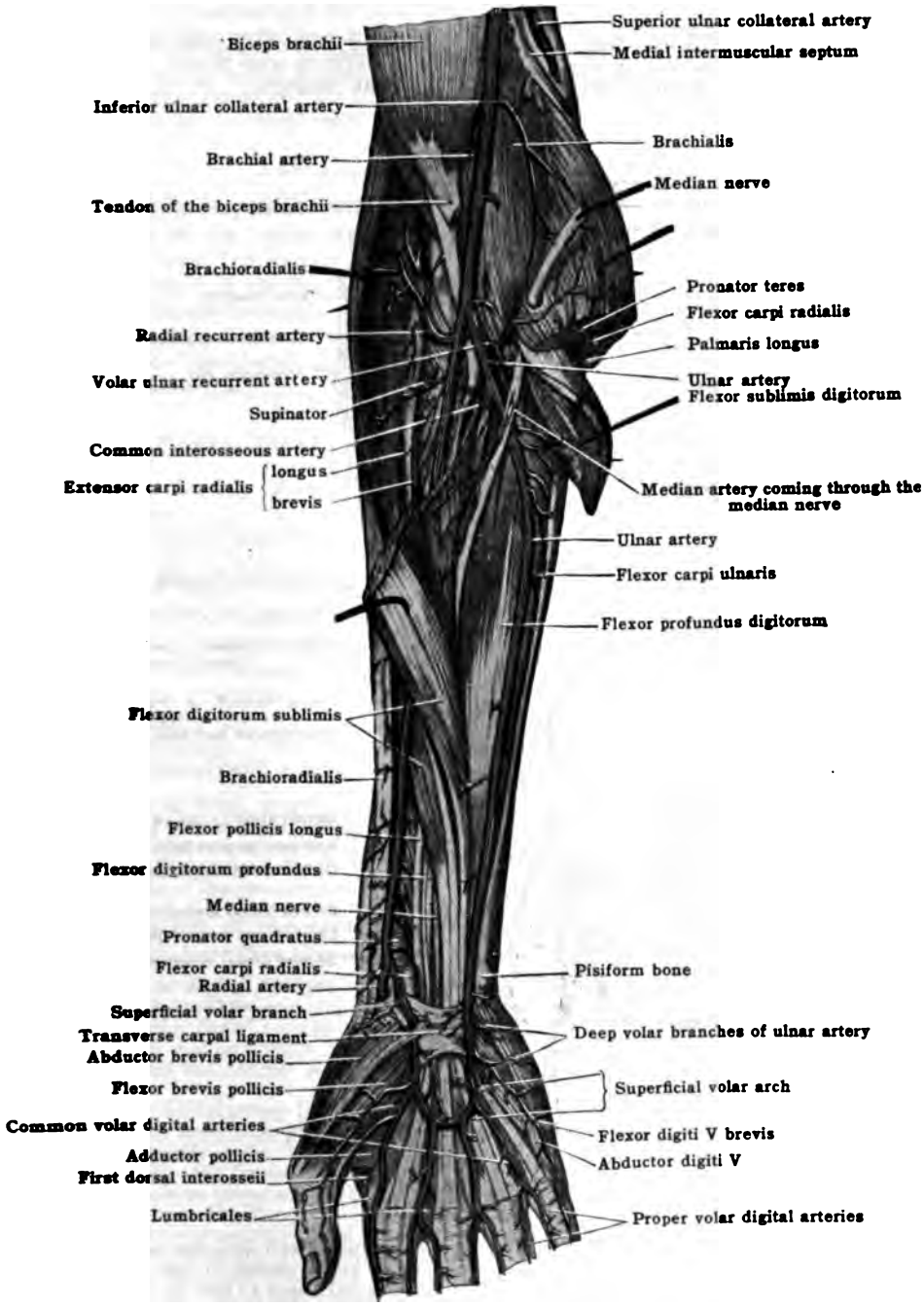
(*a*) The **volar interosseous** artery [a. interossea volaris], smaller than the dorsal, but apparently the direct continuation of the common trunk, passes distally in front of the interosseous membrane. It lies under cover of the overlapping edges of the flexor digitorum profundus and flexor pollicis longus, to both of which muscles it supplies branches. At the proximal border of the pronator quadratus it divides into two branches, the anterior and the posterior terminal (fig. 515).

The volar interosseous artery is accompanied by two veins and by the deep branch of the median nerve which lies to its radial side. The artery is bound down to the interosseous membrane by aponeurotic fibers.

The **branches of the volar interosseous artery** are: (i) The **median artery [a. mediana]** is a long slender vessel which arises from the proximal part of the artery. It passes forward

tween the flexor digitorum profundus and the flexor pollicis longus to the median nerve, with hich it descends beneath the transverse carpal (anterior annular) ligament into the palm, and en of large size sometimes enters into the formation of the superficial volar arch. At times e artery arises from the common interosseous. (ii) The **nutrient arteries** of the radius and na are usually derived from this vessel. (iii) The **volar terminal** division of the volar inter-

FIG. 512.—THE VOLAR ARTERIES OF THE FOREARM AND HAND. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

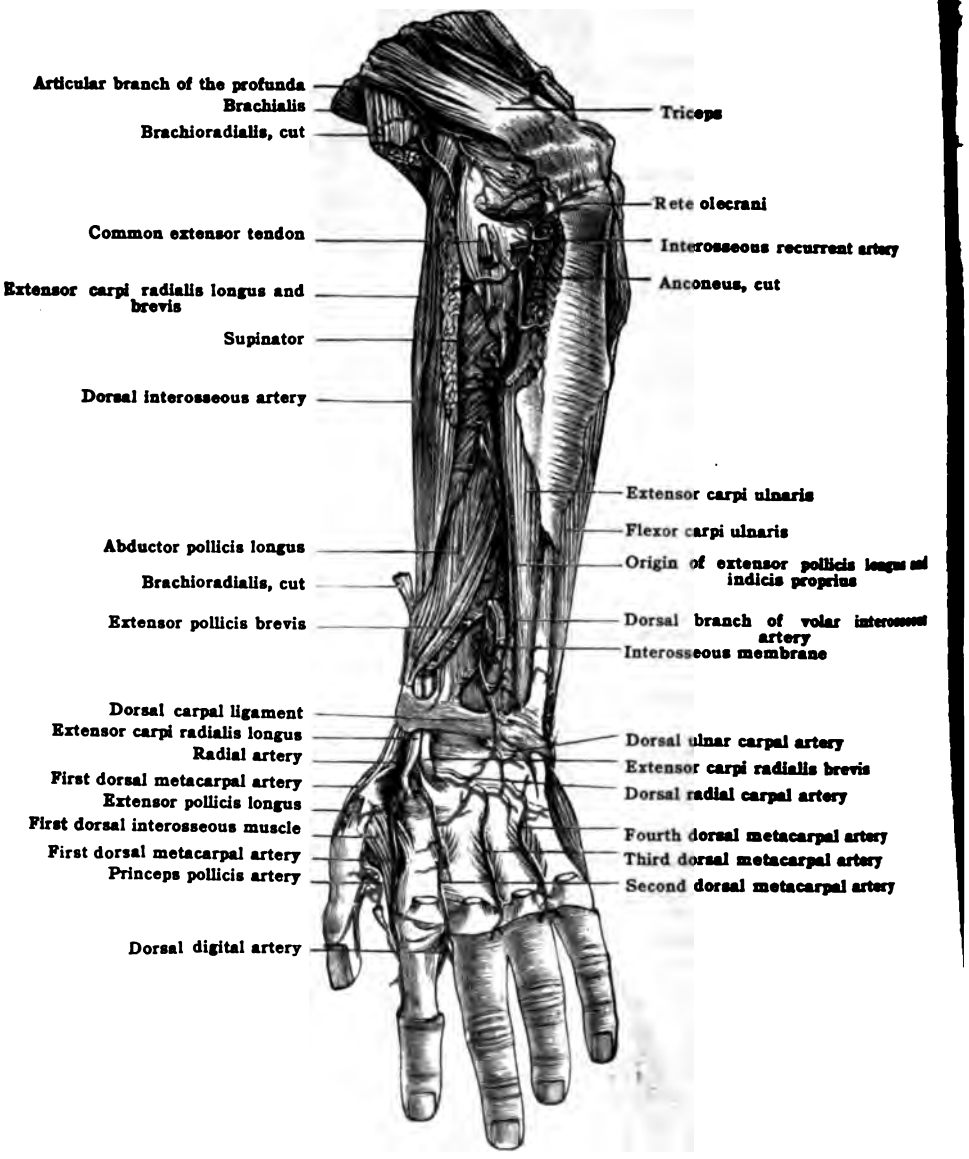


osseous artery passes either in front of or behind the pronator quadratus, but in either case in front of the interosseous membrane, and anastomoses with the volar carpal branches of the radial and ulnar arteries, and with the recurrent branches from the deep volar arch in the so-called **volar carpal rete.** (iv) **The dorsal terminal,** the larger division, pierces the interosseous membrane, and continues its course behind the interosseous membrane, under cover of the extensor muscles, to the back of the wrist, where it ends by anastomosing with the dorsal

carpal branches of the radial and ulnar arteries, in the so-called **dorsal carpal rete**. This branch anastomoses, as soon as it pierces the interosseous membrane, with the dorsal interosseous artery.

(*b*) The **dorsal interosseous** artery [a. interossea dorsalis], the larger division of the common interosseous, turns backward through the triangular interval bounded by the interosseous membrane, the oblique ligament, and the ulna. Emerging at the back of the forearm between the abductor pollicis longus and the supinator, under cover of the superficial extensors of the forearm, it passes between the superficial and the deep muscles, crossing the abductor pollicis longus, the extensor pollicis brevis, the extensor pollicis longus, and the extensor indicis pro-

FIG. 513.—THE BACK OF THE LEFT FOREARM, WITH THE DORSAL INTEROSSEOUS ARTERY AND BRANCHES OF THE RADIAL AT THE BACK OF THE WRIST.
(From a dissection in the Hunterian Museum.)



prius (fig. 513). It anastomoses with the dorsal carpal arteries and near the wrist joint, with the dorsal branch of the volar interosseous which here, as above described, has perforated the interosseous membrane. It is separated from the deep radial nerve at first by the radius and supinator, and on the back of the forearm by the extensores pollicis longus and indicis proprius.

The chief branch of the dorsal interosseous artery, the **interosseous recurrent artery** [a. interossea recurrens] arises from the dorsal interosseous as the latter emerges from beneath the supinator. It runs between the anconeus and supinator, usually under cover of the former, to the interval between the lateral epicondyle and the olecranon, where it anastomoses with the profunda, inferior ulnar collateral, radial recurrent, and dorsal ulnar recurrent arteries, and gives branches to the rete olecrani.

3. **The muscular** branches [rami musculares] are numerous. They supply the deep and superficial flexors of the fingers, the flexor carpi radialis and ulnaris, and the pronator radii teres.

4. **The dorsal ulnar carpal** [ramus carpeus dorsalis] comes off from the ulnar artery near the proximal border of the transverse carpal (anterior annular) ligament, and, winding medially round the end of the ulna or the ulnar collateral ligament of the wrist, beneath the flexor carpi ulnaris, ramifies on the back of the carpus beneath the extensor tendons. It forms by its anastomosis with the dorsal radial carpal, with the dorsal terminal branch of the volar interosseous and with the dorsal interosseous arteries a dorsal carpal arch or rete. The branches given off from the rete are described with the dorsal carpal branch of the radial artery.

5. **The volar ulnar carpal** [ramus carpeus volaris] is a small branch given off from the ulnar artery opposite the carpus. It passes beneath the flexor digitorum profundus to anastomose with the volar radial carpal, with terminal twigs of the volar branch of the volar interosseous, and with recurrent branches from the deep volar arch, forming an anastomotic arch across the front of the carpus—**the volar carpal arch** or **rete.**

The Ulnar Artery at the Wrist

The **ulnar artery at the wrist** may be said to extend from the proximal to the distal border of the transverse carpal (anterior annular) ligament upon which it rests. It here lies immediately to the radial side of the pisiform bone, and to the ulnar side of the hook of the hamate (unciform), the two bones forming for the vessel a protecting channel, which is further converted into a short canal by the expansion of the flexor carpi ulnaris passing from the pisiform to the hook of the hamate (unciform). The ulnar nerve in this situation is immediately to the ulnar side of the artery.

The Ulnar Artery in the Palm (Superficial Volar Arch)

The ulnar artery, on entering the palm, divides into two branches, the superficial and deep.

The **superficial branch** (fig. 516), the direct continuation of the vessel, anastomoses with the superficial volar, a branch of the radial, forming what is then known as the **superficial volar arch.** After descending a short distance toward the cleft between the fourth and fifth fingers, it turns toward the thumb, forming a curve with its convexity toward the fingers and its concavity toward the muscles of the thumb, and anastomoses opposite the cleft between the index and middle fingers, at the junction of the proximal with the middle third of the palm, with the superficial volar branch of the radial artery to complete the arch. A line drawn transversely across the palm on a level with the metacarpophalangeal joint of the thumb will roughly indicate the situation of the arch.

Relations.—In front, in addition to the skin and superficial fascia, the vessel is crossed successively, by the palmaris brevis, the palmar branch of the ulnar nerve, the palmar aponeurosis and the palmar branch of the median nerve. **Behind,** it rests successively upon the short muscles of the little finger, the digital branches of the ulnar nerve, the flexor tendons, and the digital branches of the median nerve.

The **branches of the superficial volar arch.** In addition to small muscular and cutaneous branches the superficial volar supplies:

The **common digital arteries** [aa. digitales volares communes]. These, usually three in number, arise from the convexity of the superficial arch and, running downward through the palm, give off the digital arteries proper to the radial side of the little finger and to both sides of the ring and middle fingers, and the ulnar side of the index finger. The radial side of the index finger and the thumb are supplied by the first volar metacarpal branch of the radial artery.

The proper digital artery for the ulnar side of the little finger passes distally over the hypothenar muscles and thence along the medial margin of the little finger. The remaining arteries pass distally in the three ulnar intermetacarpal spaces to within about 6 mm. (¼ in.) of the clefts between the figures, where they divide into branches, the **digital arteries proper** [aa. digitales volares propriæ] which supply the sides of contiguous fingers.

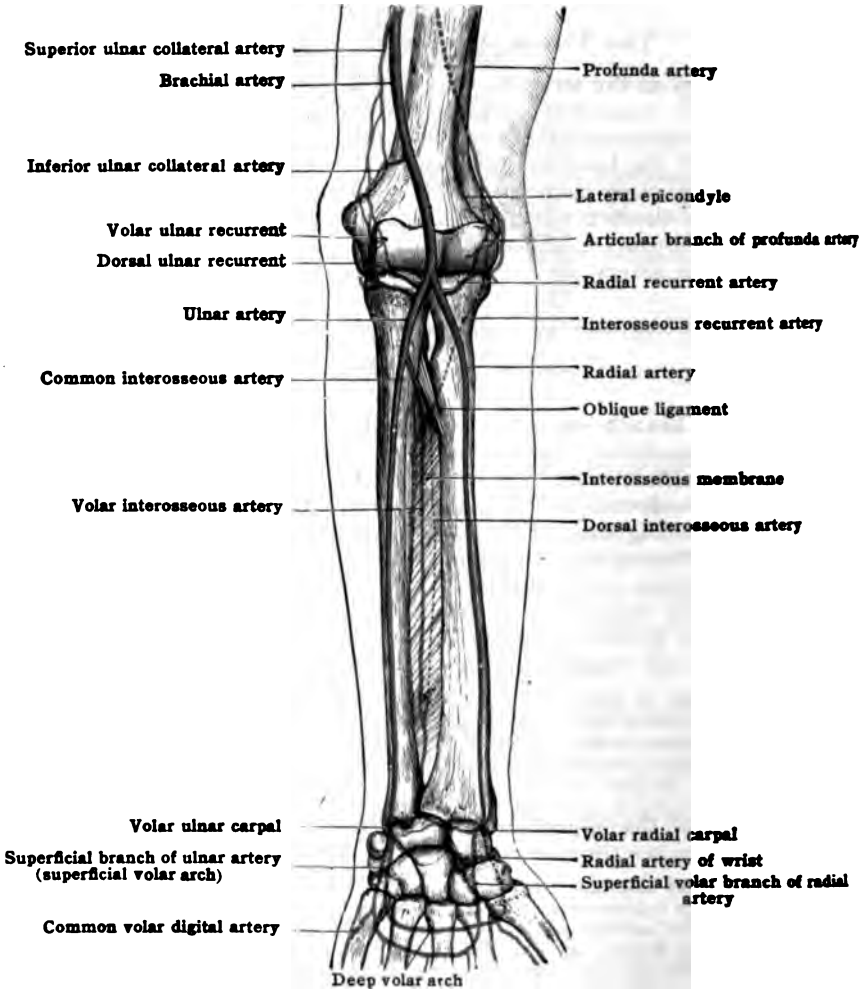
As the common digital arteries pass through the palm, they lie between the flexor tendons, on the digital nerves and lumbrical muscles, and beneath the palmar aponeurosis. Just before bifurcating they pass under the transverse fasciculi, and are joined by the volar metacarpal branches from the deep volar arch (fig. 516). Here they also receive the volar perforating branches from the dorsal metacarpal vessels. On the sides of the fingers the proper digital arteries lie between the palmar and dorsal digital nerves. They anastomose by small branches, forming an arch across the front of the bones on the proximal side of each interphalangeal joint. They supply the flexor tendons and the integument, and terminate in a plexiform manner beneath the pulp of the finger and around the matrix of the nail. A dorsal digital branch is given off to the back of the fingers about the level of the middle of the first phalanx, and a second but smaller dorsal digital branch about the level of the middle of the second phalanx.

The **deep branch** of the ulnar artery, also called the communicating arte sinks deeply into the palm between the abductor and flexor quinti digiti brev and joins the radial to form the deep volar arch. (See RADIAL ARTERY.)

THE RADIAL ARTERY

The **radial** artery—the smaller of the two arteries into which the brachi divides—appears as the direct continuation of the brachial. It runs, at fi curving laterally, along the radial side of the forearm as far as the styloid proce

FIG. 514.—DIAGRAM OF THE RELATION OF THE ARTERIES OF THE LEFT FOREARM TO THE BONES. (Walsham.)



then, curving over the radial collateral ligament and the lateral and back pa the wrist, enters the palm of the hand from behind between the first and se metacarpal bones, and ends by anastomosing with the deep branch of the to form the deep volar arch. Hence the artery is divisible into three p that in the forearm, that at the wrist, and that in the palm of the hand. course of the artery is indicated by a line drawn from a point 2.5 cm. (1 below the center of the elbow to a point situated just medial to the styloid pr of the radius.

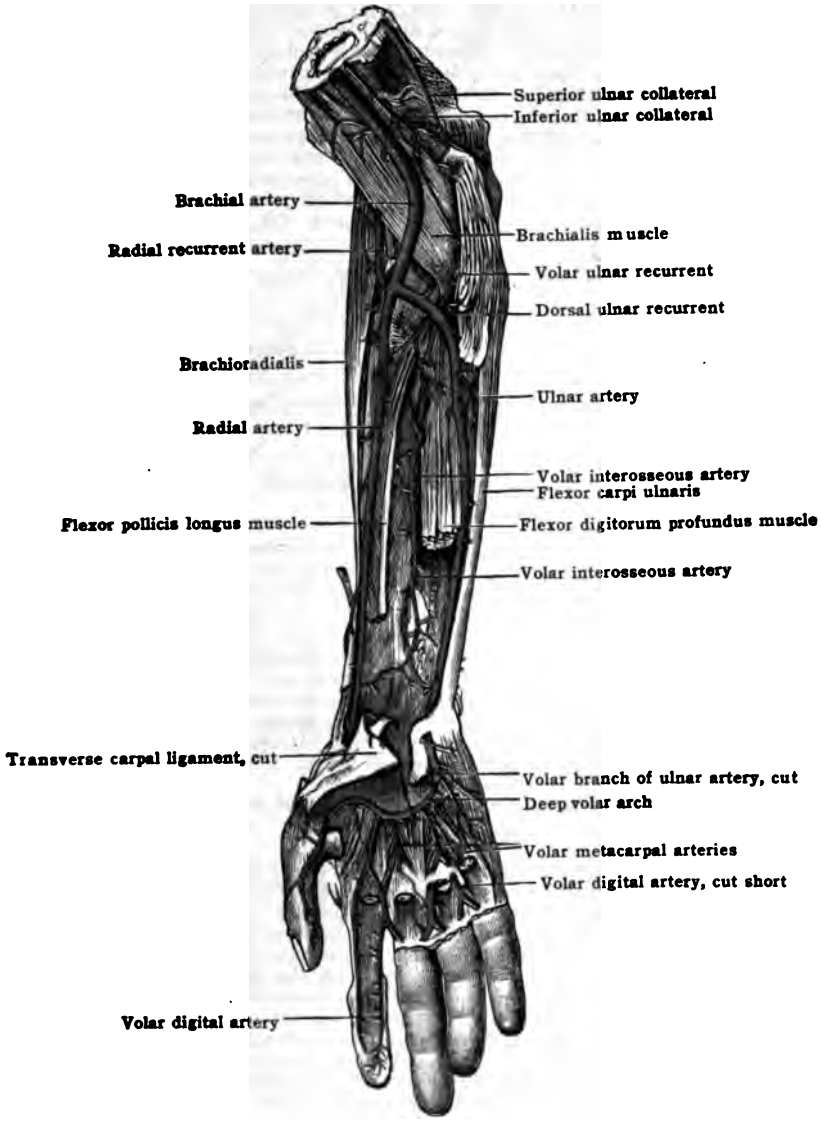
I. THE RADIAL ARTERY IN THE FOREARM

In its course through the forearm (fig. 572) the radial artery is found i most lateral of the intermuscular spaces, and it is necessary to divide onl

, superficial and deep fascia, and in addition in the upper third to separate brachioradialis from the pronator teres, to expose the vessel. There are two e comitantes.

telations.—In front, the artery is at first overlapped by the brachioradialis, but for the of its course it is merely covered by the skin, superficial and deep fasciæ, by some cutaneous s, and by cutaneous branches of the musculocutaneous nerve.
lehind, it lies successively on the tendon of the biceps, the supinator, from which it is rated by a layer of fat, the insertion of the pronator teres, the radial origin of the flexor

FIG. 515.—THE ARTERIES OF THE RIGHT FOREARM AND THE DEEP VOLAR ARCH.



orum sublimis, the flexor pollicis longus, the pronator quadratus, and the volar surface **ie distal end of the radius.** It is in this last situation, where the artery lies upon the bone **can therefore be easily pressed against it,** that the pulse is usually felt.
)n its lateral side it has, throughout the whole of its course, the brachioradialis muscle, **guide** to the artery in ligature, and, in its middle third, the superficial radial nerve as well. **s distal** third the superficial radial nerve is to its lateral side, but separated from it by the **hioradialis** and fascia.
)n its medial side, in the proximal third is the pronator teres, and in the distal third the **on** of the flexor carpi radialis, and throughout the whole of its course the medial vena **itans.**

The branches of the radial artery in the forearm are: (1) The radial re-**ent;** (2) the muscular; (3) the volar radial carpal; (4) the superficial volar.

(1) The **radial recurrent** [a. recurrens radialis] usually arises from the lateral side of the radial just beyond its origin from the brachial. It at first runs laterally on the supinator and then divides into three chief branches (figs. 1124, 1125). One of these continues laterally between the superficial (radial) and deep radial (posterior interosseous) nerves into the brachioradialis and extensor carpi radialis longus and brevis, and anastomoses with the interosseous recurrent. A second ascends between the brachialis and brachioradialis, with the radial (musculospiral) nerve, and anastomoses with the profunda artery. A third descends with the superficial radial nerve under cover of the brachioradialis, supplying that muscle. The radial recurrent also gives off branches to the elbow-joint.

(2) The **muscular branches** [rami musculares] come off irregularly to supply the contiguous muscles on the lateral side of the forearm.

(3) The **volar radial carpal** branch [ramus carpeus volaris] arises from the medial side of the radial artery about the level of the distal border of the pronator quadratus. It crosses the front of the radius beneath the flexor muscles, and anastomoses with the volar carpal branch of the ulnar, forming the volar carpal rete. This plexus is joined proximally by terminal twigs from the volar interosseous artery, and distally by recurrent branches from the deep volar arch. It supplies branches to the distal end of the radius, and to the wrist and carpal joints.

(4) The **superficial volar** branch [ramus volaris superficialis] leaves the radial artery as the latter vessel is about to turn over the radial collateral ligament to the back of the wrist. It courses forward over the short muscles of the ball of the thumb, and anastomoses with the superficial branch of the ulnar artery to complete the superficial volar arch. It supplies small branches to the muscles of the ball of the thumb, and frequently terminates in these muscles without joining the arch. Occasionally it passes beneath the abductor pollicis brevis.

II. The Radial Artery at the Wrist

The radial artery at the wrist winds over the radial side of the carpus, under the extensor tendons of the thumb, from a point a little beyond and medial to the styloid process of the radius to the base of the first interosseous space. It sinks between the two heads of the first dorsal interosseous muscle into the palm, to form, by anastomosing with the deep branch of the ulnar artery, the deep volar arch. A line drawn from a point 1.2 cm. (½ in.) to the medial side of the styloid process to the base of the first interosseous space will roughly indicate the course of the artery (fig. 516).

Relations.—The artery is covered successively by the abductor pollicis longus and extensor pollicis brevis, by branches of the superficial radial nerve and veins, and, just before it sinks between the two heads of the interosseous muscle, by the tendon of the extensor pollicis longus. The branches of the superficial radial nerve to the thumb and index finger cross it. It is at first somewhat deeply placed beneath the first-mentioned extensor muscles of the thumb; but subsequently it lies quite superficial, and can be felt pulsating in a little triangular depression bounded on either side by the extensores pollicis longus and brevis, and above by the lower end of the radius. The artery lies successively on the radial collateral ligament of the wrist, on the navicular (scaphoid), the greater multangular (trapezium), the base of the first metacarpal bone, and on the dorsal ligaments uniting these bones. It has usually with it two companion veins, and a few branches of the musculocutaneous nerve.

The **branches of the radial artery at the wrist** are: (1) The dorsal radial carpal; (2) the first dorsal metacarpal.

(1) The **dorsal radial carpal** branch [ramus carpeus dorsalis] arises from the radial as the latter vessel passes under the abductor pollicis longus, and runs medially beneath the extensor carpi radialis longus and brevis, and the extensor pollicis longus, across the dorsal surface of the carpus, to anastomose with the dorsal ulnar carpal and with the terminal twigs of the posterior branch of the volar interosseous artery. This anastomosis is called the **dorsal carpal rete** [rete carpi dorsale]. From this rete are given off the second, third, and fourth **dorsal metacarpal arteries** to the second, third, and fourth intermetacarpal spaces respectively. These vessels run distally on the dorsal interosseous muscles as far as the flexure of the fingers, and there divide into two branches (**dorsal digital**), which run along the sides of the dorsal aspect of the contiguous fingers. Near their proximal ends they anastomose with the **dorsal perforating branches of the deep volar arch.** Distally they are connected by **volar perforating** branches with the digital arteries or the corresponding spaces. The branches which run along the backs of the fingers anastomose with the dorsal branches of the first dorsal digital arteries derived from the volar common digital vessels (fig. 516).

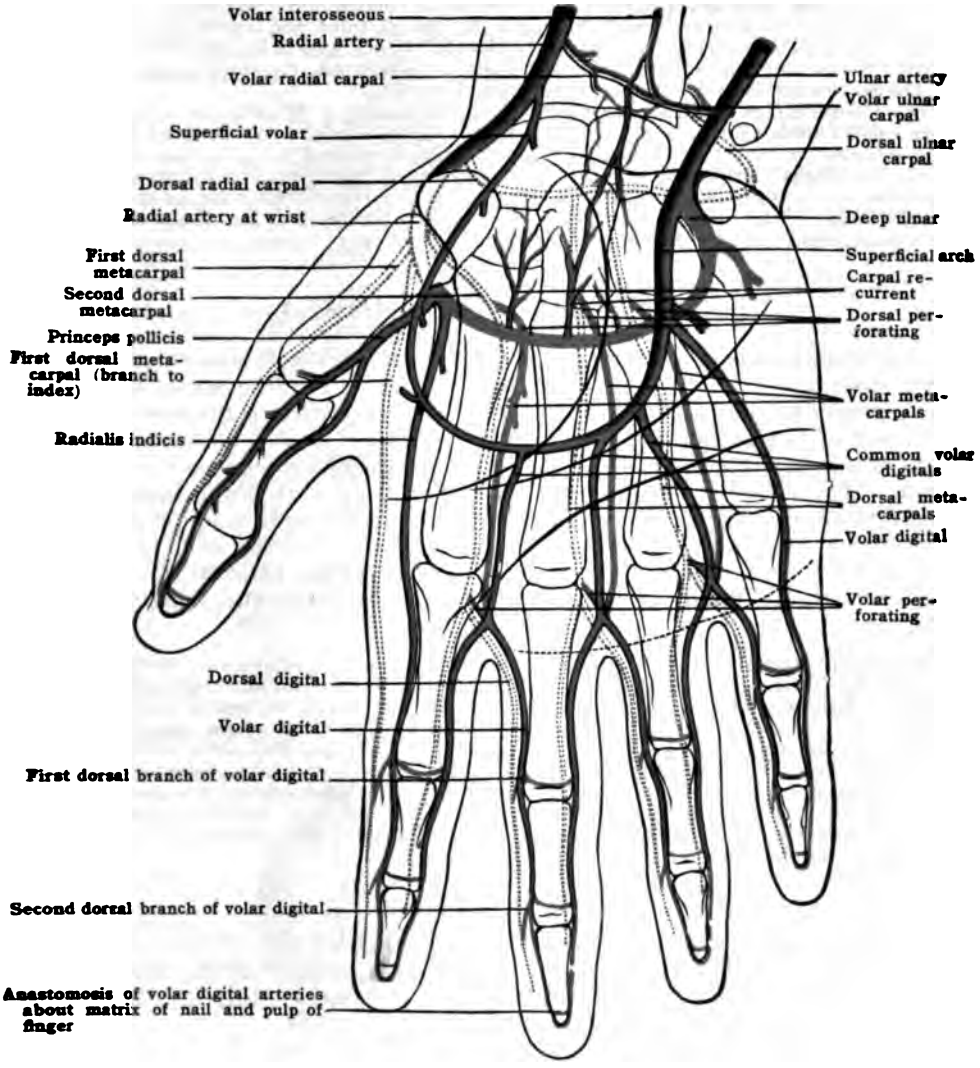
(2) The **first dorsal metacarpal** (fig. 516) is given off by the radial shortly before it passes between the two heads of the first dorsal interosseous muscle. It quickly divides into two branches which supply the dorsal surface of the thumb and the radial side of the index-finger toward its dorsal surface.

III. The Radial Artery in the Palm (Deep Volar Arch)

The radial artery enters the palm between the first and second metacarpal bones at the base of the first interosseous space, by passing between the two heads of the first dorsal interosseous muscle. It then runs medially between the

transverse and oblique heads of the adductor pollicis muscle and continuing its course in a slight curve with the convexity forward, across the base of the metacarpal bones and interosseous muscles, it anastomoses with the deep branch of the ulnar, forming the **deep volar arch** (arcus volaris profundus]. The arch may be said to extend from the first interosseous space to the base of the metacarpal bone of the little finger, and is a finger's breadth nearer the wrist than the superficial arch. It is covered by the superficial and deep flexor tendons, by the

FIG. 516.—ANASTOMOSES AND DISTRIBUTION OF THE ARTERIES OF THE HAND. (Walsham.)



superficial head of the flexor pollicis brevis, and by part of the flexor quinti digiti brevis. It is accompanied by the deep branch of the ulnar nerve, and two small venæ comitantes (figs. 515, 516).

The branches of the deep volar arch are: (1) The princeps pollicis; (2) the volaris indicis radialis; (5) the volar metacarpals (three in number); (4) the recurrent carpal; (3) the dorsal perforating. The first two are sometimes described as arising from the radial artery in the palm; the last three from the deep volar arch.

(1) **The arteria princeps pollicis** arises from the radial artery as it enters the palm between the two heads of the first dorsal interosseous muscle. It passes downward between the adductor pollicis transversus and the first dorsal interosseous muscle, parallel with the metacarpal bone, and between the two portions of the flexor pollicis brevis under cover of the flexor pollicis longus. Opposite the metacarpophalangeal joint it usually divides into two branches, one

of which is distributed to each side of the thumb on its volar aspect. These vessels anastomose with each other at the end of the thumb, like the other digital arteries.

(2) The **arteria volaris indicis radialis** comes off from the radial artery a little beyond the princeps pollicis, or as a common trunk with it, and passes forward between the first dorsal interosseous and adductor pollicis transversus, parallel with the radial side of the second metacarpal bone. After emerging from beneath the adductor pollicis transversus it continues its course along the radial side of the volar aspect of the index-finger, anastomosing in this course with the digital artery on the opposite side of the finger in a way similar to that of the other digital arteries. It frequently communicates, at the lower border of the adductor pollicis, with the superficial volar arch and princeps pollicis. It gives off a dorsal branch, which anastomoses with the branch from the first dorsal metacarpal to the index-finger.

(3) The **volar metacarpal** arteries [aa. metacarpeæ volares], three in number, come off from the convexity of the deep arch, and, running in the second, third, and fourth interosseous spaces on the interosseous muscles, terminate near the cleft of the fingers by anastomosing with the digital arteries from the superficial arch. These vessels supply the interosseous muscles and the bones, and the second, third, and fourth lumbricales.

(4) The **recurrent branches** come off from the concavity of the arch, and consist of two or three small vessels which run toward the wrist, and anastomose with the volar branch of the volar interosseous, and the volar radial and ulnar carpal arteries.

(5) The **dorsal perforating** branches [rr. perforantes], which are usually three in number, pass from the arch directly through the second, third, and fourth interosseous spaces between the two heads of the corresponding dorsal interosseous muscle, and join the proximal ends of the second, third, and fourth dorsal metacarpal arteries respectively.

THE THORACIC AORTA

The **thoracic aorta** [aorta thoracalis] (fig. 517) is the thoracic portion of the aorta descendens. It extends from the termination of the aortic arch at the lower border of the body of the fourth thoracic vertebra to the lower border of the body of the twelfth thoracic vertebra, where it passes between the medial crura of the diaphragm, and is thence continued under the name of the abdominal aorta. It is at first situated a little to the left of the vertebral column, but as it descends, approaches the front of the column, at the same time following its backward curve, and at the diaphragm is almost in the middle line. It lies in the posterior mediastinum, having the esophagus at first a little to the right of it, then in front, and finally (near the lower end of the esophagus) a little to the left side.

Relations.—In front the descending aorta is crossed from above downward by the root of the left lung, by the esophagus, which separates it from the pericardium and heart, and by the diaphragm. **Behind,** it lies upon the lower seven thoracic vertebræ, and is crossed obliquely opposite the seventh or eighth thoracic vertebra by the vena hemiazygos (azygos minor) and opposite the fifth or sixth vertebra by the accessory hemiazygos vein, or by one or more of the intercostal veins. On the **right side** it has, above, the esophagus and vertebral column; lower down the right pleura and lung. The vena azygos and thoracic duct also lie to the right, but on a somewhat posterior plane. On the **left side** it has the left lung and pleura above, and the esophagus below. The vena hemiazygos and the accessory hemiazygos vein are also to the left, but on a posterior plane.

Branches of the Thoracic Aorta

The **branches of the thoracic aorta** may be divided into (*A*) the visceral and (*B*) the parietal. The **visceral** are: (1) The pericardiac; (2) the bronchial; and (3) the esophageal. The **parietal** are: (1) The intercostal; (2) the superior phrenic; and (3) the arteria aberrans.

A. Visceral Branches

(1) The **pericardiac** branches [rami pericardiaci]—two or three small branches, irregular in their origin, course, and distribution—pass to the posterior surface of the pericardium to supply that structure, and anastomose with the other pericardiac branches. They give small twigs to the posterior mediastinal glands.

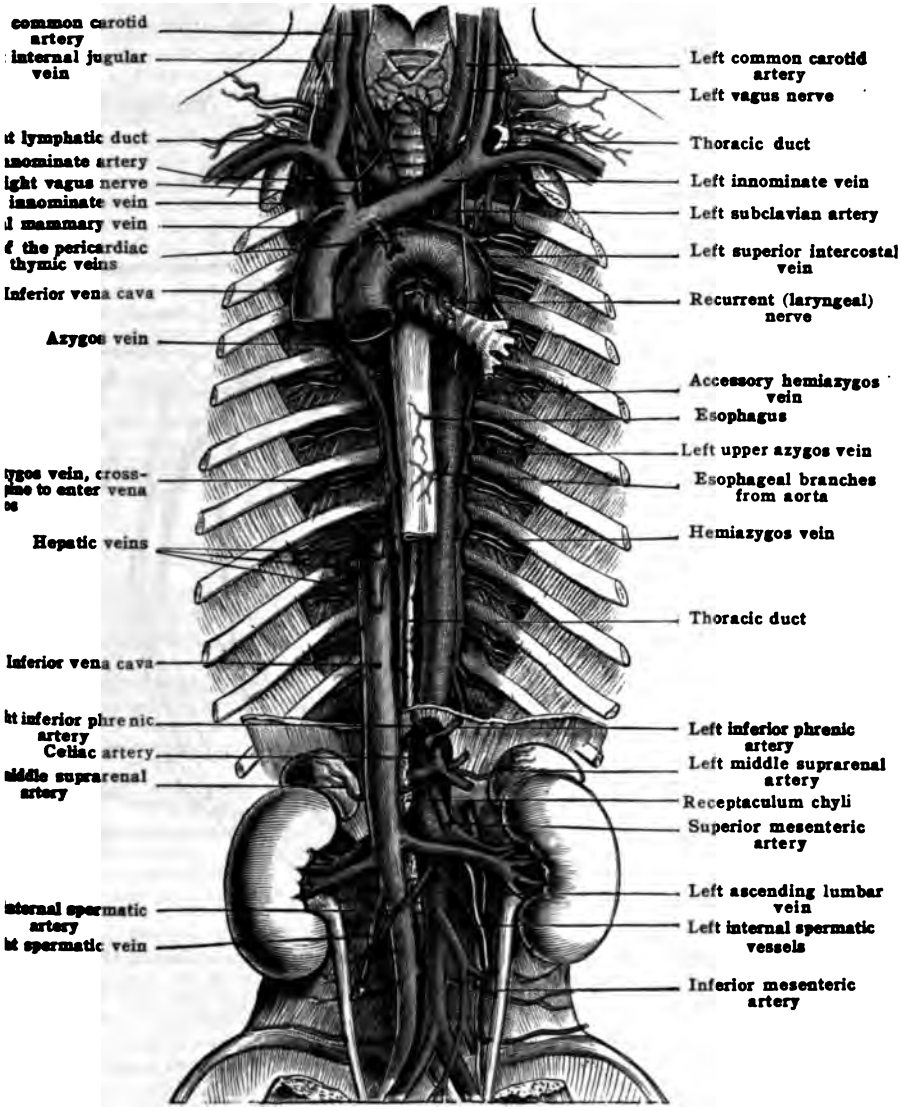
(2) The **bronchial** arteries [aa. bronchiales] supply the bronchi and the lung substance. They vary considerably in their origin, course, and distribution; they are usually three in number—one on the right side, and two on the left

(*a*) The **right bronchial** generally arises either from the first right aortic intercostal, or else as a common trunk with the left upper bronchial from the front of the aorta just below the level of the bifurcation of the trachea. It passes laterally on the back of the right bronchus, and is distributed to the bronchi and lung substance. (*b*) The **left upper bronchial** arises from the front of the aorta just below the bifurcation of the trachea, or as a common trunk with the right bronchial. (*c*) The **left lower bronchial** arises from the front of the aorta just below the level of

: **bronchus.** Like the corresponding artery on the right side, the left bronchial arteries erally on the left bronchus, and, after dividing and subdividing on the back of the bronchi, the bronchi themselves and the lung substance. Small twigs are given off from the ial arteries to the bronchial glands and to the esophagus.

) **The esophageal** arteries [aa. œsophageæ], four or sometimes five in number, ıt intervals from the front of the descending thoracic aorta, the first coming ıt below the left lower bronchial. They usually increase in size from above

. 517.—THE ARCH OF THE AORTA, THE THORACIC AORTA, AND THE ABDOMINAL AORTA, THE VENA CAVA SUPERIOR AND INFERIOR AND THE INNOMINATE AND AZYGOS VEINS.



ward, the upper coming off more toward the right side of the aorta, the lower toward the left side. They pass forward to the esophagus, supplying ube and anastomosing with each other and with the descending esophageal hes of the inferior thyroid above, and with the ascending esophageal hes of the phrenic and gastric arteries below, thus forming a chain of anas- ses along the whole length of the tube.

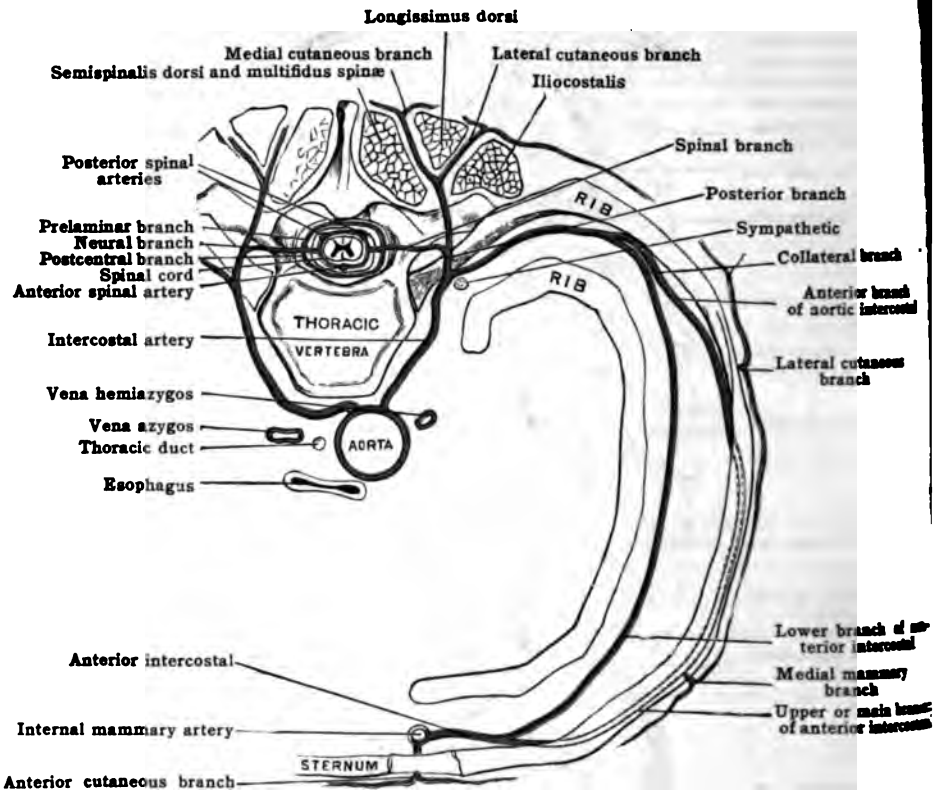
B. PARIETAL BRANCHES

) **The intercostal** arteries [aa. intercostales], usually ten in number on each upply the lower intercostal spaces, the two upper spaces (occasionally the

first only) being supplied from the costocervical trunk of the subclavian arte
The lowest artery accompanies the twelfth thoracic nerve below the last rib
is therefore called the **subcostal artery.** Its distribution is similar to that of
lumbar arteries (p. 630) except that it commonly crosses the anterior surfa
rather than the posterior, of the quadratus lumborum.

The intercostals arise in pairs from the back part of the aorta, and turning,
one to the right and the other to the left, wind backward over the front and si
of the vertebral bodies to reach the intercostal spaces. In fetal life these arte
run almost transversely backward, or even with a slight inclination downwa
to the intercostal spaces; but after the first year, in consequence of the disprop
tionate growth of the aorta and vertebral column, the upper intercostals ha
to ascend to reach their respective spaces.

FIG. 518.—SCHEME OF INTERCOSTAL ARTERY. (Walsham.)



The arteries in their course around the vertebræ differ on the two sides of the body. On the **right side** the arteries—and especially the upper, in consequence of the aorta lying a little to the left side of the spine in the upper part of its course—are longer than the left. They wind over the front and right side of the vertebræ, being crossed by the thoracic duct and vena azygos (major), and covered by the right pleura and lung. The upper are also crossed by the esophagus. They give off small branches to the bodies of the vertebræ and anterior longitudinal ligament. On the **left side,** as the intercostals wind around the sides of the bodies of the vertebræ, the lower ones are crossed by the vena hemiazygos (azygos minor), the two upper by the left superior intercostal vein, and the two next by the accessory hemiazygos, when this is present. They are all covered by the left pleura and lung (fig. 518).

The **branches of the intercostal arteries** are: (a) anterior, (b) posterior.

(*a*) The **anterior** branches [rami anteriores] at first cross the intercostal space obliquely, in consequence of the downward direction of the ribs, toward the angle of the rib above, and thence are continued forward in the costal groove. They anastomose with the superior branches of the anterior intercostal branches of the internal mammary in the upper spaces, and of the musculophrenic in the lower spaces. They lie at first on the external intercostal muscle, being covered in front by the pleura and lung, the endothoracic fascia, and the subcostal muscles. Opposite the heads of the ribs they are crossed by the sympathetic nerve. At the angle of the ribs they pass under cover of the internal intercostal muscles, and thence to the termination lie between the two intercostal muscles. They are accompanied by a nerve and

vein lying above and the nerve below, except in the upper spaces, where the artery, ascend to reach the space, at first lies below the nerve which runs more horizontally. rmost branch anastomoses with the costocervical artery from the subclavian, and at plies almost entirely the second intercostal space. The arteries to the tenth and paces on reaching the end of the costal cartilages pass between the abdominal muscles, omose with the inferior epigastric artery from the external iliac, and with the lumbar om the abdominal aorta. The artery beneath the twelfth rib anastomoses with the teries and with the deep circumflex iliac.

anterior branch gives off the following: (i) The **collateral** branch which comes off angle of the rib and runs forward, between the external and internal intercostals, upper border of the lower rib enclosing the space. It is smaller than the main anterior id anastomoses with the lower anterior intercostal in each space. (ii) **Muscular** [rami musculares] supply the intercostal, pectoral and abdominal muscles. (iii) l **cutaneous** branches [rami cutanei laterales] run with the corresponding branches of ostal nerves through the external intercostal and serratus anterior muscles. They le into *anterior* and *posterior* branches which turn forward and backward, respectively, the integument. The anterior branches from the third, fourth and fifth spaces *eral mammary* branches [rr. mammarii laterales] to the lateral region of the breast. ior **cutaneous** branches [rami cutanei anteriores] pierce the external intercostal liga- the pectoralis major near the sternum. They are distributed to the skin and give *mmary* branches [rr. mammarii mediales] to the medial region of the breast.

e **posterior** branches [rami posteriores].—These large branches are given off from the ls opposite the quadrilateral space bounded by the transverse process of the vertebra e neck of the rib below, the body of the vertebra medially, and the anterior costo- ligament laterally. Passing backward toward this space with the dorsal branch responding intercostal nerve, they divide opposite the intervertebral foramen into a and a spinal branch. (i) The **muscular** branch [r. muscularis] passes backward he quadrilateral space, and soon subdivides into a medial and a lateral branch. The ses between the longissimus dorsi and iliocostalis, and, after supplying these muscles, **medial cutaneous** branch [r. cutaneus medialis]. The latter branch pierces the multi- s, and, emerging between the longissimus dorsi and semispinalis dorsi near the spinous gives off a **lateral cutaneous** branch [r. cutaneus lateralis].

e **spinal** branch [r. spinalis] enters the intervertebral foramen with the spinal nerve esponding segment. The disposition of the spinal branches of the intercostal arteries to that of the corresponding branches which enter the canalis vertebralis in other

ARTERIES OF THE VERTEBRAL CANAL

arteries are derived from the vertebral, ascending cervical and costocervical arteries, lorsal rami of the intercostal (fig. 518) and lumbar arteries, and from the iliolumbar l sacral arteries. They divide into three branches, postcentral, prelaminar and

ostcentral branch divides on the lateral part of the posterior longitudinal ligament ending and a descending branch by which means a bilateral series of anastomosing formed throughout the length of the canal. From the concavities of the opposite nsverse connecting stems are formed which are again connected by a median longitu- nel.

elaminar branches also divide and form an anastomosis in front of the laminæ and flava. This is similar in character to the postcentral, but much less regular.

ural branches enter the dura mater and are usually small and end by supplying the s. A variable number of these (5–10 on a side) are larger than the others and rein- ngitudinal anterior and posterior spinal arteries given off from the vertebrals within m. (For arteries of the spinal cord, see Section VIII.)

he **superior phrenic** arteries [aa. phrenicæ superiores], are small twigs ff from the thoracic aorta immediately above the diaphragm. They are ed to the vertebral portion of the diaphragm on its upper surface.

he **arteria aberrans** is a small twig which, arising from the thoracic ar the right bronchial artery, passes upward and to the right behind the s and trachea, and is occasionally found to anastomose on the esophagus arteria aberrans of the right superior intercostal artery (see p. 608). It is as the remains of the right aortic dorsal stem (fig. 546).

he **mediastinal** branches [rami mediastinales], numerous, but small, are ed to the pleura, and the vessels, nerves and lymph-nodes of the posterior ium.

THE ABDOMINAL AORTA

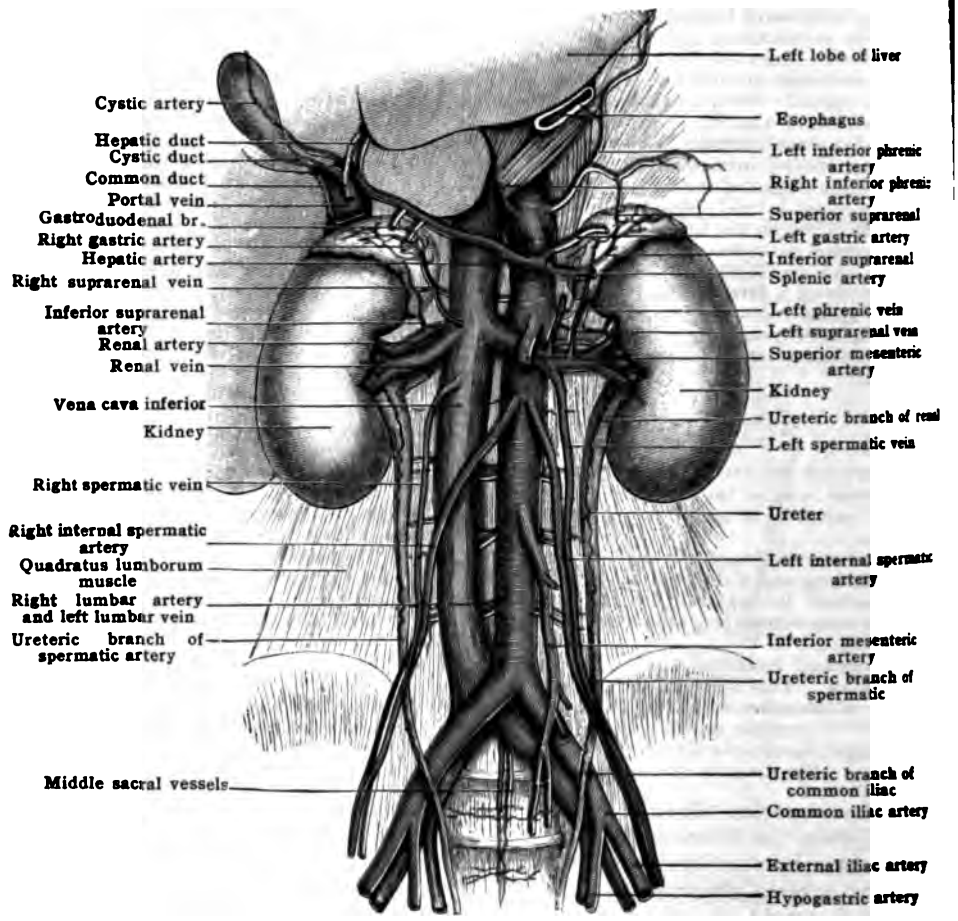
bdominal aorta [aorta abdominalis] (fig. 519), the abdominal portion of nding aorta, begins at the aortic opening in the diaphragm opposite the rder of the twelfth thoracic vertebra, and ends usually opposite the he fourth lumbar vertebra by dividing into the right and left common

iliac arteries. It is at first centrally placed between the medial crura of the diaphragm, but as it descends it deviates a little to the left side.

The place at which the aorta bifurcates may be somewhat roughly indicated on the surface of the abdomen by a point about 2.5 cm. (1 in.) below and a little to the left of the umbilicus. The level of its bifurcation may be more accurately determined by drawing a straight line between the highest points of the iliac crests.

Relations.—In front, the aorta is successively crossed from above downward by the left lobe of the liver, the celiac (solar) plexus, the lesser omentum, the termination of the esophagus in the stomach, the ascending layer of the transverse mesocolon, the splenic vein or commencement of the portal vein, the pancreas, the left renal vein, the third portion of the duodenum, the mesentery, the aortic plexus of the sympathetic nerve, the internal spermatic or ovarian arteries, the inferior mesenteric artery, the median lumbar lymphatic nodes and lymphatic vessels, and the small intestines. Of these structures the celiac (solar) plexus, the aortic

FIG. 519.—THE ABDOMINAL AORTA AND ITS BRANCHES, WITH THE VENA CAVA INFERIOR AND ITS TRIBUTARIES.



plexus, the splenic vein or the commencement of the portal vein, **the pancreas**, the left renal vein, the duodenum, the lymphatics, the spermatic or ovarian **arteries, and the peritoneal** reflexions are in direct contact with the aorta.

Behind, the aorta lies upon the bodies of the lumbar vertebræ and **intervening intervertebral** cartilages, the anterior longitudinal ligament, the origin of the left **medial crus of the diaphragm** and the left lumbar veins.

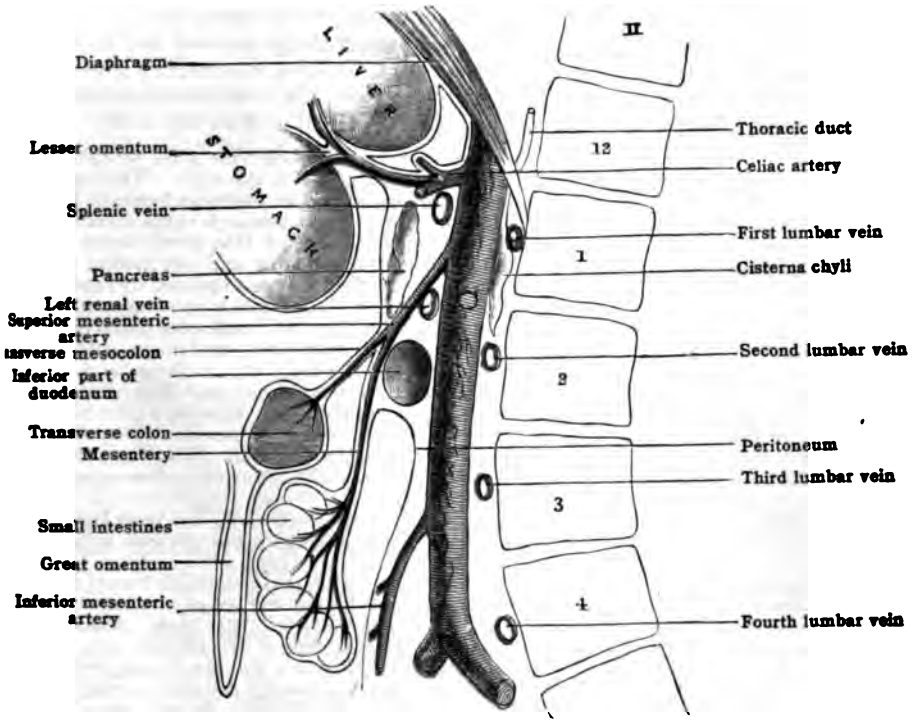
On the **right side** from above downward are the right medial **crus of the diaphragm**, the great splanchnic nerve, the caudate lobe of the liver, the **cisterna chyli and beginning of the** thoracic duct (the two latter structures are on a posterior plane), **the right celiac** (semilunar) ganglion, and the inferior vena cava. Inferiorly, the vena cava **is in contact with the aorta** and on a somewhat posterior plane. Superiorly, the vena cava **is separated from the aorta by** the right medial crus of the diaphragm, and the caval opening **of the diaphragm is on a plane** anterior to the aortic.

On the **left side** are the left medial crus of the diaphragm, **the left splanchnic nerve, and** the left celiac (semilunar) ganglion. The pancreas is also in **contact with the aorta on the** left side, and the small intestines are separated from it only by **peritoneum.**

Branches of the Abdominal Aorta

The branches of the abdominal aorta usually arise in the following order from **ve** downward (figs. 519, 520):
(1) Right and left inferior phrenic; (2) celiac; (3) right and left middle supra-**al**; (4) right and left first lumbar; (5) superior mesenteric; (6) right and **renal**; (7) right and left internal spermatic; (8) right and left second lumbar; **inferior** mesenteric; (10) right and left third lumbar; (11) right and left fourth **ıbar**; (12) right and left common iliac; (13) middle sacral.
The above branches may be divided into the (A) parietal, (B) the visceral, and) the terminal.
The **parietal branches** are distributed to the abdominal walls. They are the ht and left phrenics, and the four right and left lumbars.

Fig. 520.—Scheme of the Abdominal Aorta. (Walsham.)



The **visceral branches** supply the viscera. Three of these are given off singly n the front of the aorta, namely, the celiac, the superior mesenteric, and the erior mesenteric; and three are given off in pairs, namely, the two suprarenals, two renals, and the two spermatics.
The **terminal branches** are the middle sacral and the right and left common c arteries.

A. The Parietal Branches of the Abdominal Aorta

1. THE INFERIOR PHRENIC ARTERIES

The inferior phrenic artery [a. phrenica inferior] usually arises from the aorta t passes between the medial crura of the diaphragm. At times it comes off n the celiac artery; or when it arises as two separate vessels, either the right eft vessel may come from this artery, or from other of the upper branches of abdominal aorta.

The right phrenic (fig. 520) passes over the right crus of the diaphragm behind the vena cava then upward and to the right between the central and right leaflets of the central tendon of muscle, where it divides into an **anterior** and a **posterior** branch. The former courses riorly and medially and anastomoses with the anterior branch of the left phrenic, with the

musculophrenic branches of the internal mammary, and with the pericardiophrenic arteries; the latter passes posteriorly and laterally toward the ribs, and anastomoses with the intercostal arteries. Besides the two terminal branches and branches for the supply of the diaphragm itself the right phrenic gives off the **right superior suprarenal** [ramus suprarenalis superior] to the right suprarenal gland, as well as branches to the vena cava, to the liver, and to the pericardium.

The **left phrenic** crosses the left crus of the diaphragm behind the esophagus, and, like the right artery, divides into an anterior and posterior branch and gives off a left suprarenal branch. The distribution and anastomoses are similar on the two sides.

2. THE LUMBAR ARTERIES

The **lumbar** arteries [aa. lumbales] (fig. 519), usually eight in number, four on each side, come off in pairs from the posterior aspect of the abdominal aorta, opposite the bodies of the four upper lumbar vertebræ. A fifth pair of lumbar arteries, generally of small size, frequently arises from the middle sacral artery opposite the fifth lumbar vertebra. The lumbar arteries, which are rather longer on the right than on the left side, in consequence of the aorta lying a little to the left of the median line, wind more or less transversely around the bodies of the vertebræ to the space between the transverse processes, where they give off each a dorsal branch, and then, coursing forward between the abdominal muscles, terminate, by anastomosing with the other arteries of the abdominal wall.

Relations.—As they wind around the bodies of the vertebræ they pass beneath the sympathetic trunk, and the upper two beneath the crura of the diaphragm. The right arteries also pass beneath the vena cava inferior, and the two upper on that side beneath the cisterna chyli. The arteries on both sides then dip beneath the tendinous arch thrown across the sides of the bodies of the vertebræ by the psoas, and continue beneath this muscle until they arrive at the interval between the transverse processes of the vertebræ and the medial edge of the quadratus lumborum. While under cover of the psoas they are accompanied by rami communicantes of the sympathetic and by the lumbar veins. A little anterior to the transverse processes they are crossed by branches of the lumbar plexus of nerves, and here usually cross in front of the ascending lumbar vein. They now pass behind the quadratus lumborum, with the exception sometimes of the last, which may pass in front of the muscle. At the lateral edge of the quadratus they run between the transversus and the internal oblique, and then, after perforating the internal oblique, between the internal and external oblique. Finally, much diminished in size, they enter the rectus, and give off one or more anterior cutaneous branches, which accompany the last thoracic and the iliohypogastric nerves to the skin. They anastomose with the lower intercostals, iliolumbar, deep circumflex iliac, and inferior epigastric arteries.

The **branches of the lumbar arteries** are:

(*a*) **Vertebral** branches which supply the bodies of the vertebræ and their ligaments.

(*b*) **Muscular** branches to the psoas, quadratus lumborum, and oblique muscles of the abdomen.

(*c*) The **dorsal** branch [r. dorsalis]. This is of large size, and passes backward in company with the dorsal nerve between the transverse processes above and below, the intertransversalis medially and the quadratus lumborum laterally, to the muscles of the back. On reaching the interval between the longissimus dorsi and multifidus spinæ, it divides into a lateral and a medial branch. The former ends in the multifidus, the latter and larger supplies the sacrospinalis, and gives branches which accompany the termination of the dorsal nerves to the skin. Just before the artery passes between the transverse processes it gives off a **spinal branch** [r. spinalis], which accompanies the lumbar nerve through the intervertebral foramen into the vertebral canal (see p. 627).

(*d*) **Renal** branches of small size pass forward in front of the quadratus lumborum to the capsule of the kidney. They anastomose with the renal artery. A communication is thus established between the renal arteries and the arteries supplying the lumbar region.

B. THE VISCERAL BRANCHES OF THE ABDOMINAL AORTA

THE CELIAC ARTERY

The **celiac** artery [a. cœliaca] or **celiac axis**, is a short thick trunk given off from the front of the aorta between the medial crura of the diaphragm a little below the aortic opening. It passes horizontally forward above the upper margin of the pancreas for about half an inch, and then breaks up into three branches for the supply of the stomach, duodenum, spleen, pancreas, liver, and gall-bladder (fig. 521).

Relations. In front is the lesser omentum; behind, the aorta; above, the right lobe of the liver; below, the pancreas; to the right, the right celiac (semilunar) ganglion and caudate lobe of the liver; to the left, the left celiac (semilunar) ganglion and the cardiac end of the stomach. It is closely surrounded by the dense celiac (solar) plexus of sympathetic nerves.

Branches of the celiac artery. The celiac artery divides into (1) the left gastric, (2) the hepatic, and (3) the splenic arteries.

1. The Left Gastric Artery

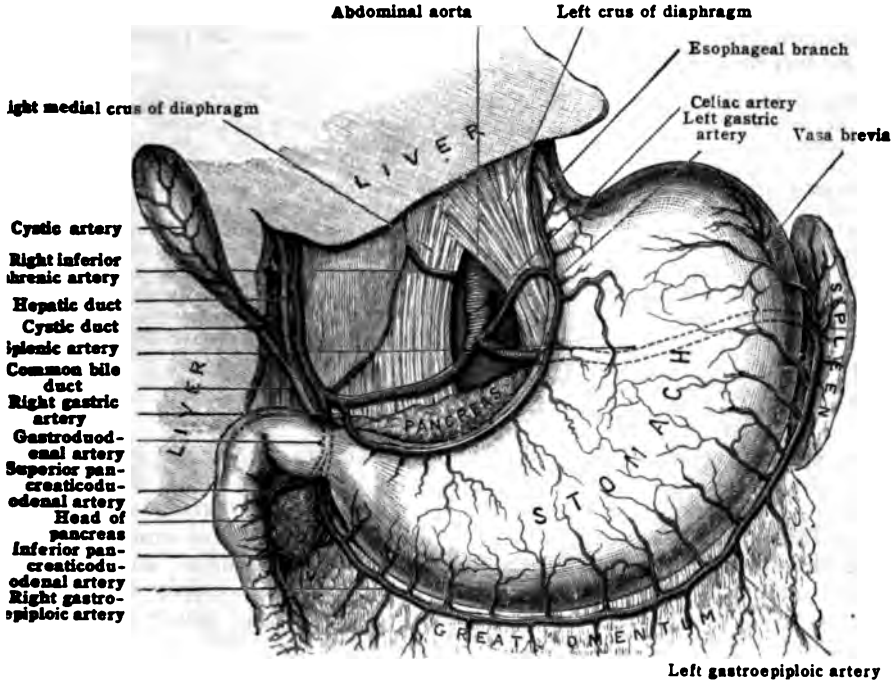
The left gastric [a. gastric sinistra] (fig. 521), the smallest of the three branches ne celiac artery, courses at first upward and to the left toward the cardiac end he stomach, where it turns sharply round, and then, following the lesser rature of the stomach, descends from left to right toward the pylorus. It stomoses with the right gastric branch of the hepatic artery, which has ceeded from the opposite direction, the two branches thus forming a con- ıous arterial arch corresponding to the lesser curvature of the stomach.

The artery at first lies behind the posterior layer of the omental bursa of peritoneum (fig. ', but on reaching the cardiac end of the stomach it passes, between the layers of peritoneum cted from the diaphragm onto the esophagus, into the lesser omentum in which it then ı to its terminal anastomosis with the pyloric. It is surrounded by a plexus of sympathetic ves. It supplies both surfaces of the stomach around the lesser curvature and gives off small phageal branches [rami œsophagei] which anastomose with the esophageal branches from thoracic aorta.

2. The Hepatic Artery

The hepatic artery [a. hepatica] is the largest branch of the celiac artery in the ıs, but intermediate in the adult between the left gastric and the splenic. arises on the right side of the celiac artery, and, winding upward and to the

Fig. 521.—The Celiac Artery and its Branches.



t to the porta (portal fissure) of the liver, there breaks up into two chief ıches for the supply of the right and left lobes of that organ. It at first courses ard and to the right along the upper border of the head of the pancreas, be l the posterior layer of the peritoneal omental bursa, to the upper margin of duodenum, where it passes forward beneath the layer of peritoneum forming floor of the epiploic foramen (of Winslow). It then runs between the two rs of the lesser omentum, and ascends along with the hepatic duct which lies s right, and with the portal vein which lies behind it (figs. 520, 521).

The branches of the hepatic artery are: (1) The right gastric; (2) the gastroduodenal; (3) the hepatic proper.

(1) The **right gastric** artery [a. gastrica dextra] arises from the hepatic as the er vessel enters the lesser omentum, and, descending to the pylorus, there ıs to the left, and, ascending from right to left, anastomoses along the lesser

curvature of the stomach, as already mentioned, with the left gastric artery, w descends from the opposite direction.

(2) The **gastroduodenal** artery [a. gastroduodenalis] arises from the hep a little beyond the right gastric. It descends behind the first part of duodenum to the lower border of the pylorus, where it divides into the ri **gastroepiploic** and the **superior pancreaticoduodenal.** It varies from 1.2 2.5 cm. (½ to 1 in.) in length.

(*a*) The **right gastroepiploic** artery [a. gastroepiploica dextra] passes from right to along the greater curvature of the stomach between the layers of the great omentum, anastomoses with the left gastroepiploic branch of the splenic. From this anastomotic are given off: (i) **Ascending** or **gastric** branches, which supply the anterior and poste surfaces of the stomach, and anastomose with the descending gastric branches of the arte along the lesser curvature. (ii) **Epiploic** [rami epiploici] or **omental branches**—long slen vessels which descend between the two anterior layers of the great omentum, and then, loop upward, anastomose with similar slender branches given off from the middle and left p and passing down in like manner between the posterior layers of the great omentum.

(*b*) The **superior pancreaticoduodenal** [a. pancreaticoduodenalis superior]—the sma division of the gastroduodenal—arises from that vessel as it passes behind the first portion the duodenum, and courses downward behind the peritoneum, in the anterior groove betw the second portion of the duodenum and the pancreas, to anastomose with the inferior p creaticoduodenal, a branch of the superior mesenteric. Both the inferior and superior p creaticoduodenal give off **duodenal** [rami duodenales] and **pancreatic** branches [rami pancrea to supply these organs.

(3) The **hepatic artery proper** [a. hepatica propria] is the continuation of hepatic after the gastroduodenal has arisen. It ascends between the layer the lesser omentum, preserving the relations of the main artery to the portal and common bile (and hepatic) duct, and divides, near the porta hepatis, **right** and **left** branches.

(*a*) The **right branch** [r. dexter], given off at the porta (portal fissure) of the liver, runs t right either behind the hepatic and cystic ducts, or between these structures. At the righ of the porta it divides into branches, which again subdivide as they enter the liver subs for the supply of the right lobe. As it crosses the cystic duct it gives off the cystic artery.

The **cystic** artery [a. cystica] courses forward and downward through the angle fo by the union of the hepatic and cystic ducts, and just before it reaches the gall-bladder di into a superficial and deep branch. The former breaks up into a number of small vessels, ramify over the free surface of the gall-bladder beneath the peritoneal covering, and fu branches to the muscular and mucous coats. The deep branch ramifies between the bladder and the liver-substance, supplying each, and anastomosing with the superficial br

(*b*) The **left** branch [r. sinister], the smaller division of the hepatic artery, runs towar left end of the porta hepatis, and, after giving off a distinct branch to the caudate (Spig lobe, enters the left lobe of the liver.

3. The Splenic Artery

The **splenic** artery [a. lienalis]—the largest branch of the celiac art arises from the left side of the termination of that vessel below the left ga and passes along the upper border of the pancreas in a tortuous manner t spleen. It at first lies behind the posterior wall of the bursa omentalis, b nearing the spleen enters the phrenolienal (lienorenal) ligament, and there b up into numerous branches, which enter the hilus and supply the organ crosses in front of the left crus of the diaphragm and the upper end of th kidney and is placed above the splenic vein.

The **branches of the splenic artery** are: (*a*) The pancreatic; (*b*) th gastroepiploic; (*c*) the vasa brevia; and (*d*) the terminal.

(*a*) The **pancreatic** branches (rami pancreatici) come off from the splenic at varying in as that vessel courses along the upper margin of the pancreas. They enter and supp organ. One larger branch usually arises from the splenic about the junction of its with its left third. Entering the pancreas obliquely, it runs from left to right, commonly and a little behind, the pancreatic duct, which it supplies together with the substance organ.

(*b*) The **left gastroepiploic** [a. gastroepiploica sinistra] arises from the splenic n greater curvature and below the fundus of the stomach, and, passing between the s layers of the great omentum, descends along the greater curvature of the stomach fr to right, and anastomoses with the right gastroepiploic. Like that vessel, it gives off asc or **gastric** branches to the anterior and posterior surfaces of the stomach respectivel long slender **descending epiploic** or **omental** branches to the great omentum which anas with like branches from the right and left colic arteries.

(*c*) The **vasa brevia** [aa. gastricæ breves] come off from the splenic just before it divid its terminal branches, or from some of the terminal branches themselves. Passing from b

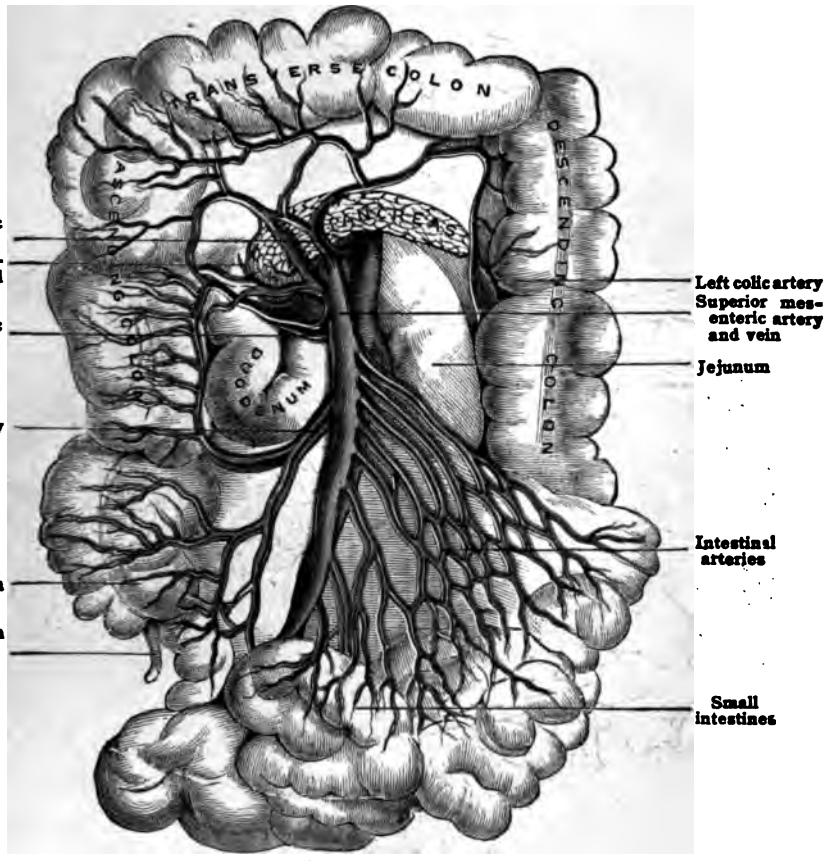
the phrenolienal ligament into those of the gastrolienal, they reach the fundus of the here, ramifying over its anterior and posterior surfaces, they anastomose with the and left gastroepiploic arteries.

splenic or terminal branches, five to eight or more in number, are given off from the it lies in the lienorenal ligament, and, entering the spleen at the hilum, are distributed the description of that organ.

THE SUPERIOR MESENTERIC ARTERY

superior mesenteric artery [a. mesenterica superior] arises from the the aorta a little below the celiac, which it nearly equals in size; some- two vessels arise by a common trunk. Lying at first behind the pan- splenic vein, it soon passes forward between the lower border of the and the upper border of the inferior portion of the duodenum. Now in front of the duodenum, it enters the mesentery, in which it runs

FIG. 522.—THE SUPERIOR MESENTERIC ARTERY AND VEIN.
e colon is turned up, and the small intestines are drawn over to the left side.)



rm of a curve with its convexity to the left, to the cecum, where it ses with its ileocolic branch. Its vein lies to its right side above, having y crossed obliquely in front of the artery from the left. It is sur- by the mesenteric plexus of nerves. The uncinate process of the head ncreas dips in behind the vessel.

branches of the superior mesenteric are: (1) the inferior pancreatico- ; (2) the intestinal arteries; (3) the ileocolic; (4) the right colic; and iddle colic.

inferior pancreaticoduodenal [a. pancreaticoduodenalis inferior] arises either from or mesenteric as that vessel emerges from the contiguous margins of the pancreas or part of the duodenum or from its first intestinal branch. Crossing behind the esenteric vein, it courses upward and to the right between the head of the pancreas uodenum, and beneath the ascending layer of the transverse mesocolon, to anas- h the superior pancreaticoduodenal.

FIG. 523.—THE BLOOD-VESSELS OF THE ILEOCECAL REGION. (From Kelly.)

Arteries red, veins blue.) The peritoneal covering is removed so as to show the vessels more clearly. Above and to the right are seen the cut ends of the ileocolic artery and vein. The artery gives off a branch to the ascending colon and a posterior and anterior cecal artery, the latter descending through the ileocolic fold. A short anastomosis connects the ileocolic with the mesenteric. The artery of the vermiform process (appendix) is seen to arise from the posterior cecal artery, 2 cm. above the ileum. It passes behind the ileum in the free border of the mesoappendix and gives off five branches (long appendices have 8–12, short appendices, 2–3), which traverse the mesoappendix at fairly regular intervals in the direction of the hilus of the appendix, where they divide into anterior and posterior branches. The branches in the mesoappendix are sometimes seen to anastomose, forming loops of varying size. The terminal branch curves around the tip. The cecoappendicular junction is supplied by a separate branch arising likewise from the posterior ileocecal trunk. This branch may or may not anastomose with the proximal appendicular twig and while in some cases it supplies only the cecum, in others, as in the present case, it sends a few delicate branches into the appendix. At the place where this cecoappendicular artery crosses the ileocecal fold it is seen to give off a delicate recurrent twig to this structure. Throughout their entire course the arteries are accompanied by veins.

) **The intestinal** arteries [aa. intestinales] arise from the convex side of the superior mesen- **and**, varying from twelve to sixteen in number, radiate in the mesentery, where each **s** into two branches, which inosculate with similar branches given off from the branch **and** below. From the primary loops thus formed, secondary loops are derived in like **er**, and from these tertiary, and at times quaternary, or even quinary loops. From **ltimate** loops terminal **jejunal and iliac** branches [aa. jejunales et ileæ] pass on to the mus- **coat** of the gut. These terminal vessels bifurcate, the two branches encircling the intes- **and** thus forming with those above and below a series of vascular rings surrounding the intestine throughout its whole length. The first intestinal artery anastomoses with the **reaticoduodenal** artery, and the last (the continuation of the main artery) with the ileo-

The branches of the superior mesenteric in their course to the intestine also supply the **ntery** and the mesenteric glands.

) **The ileocolic** [a. ileocolica] descends behind the peritoneum toward the cecum, where **ides** into a colic branch which tracks upward beneath the peritoneum to anastomose with **lescending** branch of the right colic; and into an iliac branch which passes between the **s** of the mesentery and anastomoses with the termination of the superior mesenteric **y**. Near the site of division the ileocolic gives off anterior and posterior cecal branches. **h** the latter of these arises a cecoappendicular artery, to the cecum and root of the vermi- process, and a main **appendicular** artery [a. appendicularis] (fig. 523).

) **The right colic** [a. colica dextra]—sometimes given off as a common trunk either with **iddle colic** or with the ileocolic—passes to the right behind the peritoneum to the back **ascending** colon, where it divides into an ascending branch, which anastomoses with the **nding branch** of the middle colic, and a descending branch which anastomoses with the **ding** or colic branch of the ileocolic.

) **The middle colic** [a. colica media], arising from the concavity of the superior mesenteric **e** below the pancreas, enters the transverse mesocolon, and divides into two branches— **f which passes** to the left and anastomoses with the ascending branch of the left colic; **ther, winding** downward and to the right, anastomoses with the ascending branch of the **colic**.

THE RENAL ARTERIES

he renal arteries [aa. renales] come off one on each side of the abdominal **, a little below** the superior mesenteric and first lumbar arteries, on a level **the first lumbar** vertebra. They pass laterally across the crura of the **iragm** to the kidneys, the right being on a slightly lower plane and somewhat **r than** the left, and passing behind the vena cava inferior. In front of each **corresponding renal** vein, and behind, at the hilus of the kidney, is the com- **ement** of the ureter. Each artery as it enters the hilus usually divides into **main stems, one** of which passes toward the upper part of the pelvis, a second **middle portion, and** a third to its lower. Each of these primary stems then **es so that** there result from seven to nine secondary branches, the majority **hich pass anteriorly** to the pelvis, while the remainder are posterior to it (fig.

No anastomoses take place between the branches of the anterior and **rior secondary** stems and hence a longitudinal incision into the kidney along **rved border**, half way between the anterior and posterior calices, will cut **terminal** arteries.

he branches of the renal arteries are:

) **The inferior suprarenal** [a. suprarenalis inferior] which ascends to the suprarenal body.
) **The capsular** or **perirenal** branches to the capsule of the kidney and perirenal fat.
) **The ureteral** branch to the upper end of the ureter.

THE MIDDLE SUPRARENAL ARTERIES

The middle suprarenal artery [a. suprarenalis media] comes off, one on each **from the aorta**, just above the first lumbar artery, and passes laterally to the **rarenal body**, across the crura of the diaphragm a little above the renal **eries**. In the fetus they equal the renals in size, but in the adult they are **ch** smaller. They anastomose with the superior and inferior suprarenal **eries** from the inferior phrenic and renal arteries respectively. For the **ribution** of the suprarenal vessels within the suprarenal bodies, see Section II.

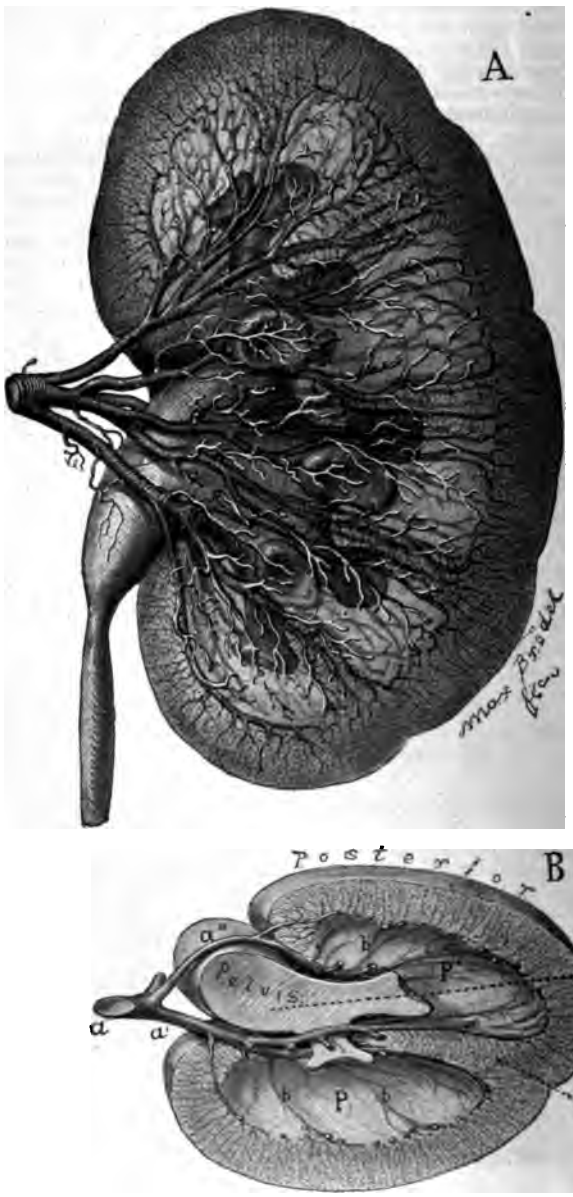
THE INTERNAL SPERMATIC ARTERIES

The **internal spermatic** arteries [a. spermatica interna], (figs. 519, 582), right left, come off from the front of the abdominal aorta. They diverge from **i** other as they descend over the aorta and psoas muscle to the abdominal **inal** (internal abdominal) ring, where they are joined by the ductus deferens, passing with it through the inguinal canal and out of the subcutaneous

inguinal (external abdominal) ring, run downward into the scrotum in a t
course to the testes. They terminate in branches to the epididymis an
Within the abdomen they lie beneath the peritoneum, and cross in their
over the ureters and distal ends of the external iliac arteries; the right be

FIG. 524.—A. THE RENAL ARTERY AND THE DISTRIBUTION OF ITS BRANCHES IN
TO THE PELVIS. B. TRANSVERSE SECTION THROUGH THE MIDDLE OF THE SA
(After Brödel, Johns Hopkins Hospital Bulletin.)

a, renal artery; *a'* and *a"*, its anterior and posterior branches; *b*, branches to pyra
of division between anterior and posterior pyramids. The arrow and dotted l
the line of separation between the terminals of the anterior and posterior bra



ficial to the vena cava, and behind the termination of the ileum; and
beneath the sigmoid colon. In the inguinal canal and in the scrotum
matic veins lie in front of the artery, and the ductus deferens lies behin

In the fetus these vessels pass in a transversely lateral direction to the testis, whi
fetal life lies in the loin in front of the kidney; but as the testes descend to the scrotu
sels become elongated, and are drawn with the testis into the scrotum.

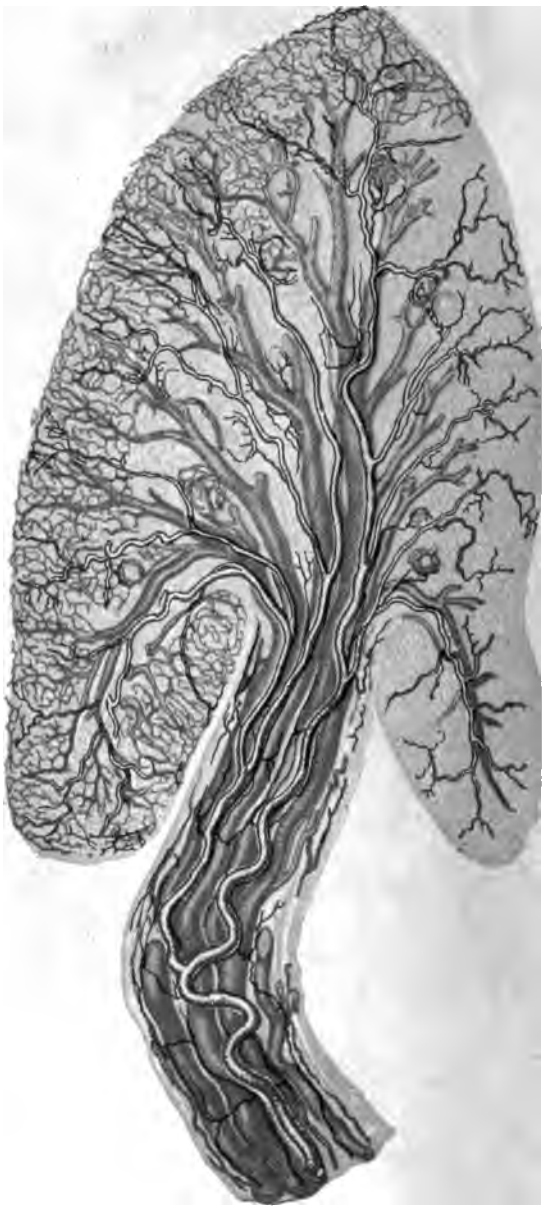
-THE VASCULAR TRUNKS OF THE LOWER ABDOMEN. (From Kelly, by Brödel.)

The **branches of the internal spermatic artery** are: (1) Ureteral; masteric; (3) epididymal; and (4) testicular.

(1) The **ureteral** are small branches given off to the ureter as the spermatic arter it. They anastomose with the other ureteral branches derived from the renal, comm and vesical arteries.

(2) The **cremasteric** are small branches given off to the cremaster muscle; they an with the cremasteric branch of the inferior epigastric.

FIG. 526.—THE OVARIAN VESSELS. (After Clark.)



(3) The **epididymal** are distributed to the epididymis, and **anastomose with the d** artery.

(4) The **testicular** arteries [aa. testiculares] are the **terminal branches of the s** they perforate the tunica albuginea posteriorly, and are distributed to the body of th described in the section on the TESTIS.

The external spermatic artery is a branch of the inferior **epigastric artery** (p. 651

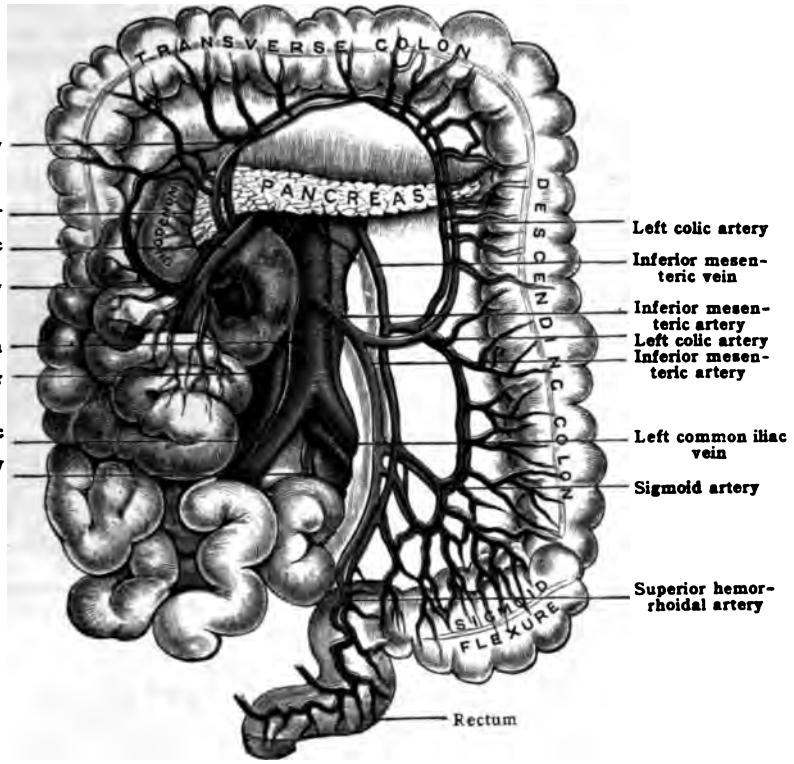
THE OVARIAN ARTERIES

varian arteries [aa. ovaricæ] (figs. 525, 526, 531) are the homologs of **ıal** spermatic arteries in the male, and correspond in their relations in **r** part of their course. They diverge somewhat less, however, and, on **the** level of the common iliac artery, turn medialward over that vessel **end** tortuously into the pelvis between the folds of the broad ligament **aries.** In the broad ligament the ovarian artery lies below the Fallopian **l** on reaching the ovary turns backward and supplies that organ. In **s** shown how the artery enters the hilus of the ovary and breaks up into which correspond to the lobules of the organ.

ıranches of the ovarian arteries are: (1) Ureteral; (2) tubal; (3) uterine; **igamentous.**

e ureteral is distributed, as in the male, to the ureter.
e tubal supplies the isthmus and ampulla of the tuba uterina (Fallopian tube) and **ted extremity.**
e uterine runs beneath the tuba uterina (Fallopian tube) to the uterus, supplying **part of the fundus, and anastomosing with the uterine arteries from the hypogastric.**

FIG. 527.—THE INFERIOR MESENTERIC ARTERY AND VEIN.
he colon is turned up, and the small intestines are drawn to the right side.)



ıe ligamentous is distributed to the round ligament, passing with that structure **ıe inguinal canal, and anastomosing with the superficial external pudendal artery.**
ıe spermatic, the ovarian arteries in the fetus come off at right angles to the aorta, transversely lateralward to the ovaries, which are formed, as are the testes, in the eft loin in front of the kidneys. They elongate as the ovaries descend into the pelvis. egnancy these arteries undergo great enlargement.

THE INFERIOR MESENTERIC ARTERY

inferior mesenteric artery [a. mesenterica inferior], smaller than the **arises from the front of the abdominal aorta about 3.7 cm. ($1\frac{1}{2}$ in.)** **ıe bifurcation of that vessel. It runs obliquely downward and to the nd the peritoneum, across the lower part of the abdominal aorta and then left psoas muscle and left common iliac artery. It descends into the tween the layers of the sigmoid mesocolon, and terminates on the rectum**

in the superior hemorrhoidal artery. It supplies the lower half of the large testine. Its vein lies at first close to the left side, but soon passes upward on psoas, away from the artery, to end in the splenic vein (fig. 527).

The **branches of the inferior mesenteric** are: (1) The left colic; (2) sigmoid; and (3) the superior hemorrhoidal.

(1) The **left colic** artery [a. colica sinistra] runs transversely to the left, beneath the toneum, and divides into two branches, one of which, entering the transverse mesocolon cends upward and to the right, to anastomose with the middle colic. The other descends, entering the sigmoid mesocolon anastomoses with the ascending branch of the sigmoid a

The distribution of the branches of the left colic and of the sigmoid artery to the co similar to that of the colic branches of the superior mesenteric, and does not require a rate description.

(2) The **sigmoid artery** [a. sigmoidea] runs downward and to the left over the psoas cle and, entering the sigmoid mesocolon, divides into two branches; the upper anastom with the left colic, the lower with the superior hemorrhoidal. The distribution of the bra of the left colic and of the sigmoid artery to the colon is similar to that of the colic branch the superior mesenteric, and does not require a separate description. (See p. 635.)

(3) The **superior hemorrhoidal** artery [a. hæmorrhoidalis superior] (fig. 525) is the cont trunk of the inferior mesenteric. It descends into the pelvis, behind the rectum, betwee layers of the sigmoid mesocolon. On reaching the wall of the bowel it bifurcates, one b proceeding on either side of the gut, to within 10 or 12 cm. (4 or 5 in.) of the anus. Here again divides, and the branches, piercing the muscular coat, descend between that coa the mucous membrane, forming with each other, and with the middle hemorrhoidal arte derived from the hypogastric (internal iliac)—a series of small vessels, running longitudina the rectum, and parallel to each other as far as the level of the internal sphincter, where, by anastomosis, they form a series of loops around the lower part of the rectum.

C. The Terminal Branches of the Abdominal Aorta

THE MIDDLE SACRAL ARTERY

The **middle sacral** artery [a. sacralis media] extends from the bifurcati the aorta to the tip of the coccyx. As it passes downward into the pelv runs behind the left common iliac vein, the hypogastric plexus of the sympat nerve, and the peritoneum. It lies successively upon the intervertebral between the fourth and fifth lumbar vertebræ, the fifth lumbar vertebra intervertebral disk between that vertebra and the sacrum, and lower down the anterior surface of the sacrum and coccyx.

(1) The **lowest lumbar** artery [a. lumbalis ima] runs laterally beneath the common iliac and vein; and, after giving off a dorsal branch, ramifies over the lateral part of the sacrum ends in the iliacus muscle by anastomosing with the circumflex iliac artery. The dorsal b passes to the back between the last lumbar vertebra and the sacrum and ramifies in the g maximus, anastomosing with the lumbar arteries above, and the superior gluteal artery

(2) **Lateral sacral** branches, are usually four in number. They are serially homologou the intercostal and lumbar arteries given off by the aorta. They run laterally, and anas with the lateral sacral branches of the hypogastric (internal iliac) artery. They give of spinal branches, which pass through the sacral foramina, and supply the sacral canal an of the sacrum.

(3) **Rectal** or **hemorrhoidal** branches pass forward beneath the peritoneum or in t moid mesocolon to the rectum, which they help to supply, and anastomose with the hemorrhoidal or rectal arteries.

THE COMMON ILIAC ARTERIES

The **common iliac** arteries [aa. iliacæ communes] arise opposite the le of the middle of the body of the fourth lumbar vertebra, at the bifurcation abdominal aorta, and, diverging from each other in the male at about an of 60°, and in the female at an angle of 68°, terminate opposite the lumbo articulation by bifurcating into the external iliac, which is continued alo brim of the pelvis to the lower limb, and into the hypogastric (internal which descends into the pelvis minor (fig. 528). The relations differ slig the two sides, which may be considered separately.

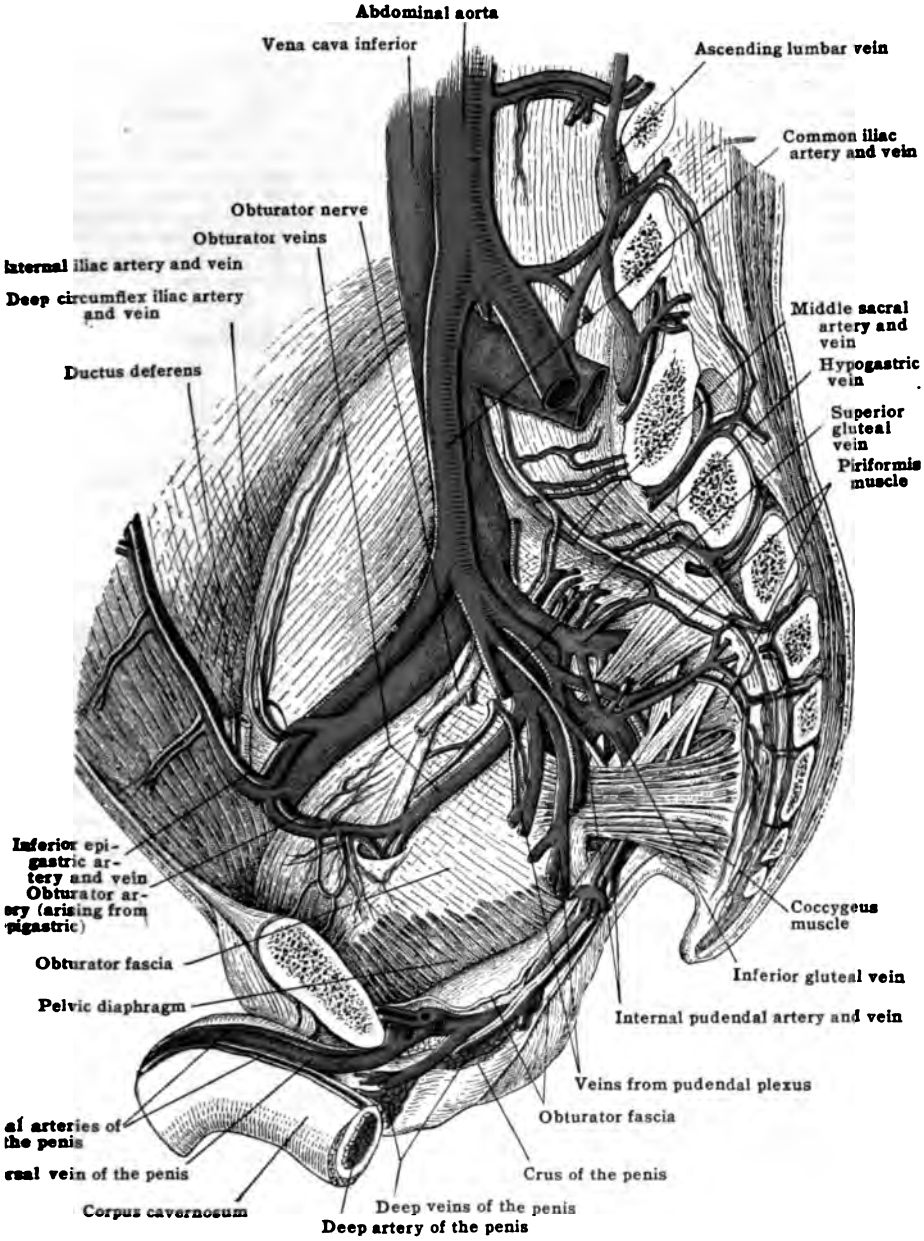
The Right Common Iliac Artery

The **right common iliac** (fig. 528) measures about 5 cm. (2 in.) in lengt is rather longer than the left, in consequence of the aorta bifurcating to the left of the median line.

Relations.—In front it is covered by the peritoneum, and is crossed by the right little before its bifurcation, by the ovarian artery in the female, by the termination of th

he terminal branches of the superior mesenteric artery, and by branches of the sympathetic e descending to the hypogastric plexus.
Behind, it lies on the right common iliac vein, the end of the left common iliac vein, and the mencement of the vena cava inferior which separate it from the fourth and fifth lumbar ebræ and their intervening disks, the psoas muscle, and the sympathetic nerve trunk. deeper in the groove between the fifth vertebra and the psoas are the lumbosacral trunk obturator nerve, and the iliolumbar artery.

528.—Blood-vessels of the Male Pelvis. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



To the **right side** are the beginning of the vena cava inferior, the end of the right common vein, and the psoas muscle. The muscle, however, is separated from the upper part of the y by the vena cava inferior.
To the **left side** are the right common iliac vein, the termination of the left common iliac vein, the hypogastric plexus.

The Left Common Iliac Artery

The left common iliac artery, 4 cm. (1.4 in.) in length, is a little shorter and **ker than the right.**

Relations.—In front it is covered by the peritoneum and is crossed by the ureter, the ova artery in the female, branches of the sympathetic nerve descending to the hypogastric ple the termination of the inferior mesenteric artery, the sigmoid colon, and the sigmoid mesoc

Behind are the lower border of the body of the fourth lumbar vertebra, the disk betwee fourth and fifth lumbar vertebra, the body of the fifth lumbar vertebra, and the disk betwe and the sacrum. Crossing deeply behind the artery between the fifth lumbar vertebra and psoas, are the obturator nerve, the lumbosacral trunk, and the iliolumbar artery.

To the **left side** is the psoas muscle.

To the **right side** are the left common iliac vein, the hypogastric plexus, and the mi sacral artery.

Collateral Circulation

The **collateral circulation** after obstruction or ligature of the common iliac artery is ca on chiefly (fig. 537) by the anastomosis of the middle sacral with the lateral sacral; the inte mammary with the epigastric; the lumbar arteries of the aorta with the iliolumbar and c circumflex iliac; the pubic branch of the epigastric with the pubic branch of the obturator; posterior branches of the sacral arteries with the superior gluteal (gluteal); the superior h orrhoidal from the inferior mesenteric, with the hemorrhoidal branches of the hypogastric ternal iliac) and pudic; the ovarian arteries from the aorta with the uterine branches of hypogastric (internal iliac); and by the anastomosis across the middle line of the pubic br of the obturator with the like vessel of the opposite side; the lateral sacral with the opp lateral sacral; and the vesical, hemorrhoidal, uterine, and vaginal branches of the hypoga with the corresponding branches of the opposite hypogastric (internal iliac).

Branches of the Common Iliac Artery

The **branches of the common iliac artery** (fig. 528) are:—(1) The hypogas (internal iliac); and (2) the external iliac.

A few small, unimportant branches are distributed to the peritoneum and subperito fat. They anastomose with vessels given off from the lumbar, inferior phrenic, and r arteries, forming a subperitoneal arterial anastomosis. The ureter as it crosses the ar receives small twigs which anastomose with the ureteral arteries given off from the inte spermatic above, and with those derived from the vesical arteries below.

THE HYPOGASTRIC ARTERY

The **hypogastric** or **internal iliac** artery [a. hypogastrica] (figs. 528, 5 arises at the bifurcation of the common iliac opposite the lumbosacral articulat It descends into the pelvis minor for about 3 cm. ($1\frac{1}{4}$ in.) and opposite the u margin of the great sciatic foramen, gives off the so-called posterior divis which forms the common stem of origin for the iliolumbar, lateral sacral superior gluteal arteries. The remainder of the artery, known as the ant division of the hypogastric, forms the common stem of origin for the obtur inferior gluteal, umbilical, inferior vesical, deferential, middle hemorrho uterine (in the female), and internal pudendal arteries.

In the fetus the hypogastric artery is larger than the external iliac; for through it the blood is returned to the placenta. The common iliac-hypogastric trunk replaces the pro part of the umbilical artery, which disappears at an early stage of development. The l part of the remainder of the intraabdominal portion of the umbilical artery is reduced, af after birth, to an impervious cord, the lateral umbilical ligament. The small part remains functional is represented by the section of the hypogastric artery giving origin t ceral branches and by the proximal part of the superior vesical artery.

Relations.—Behind, the hypogastric artery rests on the termination of the external vein, the hypogastric vein, the medial margin of the psoas muscle, the lumbosacral trunk obturator nerve, and the sacrum.

In front, it is covered by the peritoneum, and is crossed by the ureter.

The **branches of the hypogastric artery** may be divided into parietal visceral sets. The **parietal** branches are:—(1) The iliolumbar; (2) the la sacral; (3) the obturator; and (4) the gluteal arteries.

The **visceral** branches are:—(1) The umbilical; (2) the inferior vesical the middle hemorrhoidal; (4) the uterine; and (5) the internal pudendal.

Parietal Branches of the Hypogastric Artery

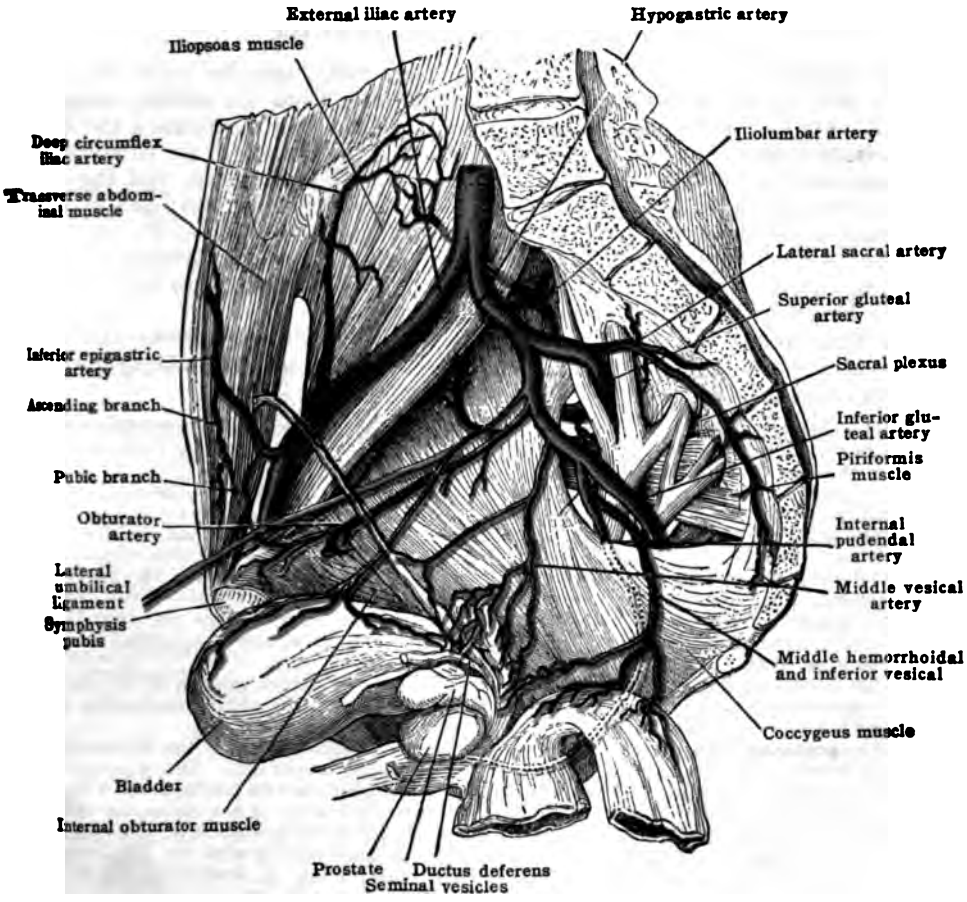
1. THE ILIOLUMBAR ARTERY

The **iliolumbar** artery [a. iliolumbalis]—a short vessel arising from the terior division of the hypogastric artery—runs upward and laterally beneath common iliac artery, first between the lumbosacral trunk and obturator n

and then between the psoas muscle and the vertebral column. On reaching the superior aperture of the pelvis minor it divides into two branches, an iliac and a lumbar (fig. 529).

The **iliac branch** [ramus iliacus] passes laterally beneath the psoas and the femoral (anterior crural) nerve and, perforating the iliacus, ramifies in the iliac fossa between that muscle and the bone. It supplies a nutrient artery to the bone, and then breaks up into several branches which radiate from the parent trunk, upward toward the sacroiliac synchondrosis, laterally toward the crest of the ilium, downward toward the anterior superior spine, and medially toward the pelvis minor. The first anastomoses with the last lumbar; the second with the lateral circumflex and gluteal; the third with the deep circumflex iliac from the external iliac; the fourth with

FIG. 529.—THE HYPOGASTRIC ARTERY. (After Henle.)



the iliac branch of the obturator. The **lumbar** branch [ramus lumbalis] ascends beneath the psoas, and, supplying that muscle and the quadratus lumborum, anastomoses with the last lumbar artery. It sends a **spinal** branch (ramus spinalis) into the vertebral canal through the intervertebral foramen between the last lumbar vertebra and the sacrum; this branch anastomoses with the other spinal arteries. The iliolumbar artery is serially homologous with the lumbar arteries. Hence the similarity in its course and distribution.

2. THE LATERAL SACRAL ARTERIES

The **lateral sacral artery** [a. sacralis lateralis], commonly arises as two vessels from the posterior division of the hypogastric. The **superior** artery (or branch, in cases in which two branches arise from a common stem), runs downward and medially to the first anterior sacral foramen, through which it passes. After supplying the spinal membranes and anastomosing with the other spinal arteries, it passes through the first posterior sacral foramen, and is distributed to the skin over the back of the sacrum, there anastomosing with branches of the superior and inferior gluteal arteries. The **inferior lateral sacral** descends on the side of the sacrum, on the lateral side of the sacral sympathetic trunk, and medially to the anterior sacral foramina, crossing in its course the slips of origin

of the piriformis muscle and the first anterior sacral nerve. On reaching the coccyx it anastomoses in front of that bone with the middle sacral artery, and with the inferior lateral sacral of the opposite side (fig. 529).

In this course it gives off:—**Spinal** branches [rami spinales], which enter the second, third and fourth anterior sacral foramina, and, after supplying the spinal membranes and anastomosing with each other, leave the spinal canal by the corresponding posterior sacral foramina, and are distributed to the muscle and skin over the back of the sacrum; and **rectal** branches which run forward to the rectum.

At times the lateral sacral arteries are exceedingly small, the spinal branches then coming chiefly from the middle sacral. The anastomosing branches between the lateral sacral and middle sacral are usually regarded as sacral segmental arteries serialy homologous with the lumbar and intercostal arteries.

3. THE OBTURATOR ARTERY

The **obturator** artery [a. obturatoria] (fig. 529), usually arises from the anterior division of the hypogastric, but sometimes from the inferior epigastric (fig. 488) or from the external iliac artery (see p. 652). It runs forward and downward a little below the brim of the pelvis, having the obturator nerve above and the obturator vein below. It here lies between the peritoneum and the endopelvic fascia, but later it passes through the obturator canal, the aperture in the upper part of the obturator membrane. In this course it is crossed by the ductus deferens. On emerging from the obturator canal the artery divides into two branches, anterior and posterior, which wind around the margin of the obturator foramen beneath the obturator externus muscle.

The **branches of the obturator artery** are:—(1) The iliac or nutrient branch; (2) a vesical branch; (3) the pubic branch; (4) the anterior, and (5) posterior terminal branches.

(1) The **iliac or nutrient** branch ascends to the iliac fossa, passing between the iliacus muscle and the bone. It supplies a nutrient vessel to the ilium, and **anastomoses** with the medial branch of the iliac division of the iliolumbar artery.

(2) The **vesical** branch or branches are small vessels which run beneath the peritoneum to the bladder, where they anastomose with the other vesical arteries.

(3) The **pubic** branch [ramus pubicus] comes off from the obturator as that vessel is leaving the pelvis by the obturator canal. It runs upward and medially behind the pubis, anastomosing with its fellow of the opposite side of the body, and with the pubic branch of the inferior epigastric artery. One of the anastomosing channels between the pubic branch of the obturator and pubic branch of the inferior epigastric arteries is sometimes of large size (fig. 1110), a fact of surgical interest in that the enlarged vessel may then run around the medial side of the femoral ring (p. 652).

(4) The **anterior** branch [ramus anterior] runs around the medial margin of the obturator foramen, and anastomoses with the posterior branch and with the medial circumflex artery. It supplies branches to the obturator and adductor muscles.

(5) The **posterior** branch [ramus posterior] skirts the lateral margin of the obturator foramen, lying between the obturator externus and the obturator membrane. At the lower margin of the foramen it divides into two branches. One branch continues its course around the lower margin of the foramen, and anastomoses with the anterior branch of the obturator and with the medial circumflex. The other branch turns laterally below the acetabulum, and ends in the muscles arising from the tuberosity of the ischium. It anastomoses with the inferior gluteal artery. This branch gives off a small twig, the **acetabular** artery [a. acetabuli], which passes under the transverse ligament into the hip-joint, where it supplies the synovial membrane, the ligamentum teres, and the fat in the fossa at the bottom of the acetabulum.

4. THE GLUTEAL ARTERIES

There are two gluteal arteries, the **superior** and **inferior** (fig. 530). The **superior gluteal** artery [a. glutea superior], the largest branch of the posterior division of the hypogastric, comes off as a short trunk from the lateral and back part of that vessel, of which indeed it may be regarded as the continuation. Passing backward between the first sacral nerve and the lumbosacral trunk through an osseo-tendinous arch formed by the margin of the bone and the upper edge of the endopelvic fascia, it leaves the pelvis through the great sciatic foramen above the piriformis muscle in company with its vein and the superior gluteal nerve. At its exit posteriorly from the great sciatic foramen it lies under cover of the gluteus maximus and beneath the superior gluteal vein, and in front of the superior gluteal nerve. It here breaks up into two chief branches, superior and inferior. Its emergence from the pelvis is indicated on the surface by a point situated at the junction of the posterior with the middle third of a line drawn from the anterior superior to the posterior superior spine of the ilium.

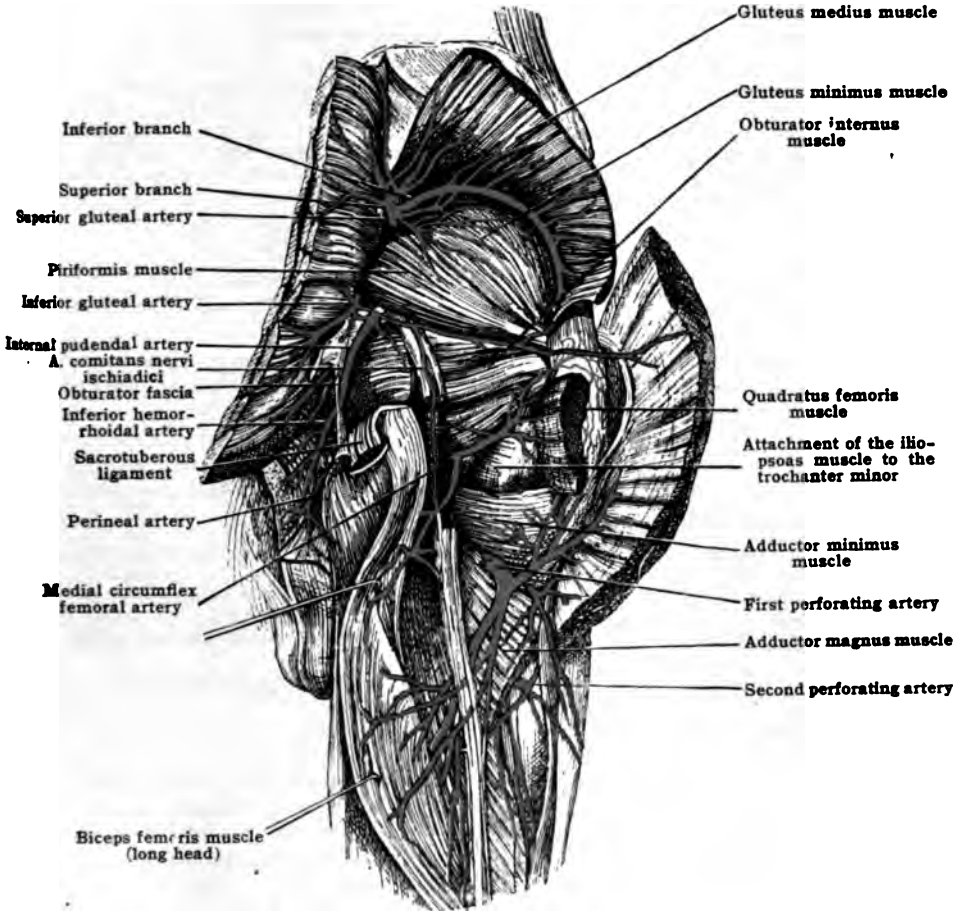
The branches of the superior gluteal artery are:—

(*a*) **Within the pelvis,** branches are distributed to the obturator internus, the piriformis, the levator ani, the coccygeus, and the pelvic bones.

(*b*) **External to the pelvis,** the artery divides into a superior and an inferior branch.

(i) The **superior** branch [ramus superior] breaks up into a number of large vessels for the supply of the upper portion of the gluteus maximus, some of them piercing the muscle and supplying the skin over it, and anastomosing with the posterior branches of the lateral sacral arteries; one of larger size, emerging from the muscle near the iliac crest, anastomoses with the deep circumflex iliac artery. The lower branches to the muscle anastomose with branches of the inferior gluteal (sciatic).

FIG. 530.—THE GLUTEAL ARTERIES. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



(ii) The **inferior** branch [ramus inferior] subdivides into two branches. One skirts along the line of origin of the gluteus minimus (fig. 530), between the gluteus medius and the bone, and, emerging in front from beneath these muscles under cover of the tensor fasciæ latæ, anastomoses with the ascending branch of the lateral circumflex and the deep circumflex iliac arteries. The other passes forward between the gluteus medius and minimus, accompanied by the branch to the tensor fasciæ latæ of the inferior division of the superior gluteal nerve, toward the greater trochanter, where it anastomoses with the ascending branch of the lateral circumflex. It supplies branches to the contiguous muscles and to the hip-joint. The inferior branch before its division gives off the external nutrient artery of the ilium.

The inferior gluteal [a. glutea inferior], is one of the terminal branches of the anterior division of the hypogastric artery. It leaves the pelvis below the piriformis muscle, and immediately breaks up into a number of diverging branches. The largest enter the gluteus maximus muscle, where they anastomose with the superior gluteal branches. Others pass to the hip-joint, and the deep muscles around it; a third group passes downward to the hamstring muscles and anastomoses with the medial and lateral circumflex and first perforating; a fourth

slender branch, the **sciatic** artery [a. comitans n. ischiadici], accompanies the sciatic nerve (fig. 530).

Visceral Branches of the Hypogastric Artery

1. THE UMBILICAL ARTERY

The **umbilical** artery in the fetus is the continuation of the hypogastric. Passing forward along the side of the pelvis, it runs beneath the lateral reflection of peritoneum from the bladder, where, after giving off one or more vesical branches, it ceases to be pervious and passes on to the side and upper part of the bladder. Thence it ascends in the lateral umbilical fold, as a fibrous cord [ligamentum umbilicale laterale], to the umbilicus, where it is joined by its fellow of the opposite side. As it lies upon the bladder it is crossed by the ductus deferens.

The **branches of the umbilical artery** are:—(1) Superior vesical arteries, the lowest of which is sometimes called (2) the middle vesical artery (fig. 529).

The **superior vesical** arteries [aa. vesicales superiores] ramify over the upper surface of the bladder, anastomosing with the artery of the opposite side and with the middle and inferior vesical below. They give off the following branches:—(*a*) The **urachal** branches which pass upward along the urachus. (*b*) The **ureteric** branches pass to the lower end of the ureter, and anastomose with the other ureteric arteries. (*c*) The **middle vesical** may come off from one of the superior vesicals or from the umbilical. It is distributed to the sides and base of the bladder, and anastomoses with the other vesical arteries.

2. THE INFERIOR VESICAL ARTERY

The **inferior vesical** artery [a. vesicalis inferior] arises from the anterior division of the hypogastric, frequently in common with the middle hemorrhoidal (fig. 529), and passes downward and medially to the fundus of the bladder, where it breaks up into branches which ramify over the lower part of the viscus. It gives off branches to the prostate, which supply that organ and anastomose with the arteries of the opposite side by passing through the prostatic plexus of veins and with the inferior hemorrhoidal branches of the internal pudendal. At times one of these prostatic branches is of large size, and supplies certain of the parts normally supplied by the internal pudendal. It is then known as the accessory **pudendal** and most commonly terminates as the dorsal artery of the penis.

The inferior vesical usually gives off the **deferential artery.** This vessel, which may come off from the superior or the middle vesical (as in fig. 529), divides, on the ductus deferens, into an ascending and a descending branch. The ascending branch follows the ductus through the inguinal canal to the testis, where it anastomoses with the internal spermatic artery. The descending branch passes downward to the dilated portion of the ductus and to the vesiculæ seminales.

3. THE MIDDLE HEMORRHOIDAL ARTERY

The **middle hemorrhoidal** artery [a. hemorrhoidalis media] (fig. 529), variable in origin, perhaps most commonly arises from the anterior division of the hypogastric along with the inferior vesical. It runs medially to the side of the middle portion of the rectum, dividing into branches which anastomose above with the superior hemorrhoidal derived from the inferior mesenteric, and below with the inferior hemorrhoidal derived from branches of the internal pudendal. Its corresponding vein terminates in the inferior mesenteric vein. In the female it also sends branches to the vagina.

4. THE UTERINE ARTERY

The **uterine** artery [a. uterina] (fig. 531), arises from the anterior division of the hypogastric close to or in conjunction with the middle hemorrhoidal or inferior vesical. It runs downward and medially through the pelvic connective tissue, crossing the ureter about 12 mm. ($^1/_2$ in.) from the cervix uteri. It then ascends in the parametrium between the layers of the broad ligament at the side of the uterus in a coiled and tortuous manner, and, after giving off a number of tortuous branches which ramify horizontally over the front and back of the uterus, supplying its substance, anastomoses with the uterine branch of the ovarian artery.

The **branches of the uterine artery** are:—(1) **Cervical.**—This branch comes off from the uterine as the latter artery crosses the ureter to turn upward on to the uterus. It is directed medially, and divides into three or four branches which pass on to the cervix at right angles to it; one branch anastomosing with its fellow of the opposite side in front and behind the neck,

ɛ **the so-called** coronary artery of the cervix. (2) **Tubal** [ramus tubarius]. This courses he lower surface of the tuba uterina (Fallopian tube) as far as fimbriated extremity, and so send a branch to the ligamentum teres. (3) **Ovarian** [ramus ovarii]. This runs along arched border of the ovary, sending branches to that structure, and terminates by anas- ng widely with the ovarian artery. Usually the vaginal artery also arises from the uter- i) **The vaginal** artery [a. vaginalis] corresponds to the inferior vesical artery of the male,

FIG. 531.—OVARIAN AND UTERINE AND VAGINAL ARTERIES. (From Kelly, by Brödel).

ay arise directly from the hypogastric artery, close to the origin of the uterine, or from the or vesical. It passes medially, behind the ureter, to the upper part of the vagina, and numerous branches to that structure and also some to the posterior part of the fundus of adder.

ie branches to the vagina tend to anastomose with one another and with the cervical h of the uterine, to form a more or less perfect vertical stem in the median line of the a, both back and front. This stem is sometimes termed the **azygos artery of the vagina.** hes also pass to the vagina from the middle hemorrhoidal artery.

5. THE INTERNAL PUDENDAL ARTERY

he internal pudendal (pudic) artery [a. pudenda interna] (figs. 532, 533, 629) e of the terminal branches of the anterior division of the hypogastric artery

FIG. 532.—THE INTERNAL PUDENDAL ARTERY. (From Kelly, by Brödel.)

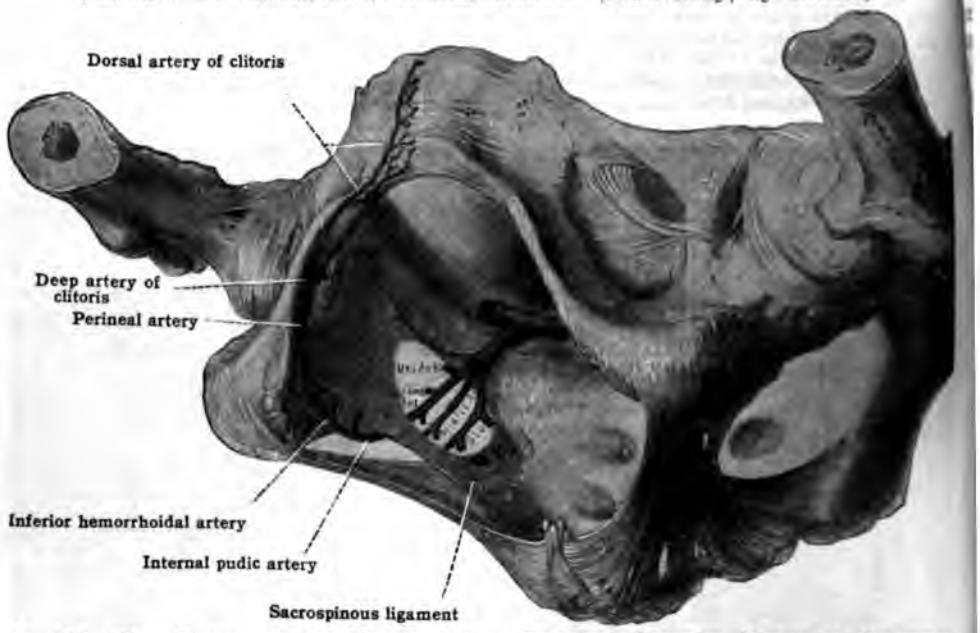
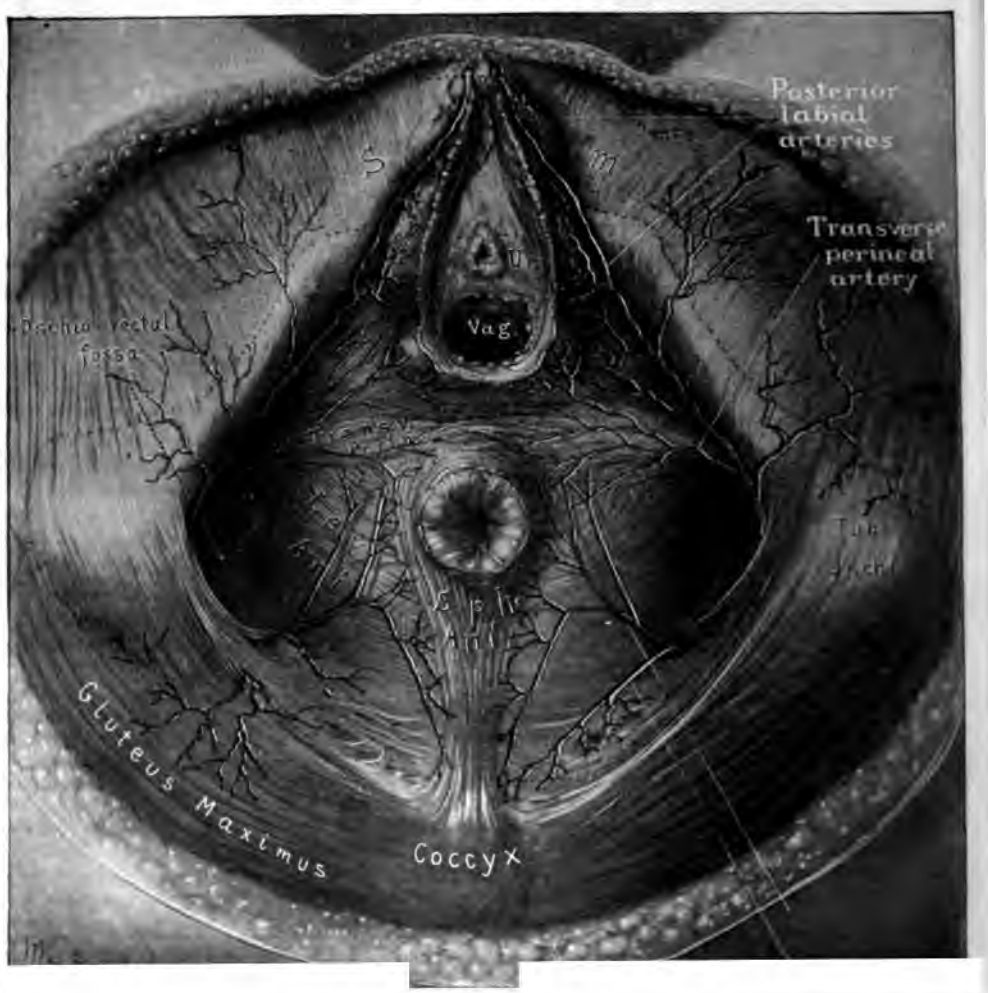


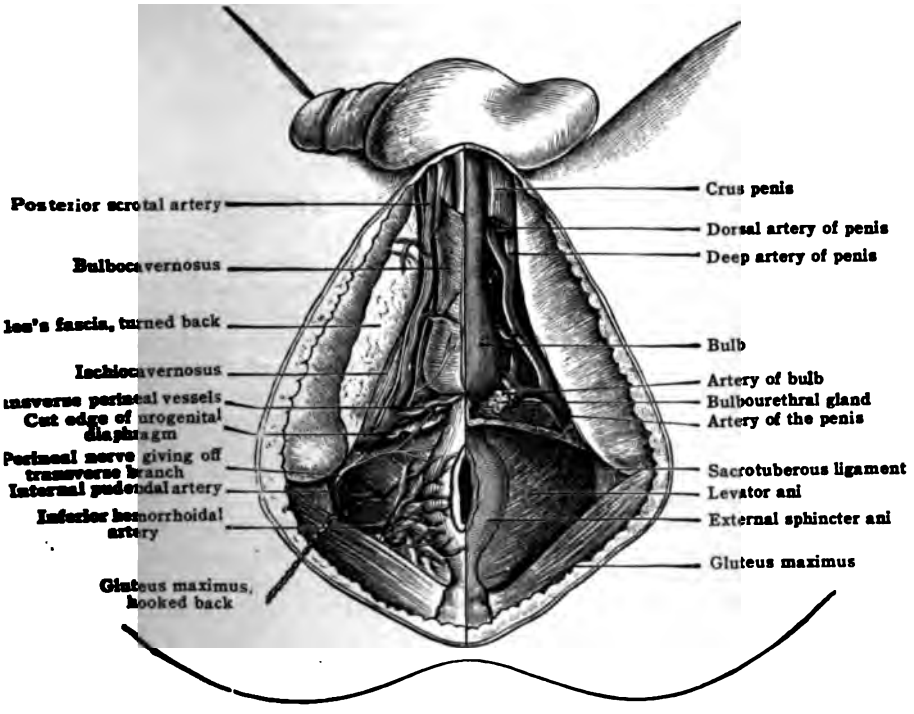
FIG. 533.—THE PERINEAL AND HEMORRHOIDAL BRANCHES OF THE INTERNAL PUDENDAL ARTERIES. (From Kelly, by Brödel.)



e inferior gluteal being the other). It arises opposite the piriformis muscle and ompanies the inferior gluteal downward to the lower border of the great ıtic foramen. It leaves the pelvis between the piriformis and coccygeus and ds over the ischial spine to enter the ischiorectal fossa through the small ıtic foramen. Running forward in the ischiorectal fossa medial to the lower ŧ of the obturator internus it ends by dividing into the **perineal artery** and the ry of the penis (or clitoris).

Relations.—*Within the pelvis*, the artery lies anteriorly to the piriformis muscle and the sacral us of nerves, and laterally to the inferior gluteal artery. It passes between the piriformis coccygeus, with the gluteal artery and pudendal nerve on the medial side, and the nerve to obturator internus upon the lateral. The sciatic and posterior femoral cutaneous (lesser ic) nerves lie still more laterally. *On the ischial spine* the artery retains its relations to pudendal nerve (which often divides in this situation into its two terminal branches and the e to the obturator internus. It is accompanied by venæ comitantes and covered by the eus maximus muscle. *In the ischiorectal fossa* the artery is placed on the lateral wall about mm. (1¼ in.) above the tuberosity of the ischium. It is accompanied in a canal in the ob- .tor fascia (Alcock's canal) by the dorsal nerve of the penis and the perineal nerve, which respectively above and below the artery.

FIG. 534.—THE ARTERIES OF THE MALE PERINEUM.



The branches of the internal pudendal artery are:—(1) Small branches to the uteal region; (2) the inferior hemorrhoidal arteries; and the terminal branches,) perineal; and (4) artery of the penis or clitoris.

(1) **The branches of the gluteal region** are:—(*a*) twigs to the gluteus maximus; (*b*) branches companying the nerve to the obturator internus; (*c*) a sacral branch which pierces the sacro- berous ligament and anastomoses with the inferior gluteal artery.

(2) **The inferior hemorrhoidal** artery [a. hæmorrhoidalis inferior] (figs. 533, 534) arises at e posterior part of the ischiorectal fossa and, perforating the obturator fascia, at once breaks into several branches. These, running medially toward the anus, traverse the ischiorectal ; and supply the fascia, skin and the levator ani and external sphincter muscles. The in- ior hemorrhoidal branches anastomose with those from the middle and superior hemor- oidal, and from the gluteal and perineal arteries.

(3) **The perineal artery** [a. perinei] (figs. 533, 534), one of the terminal arteries of the in- nal pudendal, arises at the anterior part of the ischiorectal fossa. It pierces the base of the ogenital diaphragm (triangular ligament), and enters the space deep to Colles's fascia. Here runs forward between the ischiocavernosus and bulbocavernosus muscles to the scrotum or ium majus and divides into numerous terminal branches. Immediately after piercing the phragm, the perineal artery gives off a constant transverse perineal branch which runs toward e median line along the superficial transverse perineal muscle. The terminal branches of the

perineal are the **posterior scrotal or labial** arteries [aa. scrotales, or labiales posteriores] which ramify on the scrotum or labia majora (according to sex) and anastomose with external pudendal arteries.

(4) The **artery of the penis, or clitoris** [a. penis or clitoridis] (figs. 533, 534) pierces the posterior border of the urogenital diaphragm and runs forward between the layers of the diaphragm with the dorsal nerve of the penis along the inferior ramus of the pubis. It traverses the fibers of the deep transverse perineal muscle and of the sphincter of the membranous urethra and ends by dividing into deep and dorsal arteries of the penis, or clitoris, according to sex.

On the right side Colles's fascia has been turned back to show the perineal artery. On the left side the perineal vessels have been cut away with the inferior layer of the urogenital diaphragm to show the artery of the penis.

The **branches of the artery of the penis (or clitoris)** are:—(*a*) The artery to the bulb; (*b*) the urethral artery; and (*c*) the terminal, deep artery of the penis or clitoris.

(*a*) The **artery of the bulb** [a. bulbi urethræ or vestibuli vaginæ] takes a medial direction through the fibers of the m. transversus perinei profundus. It then pierces the inferior fascia of the urogenital diaphragm to reach the bulb, the erectile tissue of which it supplies, in either sex. This vessel also supplies branches to the bulbourethral gland (Cowperi) or the gland of the vestibule (Bartholini).

(*b*) The **urethral** artery [a. urethralis] is a small branch which passes into the corpus spongiosum (corpus cavernosum urethræ) and anastomoses with branches from the artery of the bulb.

(*c*) The **deep artery of the penis or clitoris** [a. profunda penis or clitoridis], larger in the male sex, pierces the inferior layer of the urogenital diaphragm near the inferior ramus of the pubis. It enters the crus of the penis (fig. 534) or clitoris, and is distributed in the corpus cavernosum urethræ.

(*d*) The **dorsal artery of the penis or clitoris** [a. dorsalis penis or clitoridis] (figs. 532, 534), perforates the inferior fascia of the urogenital diaphragm near its apex. The dorsal nerve lies on the lateral side of the artery and joins the dorsal vein (which lies between the arteries of either side) on the dorsum of the penis or clitoris. The artery is much larger in the male than the female; in either sex it supplies the glans, corona, and prepuce and anastomoses with the external pudendal artery.

THE EXTERNAL ILIAC ARTERY

The **external iliac** artery [a. iliaca externa]—the larger in the adult of the two vessels into which the common iliac divides opposite the lumbosacral articulation—extends along the superior aperture of the pelvis minor, lying upon the medial border of the psoas muscle, to the lower margin of the inguinal ligament, where, midway between the anterior superior spine of the ilium and the symphysis pubis, it passes into the thigh, and takes the name of the femoral.

It measures 8.5 to 10 cm. (3½ to 4 in.) in length. The course of the vessel is indicated by a line drawn from 2.5 cm. (1 in.) below and a little to the left of the umbilicus to a point midway between the symphysis pubis and the anterior superior spine of the ilium. If this line is divided into thirds, the lower two-thirds of it will indicate the situation of the external iliac, and the upper third that of the common iliac. The external iliac vein, the continuation upward of the femoral vein from the thigh, lies to the medial side of the artery but on a slightly deeper plane, and, just before its termination, extends a little behind the artery on the right side.

Relations.—In front, the artery together with the vein is covered by the parietal peritoneum descending from the abdomen into the pelvis, and by a layer of condensed subperitoneal tissue (Abernethy's fascia). It is crossed by the termination of the ileum on the right side, and by the sigmoid colon on the left. The external spermatic (genital) branch of the genital femoral (genitocrural) nerve runs obliquely over its lower third, and just before its termination it is crossed transversely by the deep circumflex iliac vein. The internal spermatic or ovarian vessels lie for a short distance on the lower part of the artery, and the ductus deferens in the male curves over it to descend to the pelvis. It is sometimes crossed at its origin by the ureter. The external iliac lymphatic nodes lie along the course of the artery. The commencement of its inferior epigastric branch is also in front.

Behind.—The artery at first lies partly upon its own vein; lower down upon the medial border of the psoas; just before it passes through the lacuna vasorum, beneath the inguinal ligament, it lies upon the tendon of the psoas. The iliac fascia is also behind it.

To its **medial, side** are the external iliac vein, the peritoneum, and the ductus deferens in the male, or the ovarian vessels in the female.

To its **lateral side** are the psoas muscle and the iliac fascia.

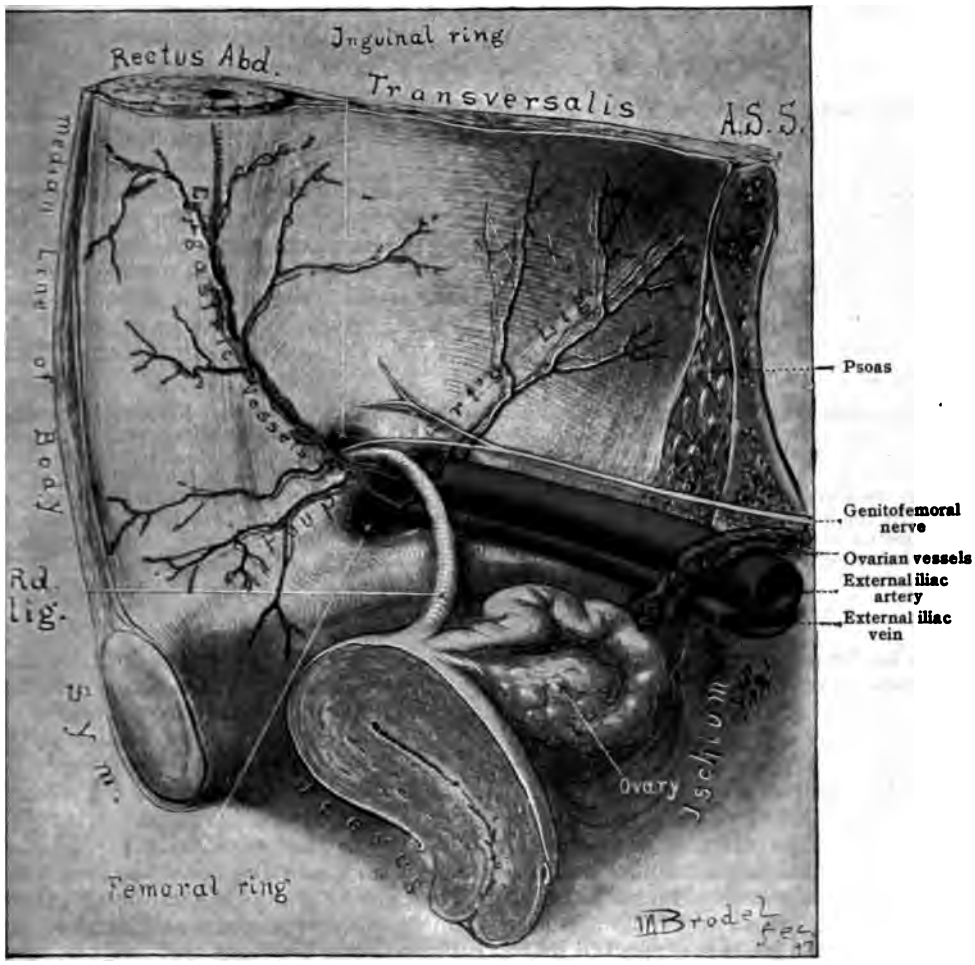
The **collateral circulation** is carried on (fig. 537) when the external iliac is tied, by the anastomosis of the iliolumbar and lumbar arteries with the circumflex iliac; the internal mammary with the inferior epigastric; the obturator with the medial circumflex; the inferior gluteal with the medial circumflex and superior perforating; the gluteal with the lateral circumflex; the arteria comitans nervi ischiadici from the inferior gluteal, with the perforating branches of the profunda; the external pudenal with the internal pudendal; the pubic branch of the obturator with the pubic branch of the epigastric.

The branches of the external iliac artery are:—(1) The inferior epigastric; (2) the deep circumflex iliac; and (3) several small and insignificant twigs to the neighboring psoas muscle and lymphatic glands.

(1) The Inferior Epigastric Artery

The inferior or deep epigastric artery [a. epigastrica inferior] (fig. 535) usually comes off from the external iliac just above the inguinal (Poupart's) ligament. Immediately after its origin, the ductus deferens in the male, or the round ligament in the female, loops around it where it lies medially to the abdominal inguinal (internal abdominal) ring, behind the inguinal canal, and a little above and laterally to the femoral ring. Thence it ascends with a slightly medial direction passing above and to the lateral side of the subcutaneous inguinal

Fig. 535.—The Inferior (Deep) Epigastric Artery. (From Kelly, by Brödel.)



(external abdominal) ring, lying between the fascia transversalis and the peritoneum. Having pierced the fascia transversalis, it passes in front of the linea semicircularis (Douglas' fold) and turns upward between the rectus and its sheath. Finally, it enters the substance of the rectus muscle, and anastomoses with the superior epigastric artery from the internal mammary.

The situation of the artery between the two inguinal rings should be borne in mind in the operation for strangulated inguinal hernia, and its near proximity to the upper and lateral side of the femoral ring should not be forgotten in the operation for femoral hernia. The artery is accompanied by two veins which end in a single trunk before opening into the external iliac vein.

The branches of the inferior epigastric are small and include:—(*a*) The **external spermatic**

[a. spermatica externa], which runs with the ductus through the inguinal canal, supplies the cremaster muscle, and anastomoses with the internal spermatic, external pudendal, and perineal arteries. In the female a corresponding artery [a. lig. teretis uteri] accompanies the round ligament of the uterus through the inguinal canal and anastomoses in a similar manner. (*b*) The **pubic** [ramus pubicus], which passes below, or sometimes above, the femoral ring to the back of the pubis, where it anastomoses with the pubic branch of the obturator. This branch, though usually small, is occasionally considerably enlarged (fig. 1110), when its exact course becomes of great interest to the surgeon. Thus it may descend on the medial side of the external iliac vein, and therefore lateral to the side of the femoral ring, or it may course medially in front of the femoral ring and turn downward either behind the os pubis or immediately behind the free edge of the lacunar (Gimbernat's) ligament, in which situation it would be exposed to injury in the operation for the relief of a strangulated femoral hernia. In such cases the obturator may not be connected with the hypogastric artery at all, but may take origin entirely from the external iliac or from the inferior epigastric. This abnormal origin of the obturator is said to occur once in every three and a half subjects but the abnormal artery courses around the medial side of the ring—in which situation it is liable to injury in operation for femoral hernia—in exceptional cases only. According to Langton (Holden's 'Anatomy'), the chances are about seventy to one against this occurrence. But even when it takes the abnormal course it lies 3 mm. or so from the margin of the ring, and will probably escape injury in the division of the stricture if several short notches are made in place of a single and longer incision.

(2) The Deep Circumflex Iliac Artery

The **deep circumflex iliac** artery [a. circumflexa ilium profunda], (fig. 535) arises from the lateral side of the external iliac artery either opposite the epigastric or a little below the origin of that vessel. It courses laterally just above the lower margin of the inguinal (Poupart's) ligament, lying between the fascia transversalis and the peritoneum, or at times in a fibrous canal formed by the union of the fascia transversalis with the iliac fascia. Near the anterior superior spine of the ilium, it perforates the transversus, and then courses between that muscle and the internal oblique, along and a little above the crest of the ilium. It finally runs backward to anastomose with the iliolumbar artery. It is accompanied by two veins. These unite into one trunk, which then crosses the external iliac artery to join the external iliac vein.

The **branches of the deep circumflex iliac artery** are as follows:—(*a*) **Muscular** branches which supply the psoas, iliacus, sartorius, tensor fasciæ latæ, and the oblique and transverse muscles of the abdomen. One of these branches, larger than the rest, usually arises about 2.5 cm. (1 in.) behind the anterior superior spine of the ilium and ascends perpendicularly between the transversus muscle and the internal oblique. It has received no name but is important to the surgeon, as it indicates the intermuscular plane between the two muscles. (*b*) **Cutaneous** branches, which supply the skin over the course of the vessel, and anastomose with the superficial circumflex iliac, the superior gluteal, and the ascending branch of the lateral circumflex.

THE FEMORAL ARTERY

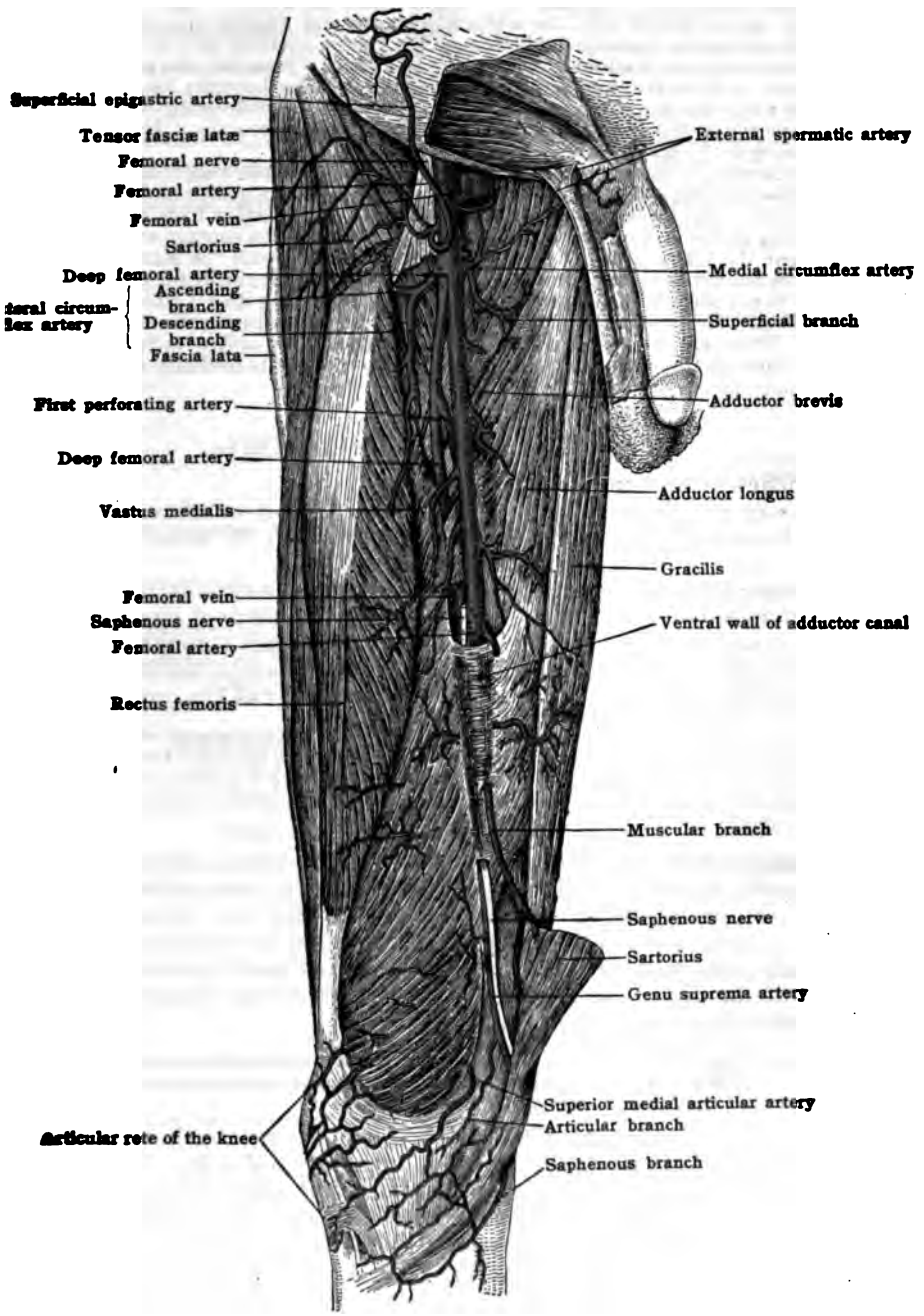
The **femoral** artery (fig. 536) is the continuation of the external iliac, and extends from the lower border of the inguinal (Poupart's) ligament, down the anterior and medial aspect of the thigh, to the tendinous opening in the adductor magnus, through which it passes into the popliteal space, and is then known as the popliteal. The femoral artery is at first quite superficial, being merely covered by the skin, and superficial and deep fascia; but after passing about 13 cm. (5 in.) downward through the space known as the femoral trigone (Scarpa's triangle), it sinks at the apex of that triangle beneath the sartorius muscle. Thence to its termination it continues beneath the sartorius, coursing deeply between the vastus medialis and adductor muscles in the space known as the adductor (Hunter's) canal. It at first rests upon the brim of the pelvis minor and head of the femur from which it is separated by the capsule of the hip-joint and the tendon of the psoas. Owing to the obliquity of the neck of the femur and the direct course taken by the artery, the latter lies lower down on muscles only, at some distance from the bone. At its termination, in consequence of the shaft of the femur inclining toward the middle line of the body, the artery lies close to the medial side of the femur.

The *course of the vessel* when the thigh is slightly flexed and abducted is indicated by a line drawn from a spot midway between the anterior superior spine of the ilium and the symphysis pubis to the adductor tubercle. When the thigh is in the extended position and parallel with its fellow, the course of the artery will correspond to a line drawn from the spot above mentioned to the medial border of the patella. Its *anastomoses* are shown in figs. 537 and 1140.

The relations of the femoral artery in the femoral trigone.—In front, the femoral artery (fig. 536) is covered by the skin, the superficial fascia, the iliac portion of the fascia lata, and the

boinguinal (crural) branch of the genitofemoral nerve. The superficial circumflex iliac a descends over the artery from the lateral to the medial side. Just proximally to the orius, the artery is crossed by the most medial of the anterior cutaneous branches of the oral nerve. The fascia transversalis, which is continued into the thigh beneath the in- nal ligament, is also in anterior relation, but it soon becomes indistinguishable from the ath of the vessel.

. 536.—THE FEMORAL ARTERY. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



Behind, the artery rests in turn upon the tendon of the psoas muscle, which separates rom the brim of the pelvis and capsule of the hip-joint; the pectineus, and adductor longus. artery is partially separated from the pectineus by the femoral vein and the profunda vein artery, and from the adductor longus by the femoral vein which is almost directly behind artery near the apex of the femoral trigone. The small nerve to the pectineus crosses ind the artery to reach its medial side.

A prolongation similar to that derived from the fascia transversalis in front, descends behind the vessel from the iliac fascia; but this, like the anterior prolongation or fascia, soon blends with the sheath of the vessels.

To the **medial side** is the femoral vein. This is separated from the artery, where the two vessels lie in the femoral sheath, by a thin fascial septum. More distally, the vein gradually reaches the posterior aspect of the artery.

To the **lateral side.**—Proximally, the common stem of the femoral (anterior crural) nerve is about 1 cm. (⅓ in.) lateral to the artery. When the femoral nerve gives off its branches, the saphenous nerve and the nerve to the vastus medialis accompany the artery on the lateral side.

The **adductor (Hunter's) canal** (fig. 536) is the somewhat trihedral space bounded by the vastus medialis on the lateral side, the adductors longus and magnus posteriorly, and by an aponeurosis thrown across from the adductors to the vastus medially and in front. Distally, the canal terminates at the tendinous opening in the adductor magnus; proximally, its limit is less well defined, as here the aponeurosis between the muscles becomes less tendinous, and gradually fades away into the perimuscular fascia. The transverse direction of the fibers of the aponeurotic covering at the distal two-thirds of the canal is characteristic. Lying superficially to the aponeurosis is the sartorius muscle.

The femoral artery, in the adductor (Hunter's) canal, has the **following relations:**—**In front,** in addition to the skin, superficial and deep fascia, are the sartorius muscle and the aponeurotic fibers of the canal. The saphenous nerve crosses in front of the artery from the lateral to the medial side, lying in the wall of the canal. **Behind,** the artery is in contact with the adductor longus, and near the opening in the adductor magnus, usually with the latter muscle. The femoral vein lies behind the artery, but gets a little lateral to it at the distal part of the canal. It is here very firmly and closely attached to the artery, embracing it as it were on its posterior and lateral aspect. Hence it is very liable to be punctured on ligaturing the artery in this part of its course. There are sometimes two veins, which then more or less surround the artery. To the **lateral side** are the vastus medialis, the nerve to the vastus medialis, and at the distal part of the canal, the femoral vein.

Branches of the Femoral Artery

The **branches of the femoral artery** are:—

(1) The superficial epigastric; (2) the superficial circumflex iliac; (3) the external pudendal; (4) the inguinal; (5) the profunda; (6) muscular branches; and (7) the suprema genu (anastomotica magna).

(1) The **superficial epigastric** artery [a. epigastricas uperficialis] (fig. 536) comes off from the femoral about 1.2 cm. (½ in.) beyond the inguinal ligament. At its origin it is beneath the fascia lata, but almost at once passes through this fascia, or else through the fossa ovalis, and courses in an upward and slightly medial direction in front of the external oblique muscle almost as far as the umbilicus.

It ends in numerous small twigs, which anastomose with the cutaneous branches from the inferior epigastric and internal mammary. In its course it gives off small branches to the inguinal glands and to the skin and superficial fascia. Running with it is the superficial epigastric vein, which ends in the great saphenous just before the latter passes through the fossa ovalis (saphenous opening).

(2) The **superficial circumflex iliac** artery [a. circumflexa ilium superficialis], (fig. 536), usually smaller than the superficial epigastric, arises either in common with that vessel, or as a separate branch from the femoral. It passes laterally over the iliacus, and, soon perforating the fascia lata a little to the lateral side of the fossa ovalis, runs more or less parallel with the inguinal ligament about as far as the crest of the ilium, where it ends in branches which anastomose with the deep circumflex iliac artery.

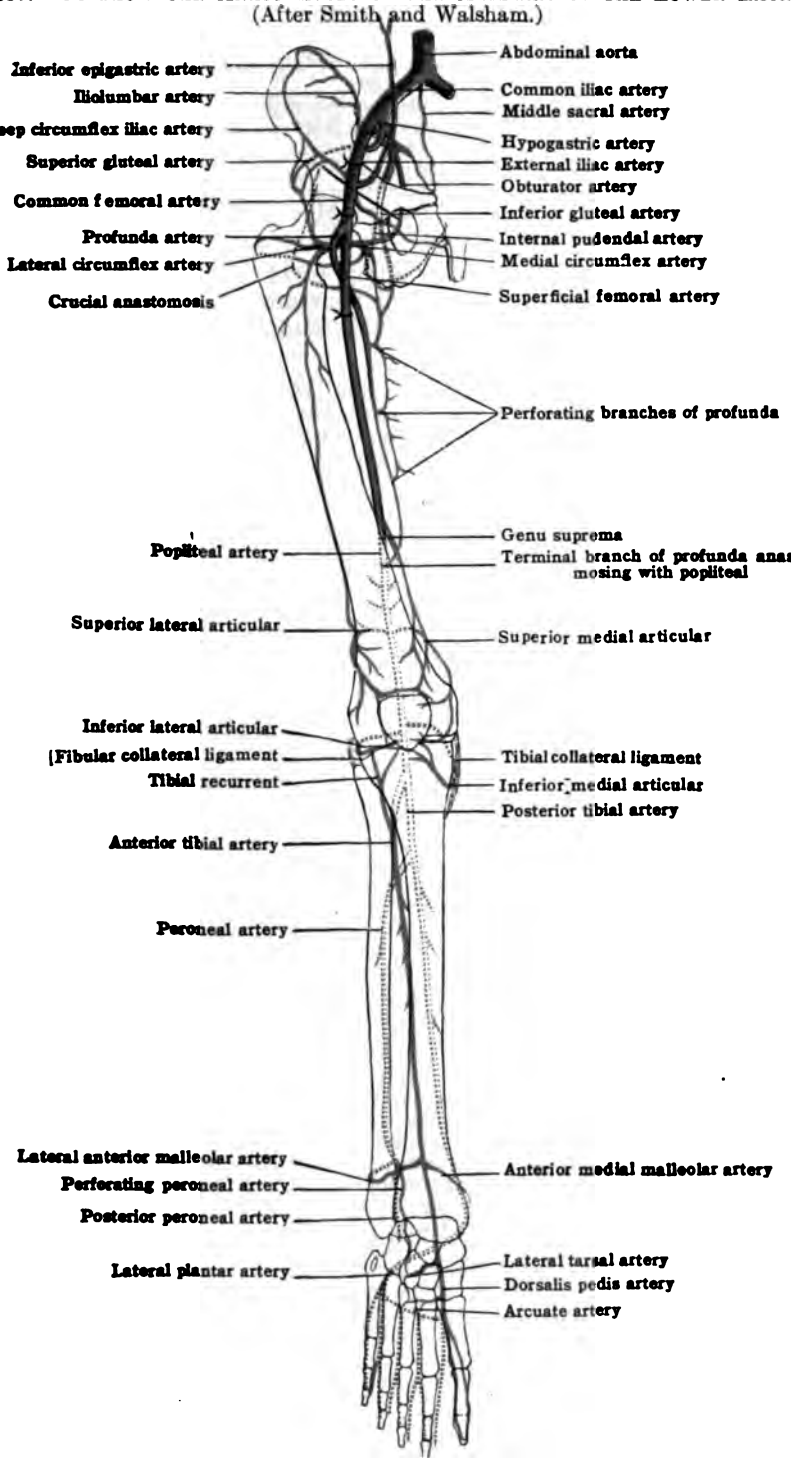
In its course it gives off branches to the iliacus and sartorious muscles to the inguinal glands, and to the fascia and skin. Its companion vein ends in the great saphenous vein just before the latter passes through the fossa ovalis (saphenous opening).

(3) The **external pudendal** arteries [aa. pudendæ externæ], arise from the medial side of the femoral or, occasionally, from the profunda. Some of them pass either through the fascia lata or through the fascia covering the fossa ovalis (saphenous opening) and cross the spermatic cord in the male, or round ligament in the female, to reach and supply the integument above the pubes.

One branch descends along the penis and anastomoses at the corona with the dorsal artery, and with the corresponding artery of the opposite side. In the female, this branch terminates in the preputium clitoridis, anastomosing with the dorsal artery of the clitoris. Other branches run medially beneath the deep fascia, across the pectineus and adductor longus muscles, and, perforating the fascia close to the ramus of the pubis, supply the skin of the scrotum or the *labium majus* in the female [aa. scrotales or labiales anteriores] anastomosing with the posterior scrotal or labial branches of the perineal artery. The external pudendal supplies small twigs to the pectineus and adductor muscle. Its companion veins terminate as a single trunk in the great saphenous.

(4) The **inguinal** branches [rami inguinales], a series of five or six small nches arise a short distance below the inguinal ligament. They supply the nguinal lymph-nodes, and the skin and muscles in this region.

G. 537.—To show the Anastomoses of the Arteries of the Lower Extremity. (After Smith and Walsham.)



(5) The **profunda** artery [a. profunda femoris] (figs. 536, 537), is the chief ient vessel of the thigh. It is usually given off from the back and lateral of the common femoral, about 4 cm. (1½ in.) beyond the inguinal (Poupart's)

ligament. At first it is a little lateral to the femoral, but as it runs distally and backward it gets behind that artery and closer to the bone. On reaching the proximal border of the adductor longus muscle, it leaves the femoral, and, passing beneath the muscle, pierces the adductor magnus. Finally, much reduced in size, it ends in the hamstring muscles, anastomosing with the third perforating and muscular and articular branches of the popliteal.

The profunda in some cases arises 5 cm. or more distally to the inguinal ligament; or, more rarely, proximally to it, from the external iliac artery.

Relations.—**Behind**, the profunda artery lies successively upon the iliacus, the pectineus, the adductor brevis, and adductor magnus muscles. **In front**, at first it is superficial, being merely covered by the skin, superficial and deep fasciæ, and branches of the femoral (anterior crural) nerve; but as it sinks behind the femoral artery, it has in front of it both the femoral and the profunda veins and, more distally, the adductor longus muscle. **Laterally** is the femur at the angle of union of the adductors longus and brevis. **Medially** is the pectineus in the proximal part of its course.

Branches of the profunda.—The profunda gives off the following branches:—(*a*) The lateral circumflex; (*b*) the medial circumflex; and (*c*) the three perforating. The termination of the artery is sometimes called the fourth perforating branch.

(*a*) The **lateral circumflex** [a circumflexa femoris lateralis] a short trunk, but the largest in diameter of the branches of the artery, arises from the lateral side of the profunda as it lies on the iliacus muscle, about 2 cm. (¾ in.) beyond the origin of that vessel from the femoral. It passes in a transversely lateral direction over the iliacus, under the sartorius and rectus, and between the branches of the femoral (anterior crural) nerve. In this course it gives off branches to the rectus and vastus intermedius (crureus), and then divides into two chief sets of branches—ascending and descending.

The **ascending** branch [ramus ascendens] either breaks up at once into numerous branches or it may arise as several vessels some of which are apt to come from the profunda itself or even from the femoral. These run upward under the sartorius and tensor faciæ latæ or laterally under the rectus femoris. The highest branches reach the gluteus medius and minimus and anastomose with the gluteal and deep circumflex iliac arteries; one branch runs beneath the rectus femoris to the hip-joint, and the others cross the vastus intermedius and pierce the vastus lateralis to anastomose with the first perforating and the medial circumflex.

The **descending** branches [rami descendentes] run distally along with the nerve to the vastus lateralis muscle. They lie beneath the rectus muscle and on the vastus intermedius (crureus) or vastus lateralis, some of them being just under cover of the anterior edge of the latter muscle. They are distributed to the vastus lateralis, vastus intermedius, and rectus, one branch usually running along the anterior border of the vastus lateralis as far as the knee-joint, where it anastomoses with the superior lateral genicular branch of the popliteal (fig. 538); another, entering the vastus intermedius, anastomoses with the termination of the profunda and with the genu suprema (anastomotica magna).

(*b*) The **medial circumflex** artery [a. circumflexa femoris medialis] comes off from the back and medial aspect of the profunda artery on about the same level as the lateral circumflex; sometimes as a common trunk with that vessel. As it winds around the medial side of the femur to reach the region of the trochanters, it lies successively, first, between the psoas and pectineus, then between the obturator externus and adductor brevis; finally, between the adductor magnus and quadratus femoris, where it anastomoses with the lateral circumflex, with the inferior gluteal (sciatic), and with the superior perforating, forming the so-called **crucial anastomosis**. While still in the femoral trigone it gives off a *superficial* branch [r. superficialis] which runs in a transversely medial direction to supply the pectineus, adductor longus and brevis, and the gracilis. The remainder of the artery is designated as the *deep* branch ([r. profundus]. An acetabular branch [r. acetabuli] courses upward beneath the tendon of the psoas, and enters the hip-joint beneath the transverse ligament, and, together with the articular branch of the obturator, supplies the fatty tissue in the acetabulum, and sends branches to the synovial membrane. The medial circumflex veins join the profunda vein.

(*c*) The **perforating arteries of the profunda** are so called because they perforate, in a more or less regular proximodistal order certain of the adductor muscles. They form a series of loops by anastomosing with one another (fig. 537), and with the superior gluteal, medial circumflex, and inferior gluteal arteries, and with the muscular and genicular branches of the popliteal. They are distributed chiefly to the hamstring muscles, but send twigs along the lateral intermuscular septum to supply the integuments at the back and lateral parts of the thigh. Other branches perforate the lateral intermuscular septum and the short head of the biceps, and, entering the vastus intermedius (crureus) and vastus lateralis, anastomose with the descending branch of the lateral circumflex. All the perforating arteries, moreover, contribute to reinforce the artery of the sciatic nerve, a branch of the inferior gluteal (sciatic) artery. They are each accompanied by two veins which terminate in the profunda vein.

The **first perforating** artery [a. perforans prima] is given off from the profunda as that vessel sinks beneath the adductor longus. It either pierces the adductor brevis, or runs between the pectineus and adductor brevis, and then passes through a small aponeurotic opening in the adductor magnus close to the medial lip of the linea aspera. In this course it supplies branches to the adductors, and, after perforating the adductor magnus, is distributed to the lower part of the gluteus maximus and the hamstring muscles, a recurrent branch commonly running beneath the gluteus maximus to anastomose with the lateral circumflex, medial circumflex, and inferior

uteal (sciatic) arteries, forming the **crucial anastomosis** at the junction of the neck of the mur with the great trochanter (fig. 537). A second branch anastomoses with a recurrent anch of the second perforating.

The second perforating artery [a. perforans secunda] which is given off from the profunda as it lies behind the adductor longus, pierces the adductor brevis, and then passes through a second aponeurotic opening in the adductor magnus a little distally to that of the first perforating artery, and also close to the linea aspera. It supplies the hamstring muscles, sends a branch to anastomose with the first perforating, and another branch to anastomose in like manner with a recurrent branch of the third perforating.

The third perforating artery [a. perforans tertia] also arises from the profunda as it lies under the adductor longus, usually about the level of the distal border of the adductor brevis. It turns beneath this border, and then, like the first and second perforating, passes through an aponeurotic opening in the adductor magnus close to the linea aspera. It also supplies the hamstring muscles, and divides into two branches, which anastomose above the second perforating, and with the termination of the profunda.

Two nutrient arteries to the femur (aa. nutritiæ femoris superior et inferior] arise from the perforating arteries. The superior generally arises from the first perforating, the inferior usually from the third, but there is some variation in this regard.

(6) The **muscular** branches [rami musculares], of the femoral artery supply the sartorius, the rectus, the vastus medialis, the vastus intermedius (crureus), and the adductor muscles.

(7) The arteria **genu suprema** (or anastomotica magna) arises from the front and medial side of the femoral just before the latter perforates the adductor magnus muscle, and almost immediately divides into branches, (*a*) saphenous, (*b*) muscular, and (*c*) articular. These branches may sometimes come off separately from the femoral.

(*a*) **The saphenous** branch [a. saphena] pierces the aponeurotic covering of the adductor canal, passes between the sartorius and gracilis muscles along with the saphenous nerve, and, perforating the deep fascia, supplies the skin of the proximal and medial side of the leg and anastomoses with the inferior medial genicular branch of the popliteal and the other vessels forming the plexus or rete at the medial side of the knee. In its course it gives twigs to the distal part of the sartorius and gracilis muscles.

(*b*) **The muscular** branches [rr. musculares] run distally in front of the adductor magnus tendon, burrowing amongst the fibers of the vastus medialis as far as the medial condyle. They break up into numerous twigs which supply the distal ends of the vasti muscles and adductor magnus. One branch runs laterally across the distal end of the femur to end in the vastus lateralis.

(*c*) **The articular** branches [rr. articulares] come off from the saphenous and muscular branches and enter the arterial rete on the medial and lateral sides of the knee. They anastomose with the medial and lateral superior genicular branches of the popliteal and the anterior tibial recurrent and supply branches to the joint.

THE POPLITEAL ARTERY

The popliteal artery [a. poplitea] (fig. 539) runs through the popliteal fossa. It is a continuation of the femoral, and extends from the aponeurotic opening in the adductor magnus at the junction of the middle with the distal third of the thigh to the distal border of the popliteus muscle, where it terminates by dividing into the anterior and posterior tibial arteries. This division is on a level with the distal border of the tuberosity of the tibia. The proximal part of the artery is accompanied by the branch of the obturator nerve to the knee-joint. The vein is behind the artery throughout; it lies at first a little laterally, but as the vessels pass through the popliteal fossa the vein crosses obliquely over the artery, and at the termination of the artery lies a little to its medial side. The tibial (internal popliteal) nerve is superficial to both artery and vein. At the proximal part of the fossa it is well to the lateral side of the vessels, but as it descends it crosses behind them, and reaches their medial side. The artery in the whole of its course is deeply placed and covered by a considerable amount of fat and areolar tissue.

Relations (fig. 539).—**In front,** the artery lies successively on the popliteal surface of the femur (from which it is separated by a little fat and sometimes one or two small glands); on the popliteal ligament of the knee; on the hinder edge of the articular surface of the head of the tibia; and on the popliteus muscle. From the latter muscle it is separated by the expansion from the semimembranosus which covers the muscle, and is attached to the popliteal line on the tibia.

Behind, the artery is covered, proximally by the semimembranosus; in the center of the popliteal fossa by the skin, superficial and deep fascia; and distally, by the gastrocnemius. The popliteal vein is behind it in the whole of its course. The tibial (internal popliteal) nerve crosses behind it obliquely, from the lateral to the medial side, about the center of the fossa.

As the artery divides into the anterior and posterior tibial, it is crossed by the aponeurotic a of the soleus which stretches between the tibial and fibular origins of that muscle.

To the **medial side** are the semimembranosus proximally, and the medial head of the g trocnemius and the tibial (internal popliteal) nerve distally.

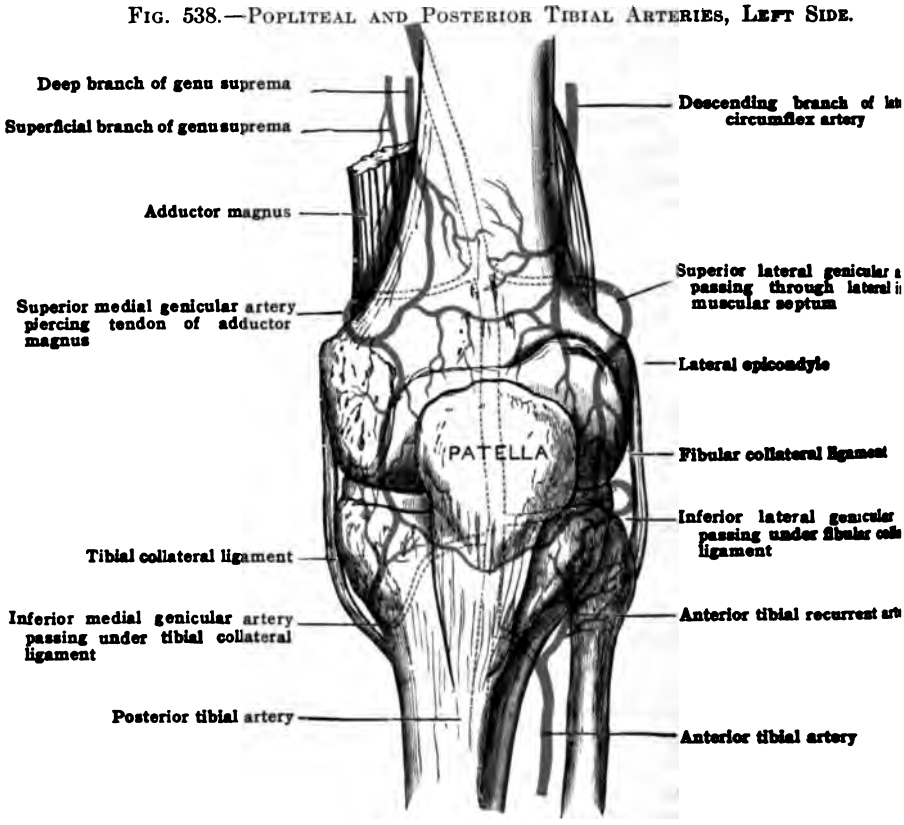
To the **lateral side** are the biceps and the tibial (internal popliteal) nerve proximally, and lateral head of the gastrocnemius and the plantaris distally.

Branches of the Popliteal Artery

The **branches of the popliteal** include the following:—(1) the sural; (2) genicular; and (3) the terminal.

(1) The **sural** arteries [aa. surales] arise irregularly from the popliteal; supply the muscles of the calf, sending branches to the muscles bounding proximal part of the popliteal fossa. From the sural arteries also arise

Fig. 538.—Popliteal and Posterior Tibial Arteries, Left Side.


Deep branch of genu suprema
Superficial branch of genu suprema
Adductor magnus
Superior medial genicular artery piercing tendon of adductor magnus
Tibial collateral ligament
Inferior medial genicular artery passing under tibial collateral ligament
Posterior tibial artery
Descending branch of lat circumflex artery
Superior lateral genicular a passing through lateral i muscular septum
Lateral epicondyle
Fibular collateral ligament
Inferior lateral genicular passing under fibular coll ligament
Anterior tibial recurrent art
Anterior tibial artery
PATELLA

superficial sural or cutaneous branches which pass distally between the heads of the gastrocnemius, and, perforating the deep fascia, supply the and fascia of the calf. A branch, usually of moderate size, accompanies the saphenous vein.

(2) The **genicular** arteries, five in number, are divided into two su (medial and lateral), two inferior (medial and lateral), and the middle or a (figs. 538, 539). The superior and inferior come off transversely in pairs either side of the popliteal, the superior above, the inferior below the Winding round the bones to the front of the knee, they form—by anastom with one another and with the genu suprema (anastomotica magna), the ter tion of the profunda, the descending branch of the lateral circumflex, ar tibial recurrent arteries—a superficial and deep arterial rete (fig. 538). superficial anastomosis or rete lies between the skin and fascia round the patella (**patellar rete**), which it supplies, the larger branches entering i above. The deep anastomosis or **articular rete** [rete articularis genu] lies surface of the bones around the articular surfaces of the femur and tibia, sup branches to the contiguous bones and to the joints. The middle genicul

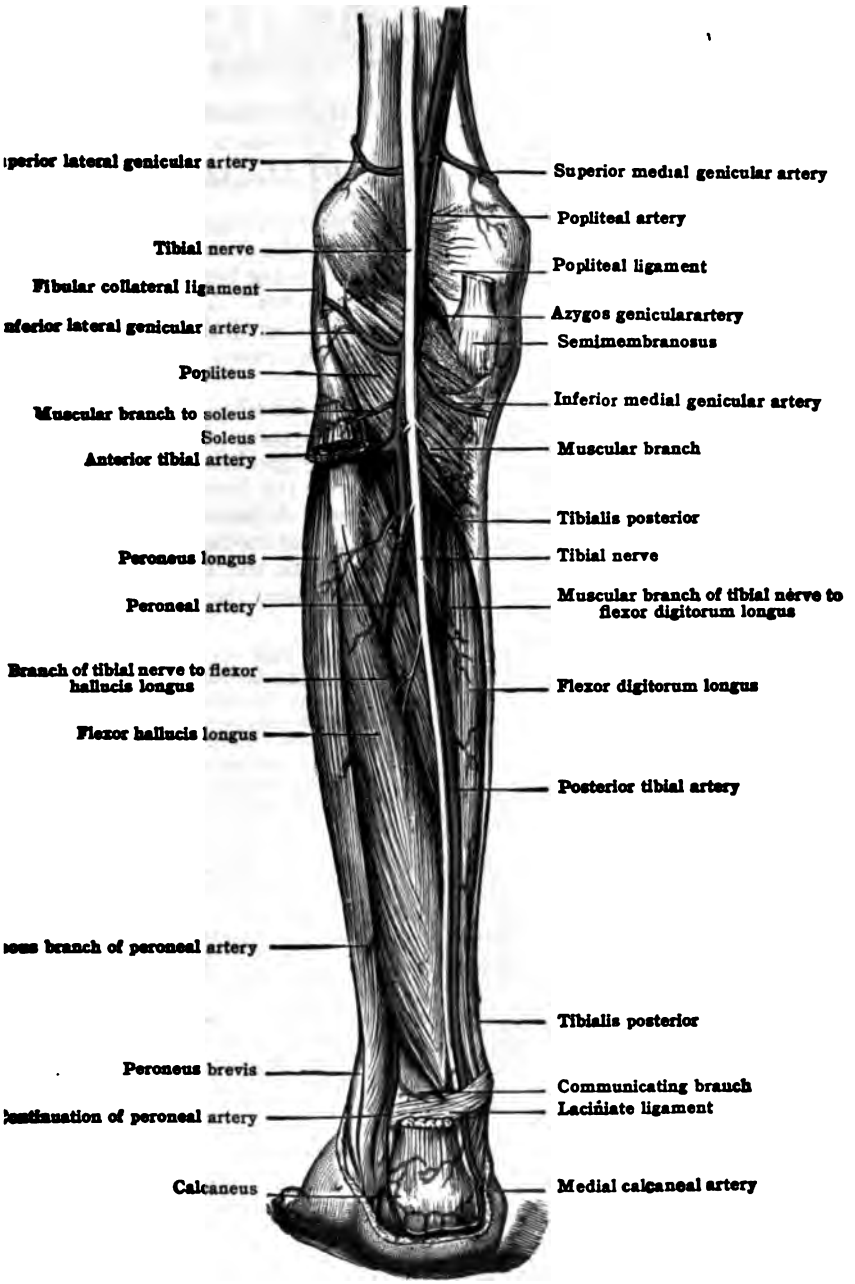
ıort trunk coming off from the deep surface of the popliteal artery. It at ıses through the popliteal ligament into the joint.

he **superior lateral genicular** artery [a. genu superior lateralis], the larger of the two genicular branches, runs in a lateral direction above the lateral head of the gastrocnemius, passing beneath the biceps and through the lateral intermuscular septum and vastus enters the substance of the vastus intermedius (crureus), and anastomoses, proximally

G. 539.—THE ANASTOMOSIS ABOUT THE LEFT KNEE-JOINT. (Walsham.)
(Semi-diagrammatic.)

descending branch of the lateral circumflex, distally with the inferior lateral genicular, s the front of the femur with the superior medial genicular, the genu suprema (anas-magna), and termination of the profunda, forming with them, as already described, the ular rete. Branches are given off to the patella, to the upper and lateral part of the the bone, and to the contiguous muscles.

e **superior medial genicular** artery [a. genu superior medialis] runs medially just above al head of the gastrocnemius, beneath the semimembranosus, and, after perforating the f the adductor magnus, enters the substance of the vastus medialis. Here it anasto-



moses with the deep branch of the genu suprema (anastomotica magna) and termination of profunda above, with the inferior medial genicular below, and with the superior lateral genicular across the front of the femur. It supplies small branches to the contiguous muscles, to the femur, to the patella, and to the joint.

(*c*) The **inferior medial genicular** artery [a. genu inferior medialis], the larger of the two inferior genicular arteries, passes in an obliquely medial direction across the popliteus, below the medial condyle (tuberosity) of the tibia and beneath the tibial collateral ligament to the front and medial side of the knee-joint. Here it anastomoses (fig. 538), proximally with the superior medial genicular and the superficial branch of the genu suprema (anastomotica magna), and across the front of the tibia with the inferior lateral genicular. It supplies branches to the lower and medial part of the joint.

(*d*) The **inferior lateral genicular** artery [a. genu inferior lateralis] passes laterally above the head of the fibula, along the tendon of the popliteus muscle, beneath the lateral head of the gastrocnemius, and then under the tendon of the biceps, and between the long and short fibular collateral ligaments. Then winding to the front of the joint, it anastomoses proximally with the superior lateral genicular, distally with the anterior tibial recurrent, and across the front of the tibia with the inferior medial genicular. It also supplies branches to the lateral and lower part of the joint.

(*e*) The **middle or azygos genicular** artery [a. genu media] arises from the deep surface of the popliteal artery, and passes, with the articular branch of the obturator nerve, through the popliteal ligament, directly into the knee-joint, where it supplies the crucial ligaments and the patellar synovial and alar folds. It anastomoses with the intrinsic branches of the other genicular arteries.

(3) The **terminal branches** of the popliteal are the posterior and the anterior tibial arteries.

THE POSTERIOR TIBIAL ARTERY

The **posterior tibial** artery [a. tibialis posterior] (fig. 540), the larger of the two branches into which the popliteal divides at the distal border of the popliteus muscle, runs distally on the flexor aspect of the leg between the superficial and deep muscles to the back of the medial malleolus. Midway between the tip of the malleolus and the calcaneus, and under cover of the origin of the abductor hallucis as it arises from the laciniate (internal annular) ligament, it divides into the medial and lateral plantar arteries.

The artery is first situated midway between the tibia and fibula, and is deeply placed beneath the muscles of the calf. As it passes distally it inclines to the medial side and at the distal third of the leg is superficial, being covered only by the skin and fasciæ. At the ankle it lies beneath the laciniate ligament, and at its bifurcation also beneath the abductor hallucis. A line drawn from the center of the popliteal fossa to a spot midway between the medial malleolus and point of the heel will indicate its course. In addition to the branches named below it supplies the muscles between which it passes, and the integument of the lower medial region of the leg.

Relations.—Anteriorly, it is in relation successively with the tibialis posterior, the flexor digitorum longus, the posterior surface of the tibia, and the deltoid ligament of the ankle-joint.

Posteriorly, it is covered by the skin and fascia, the gastrocneumius and soleus, and the deep or intermuscular fascia of the leg, by which it is tightly bound down to the underlying muscles. It is crossed by tibial nerve about 4 cm. (1¾ in.) beyond its origin, after it has given off its peroneal branch; the nerve first lies on the medial, and for the rest of its course on the lateral side of the vessel. It is accompanied by two veins, which send numerous anastomosing branches across it. In the distal third of the leg the artery is superficial, being covered only by the skin and by the superficial and deep fasciæ.

At the **medial malleolus** it lies beneath the laciniate (internal annular) ligament and abductor hallucis, upon the deltoid ligament of the ankle-joint. Here it has the tibialis posterior and flexor digitorum longus in front of it, and the tibial nerve and the flexor hallucis longus behind and to its lateral side. At times the tibial nerve divides higher than usual, when one branch lies on the medial side of the artery and the other branch on the lateral side.

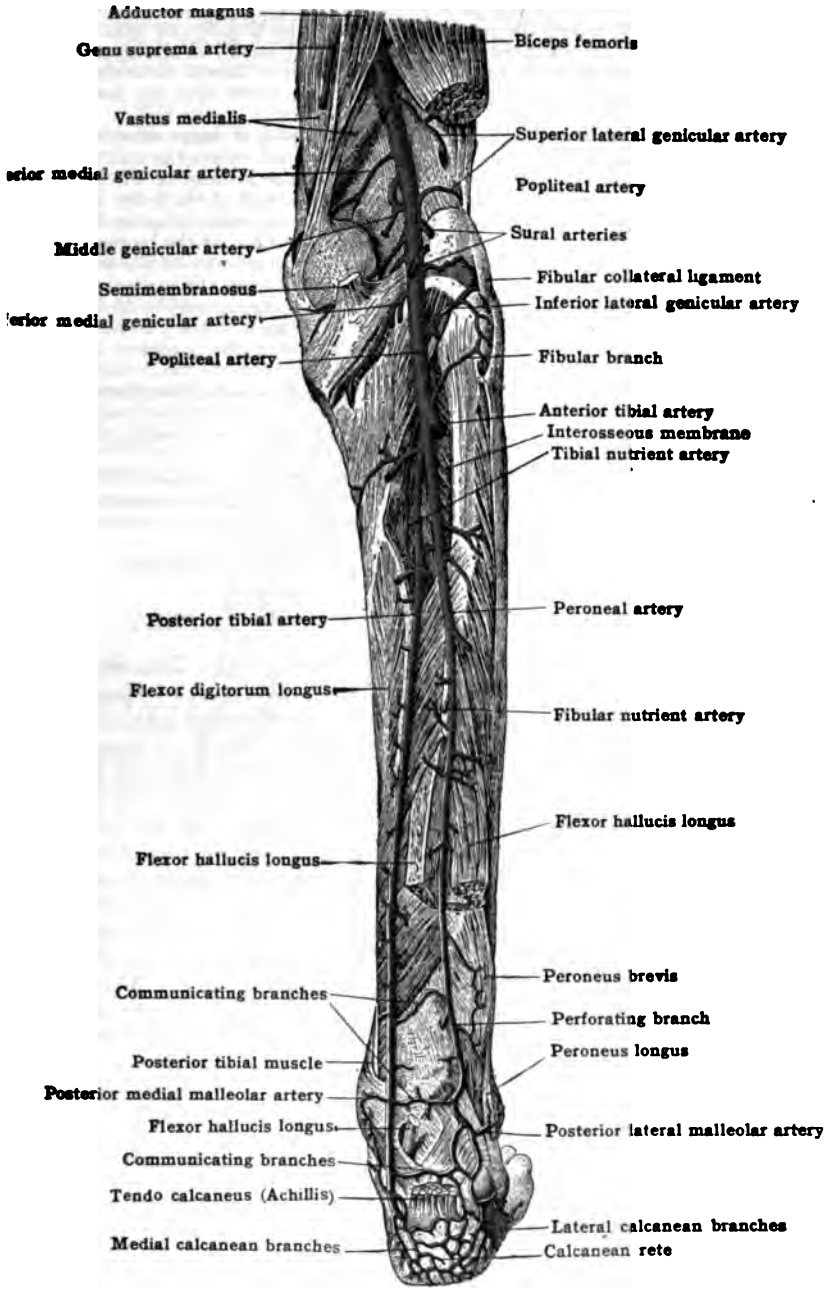
The **branches of the posterior tibial artery** (figs. 539, 540) are:—(1) The fibular; (2) the peroneal; (3) the tibial nutrient; (4) the communicating; (5) the posterior medial malleolar; (6) the medial calcanean; and (7) the terminal, medial and lateral plantar. The anastomoses of the posterior tibial branches are shown in fig. 1152.

(1) The **fibular** or superior fibular branch [ramus fibularis], usually arises from the beginning of the anterior tibial or from the posterior tibial recurrent (see fig. 540). It runs laterally toward the head of the fibula. It is small and gives twigs to the soleus, peroneus longus, and extensor digitorum longus, and anastomoses with the inferior lateral genicular and the lateral sural arteries.

(2) The **peroneal** artery [a. peronea] is a large vessel which (figs. 539, 540) arises from the posterior tibial about 2.5 cm. (1 in.) below the distal border of the

s muscle. It first curves laterally beneath the soleus muscle and reaches
la at the proximal margin of the flexor hallucis longus muscle. It then
eath that muscle and enters a canal bounded by the fibula and the flexor
allucis and tibialis posterior muscles. At the distal margin of the latter
t lies upon the interosseous membrane where it gives off a large perforat-

540.—The Popliteal, the Posterior Tibial, and the Peroneal Arteries. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



terior peroneal) branch. It now passes over the tibiofibular syndesmosis under the name of the posterior lateral malleolar (posterior peroneal) upon the posterior aspect of the lateral malleolus. It terminates upon ral surface of the tuber calcanei by breaking up into lateral calcaneal s.

The **branches of the peroneal** artery (fig. 540) are:—(*a*) The fibular nutrient; (*b*) the communicating; (*c*) the perforating; (*d*) the lateral malleolar; and (*e*) the lateral calcaneal.

(*a*) The *fibular nutrient* artery [a. nutritia fibulæ] enters the nutrient canal of the fibula.

(*b*) The *communicating* branch [r. communicans] passes between the interosseous membrane and the tendon of the flexor hallucis longus in the supramalleolar region and joins the communicating branch of the posterior tibial artery.

(*c*) The *perforating* (or anterior peroneal) branch [r. perforans] arises usually a short distance below, but sometimes above, the communicating branch, and passes through the interosseous membrane (fig. 543). It supplies the tibiofibular syndesmosis and anastomoses with the lateral tarsal, arcuate and anterior lateral malleolar arteries.

(*d*) The *lateral posterior malleolar* artery [a. malleolaris posterior lateralis] is the terminal part of the peroneal. It crosses the posterior aspect of the tibiofibular syndesmosis and lateral malleolus to reach the lateral aspect of the tuber calcanei. It gives off branches on the malleolus which anastomose with branches of the anterior *lateral malleolar rete;* also (*e*) the *lateral calcaneal* branches [rr. calcanei laterales] which enter into the formation of the *rete calcaneum.*

(3) The **tibial nutrient** artery [a. nutritia tibiæ], a vessel of large size, leaves the posterior tibial at its proximal part, pierces the tibialis posterior, and enters the nutrient foramen in the proximal third of the posterior surface of the tibia. In the interior of the bone it divides into two branches: a smaller branch, which runs toward the head of the bone; and a larger, which courses toward the distal end. It gives off two or three muscular twigs to the tibialis posterior before it enters the foramen. The nutrient artery of the tibia is the largest artery of its kind in the body, and is accompanied by a nerve given off by the nerve to the popliteus.

(4) The **communicating** branch [r. communicans] arises from the posterior tibial about 5 cm. (2 in.) above the medial malleolus, and, passing transversely across the tibia beneath the flexor hallucis longus, anastomoses with the communicating branch of the peroneal.

Frequently another branch of communication between the posterior tibial and peroneal arteries is likewise present in the loose connective tissue behind the flexor hallucis longus tendon.

(5) The **posterior medial malleolar** branch [ramus malleolaris posterior medialis] divides for distribution over the medial malleolus, anastomosing with the anterior medial malleolar artery in the *medial malleolar rete* [rete malleolare mediale]. It runs beneath the flexor digitorum longus and tibialis posterior muscles.

(6) The **medial calcanean** branches [rami calcanei mediales] are distributed to the soft parts over the medial side of the calcaneus. These branches come off more frequently from the lateral plantar artery than from the posterior tibial; they enter the rete calcaneum and anastomose with the lateral calcaneal and posterior medial malleolar arteries.

(7) The **terminal branches** are the lateral and medial plantar arteries.

THE LATERAL PLANTAR ARTERY

The **lateral plantar** artery [a. plantaris lateralis] (figs. 541, 542)—the larger of the two branches into which the posterior tibial divides beneath the laciniate (internal annular) ligament—passes at first laterally and forward across the sole of the foot to the base of the fifth metatarsal bone, where it bends medially, and still running forward sinks deeply into the foot and terminates at the proximal end of the first interosseous space by anastomosing with the deep plantar (communicating) branch of the dorsal artery of the foot. In its course to the fifth metatarsal bone the artery runs in a more or less straight line obliquely across the foot; while its deep portion, extending from the fifth metatarsal bone to the proximal end of the first interosseous space, forms a slight curve with the convexity forward, and is known as the **plantar arch.** The plantar arch is comparable to the deep volar arch formed by the deep branch of the ulnar anastomosing with the radial through the first interosseous space. The lateral plantar artery is accompanied by two veins. The course of the artery is indicated by a line drawn across the sole of the foot from a point midway between the tip of the medial malleolus and the medial tubercle of the calcaneus to the base of the fifth metatarsal bone, and thence to the lateral side of the base of the first metatarsal.

The lateral plantar artery, besides the branches named below, gives twigs to supply the muscles between which it passes, and the tarsal joints. It almost invariably also gives off a number of medial calcaneal branches. These branches occasionally arise from the posterior tibial artery, and are described with the other branches of that vessel.

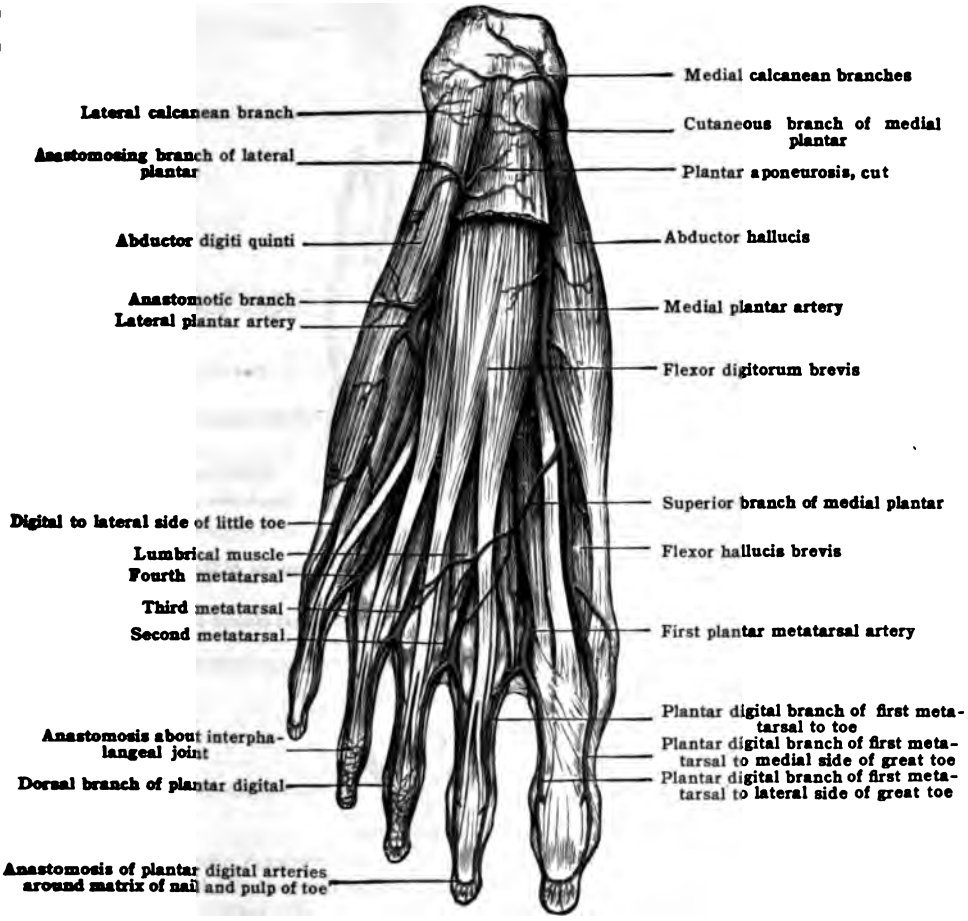
Relations.—In the first part of its course from the medial malleolus to the base of the fifth metatarsal bone, the artery is covered successively by the abductor hallucis and the flexor digitorum brevis, by which it is separated from the plantar aponeurosis, and may be slightly overlapped in muscular subjects by the abductor quinti digiti. As it approaches the base of the fifth metatarsal bone it lies, as it turns medially before sinking into the foot, in the interspace between the flexor digitorum brevis and the abductor quinti digiti, and is here covered only by the skin and superficial fascia and the plantar aponeurosis. It lies upon the calcaneus, the quadratus plantæ (flexor accessorius), and the flexor digiti quinti brevis. It is accompanied by the lateral plantar nerve, the smaller of the two divisions into which the tibial nerve divides. In this part of its course it gives off small branches to the contiguous muscles and to the heel.

the second part of its course the artery, which is here known as the **plantar arch** [arcus [illegible]aris], sinks into the sole, and is covered, in addition to the skin, superficial fascia, plantar [illegible]urosis, and flexor digitorum brevis, by the tendons of the flexor digitorum longus, the [illegible]icales, branches of the medial plantar nerve, and the abductor hallucis. It lies upon the [illegible]imal ends of the second, third, and fourth metatarsal bones and the corresponding interos[illegible] muscles.

The **branches of the lateral plantar artery** are:—(1) Perforating; and (2) [illegible]ntar metatarsal (digital).

(1) The **perforating** branches [rr. perforantes], three in number, ascend through the [illegible]imal end of the second, third, and fourth spaces, between the two heads of the correspond[illegible]y named dorsal interosseous muscles, and communicate with the proximal ends of the [illegible], second, and third dorsal metatarsal (interosseous) arteries (fig. 542).

FIG. 541.—THE PLANTAR ARTERIES, LEFT FOOT.
(From a dissection in the Museum of St. Bartholomew's Hospital.)


Medial calcanean branches
Lateral calcanean branch
Cutaneous branch of medial plantar
Anastomosing branch of lateral plantar
Plantar aponeurosis, cut
Abductor digiti quinti
Abductor hallucis
Anastomotic branch
Lateral plantar artery
Medial plantar artery
Flexor digitorum brevis
Superior branch of medial plantar
Digital to lateral side of little toe
Lumbrical muscle
Flexor hallucis brevis
Fourth metatarsal
Third metatarsal
Second metatarsal
First plantar metatarsal artery
Plantar digital branch of first metatarsal to toe
Anastomosis about interphalangeal joint
Plantar digital branch of first metatarsal to medial side of great toe
Dorsal branch of plantar digital
Plantar digital branch of first metatarsal to lateral side of great toe
Anastomosis of plantar digital arteries around matrix of nail and pulp of toe

(2) The **plantar metatarsal** arteries [aa. metatarseæ plantares] are usually four in number and pass forward in the four intermetatarsal spaces, which are numbered from the medial side They rest upon the interosseous muscles of their spaces, and are at first under cover of the lumbricals, but as they approach the clefts of the toes each divides into two branches, the **plantar digital arteries** [aa. digitales plantares], which supply the contiguous sides of the toes. The plantar digital branch for the medial side of the great toe is usually given off by the first plantar metatarsal; that for the lateral side of the little toe is usually a separate branch from the lateral end of the plantar arch.

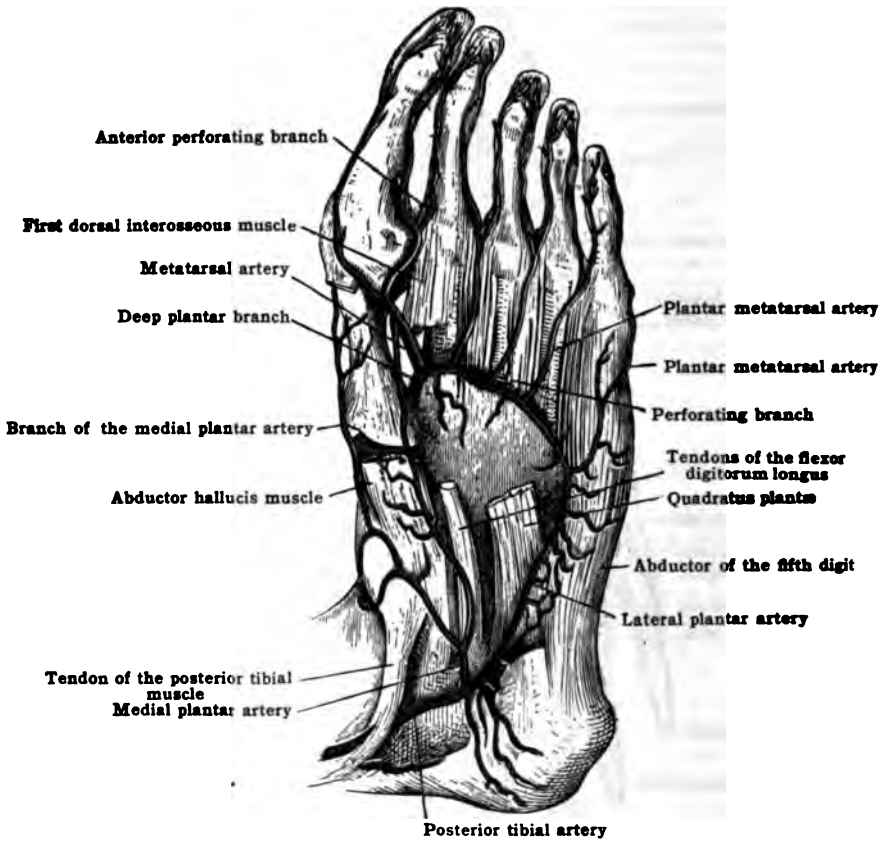
The plantar metatarsal arteries, immediately before they bifurcate, send to the dorsum of the foot a perforating branch each to the corresponding dorsal metatarsal arteries. They anastomose by many small twigs with the dorsal metatarsal arteries, which also run along the sides of the metatarsal bones, but more toward the dorsal aspect. Immediately below each phalangeal joint the plantar digital vessels communicate by cross branches, forming a rete for the supply of the articular end of the phalanges and the contiguous joints. At the distal end of the toes they also freely anastomose with each other, forming a rete beneath the pulp and around the matrix of the nail. The metatarsal and digital arteries are each accompanied by two small veins.

THE MEDIAL PLANTAR ARTERY

The **medial plantar** artery [a. plantaris medialis] (figs. 541, 542)—much smaller of the two divisions into which the posterior tibial divides—passes forw along the medial side of the sole of the foot usually to the first interosseous spa Here it ends by anastomosing either with the first plantar metatarsal arte derived from the plantar arch, or with the branch given off by the first plant metatarsal to the medial side of the great toe.

Relations.—The artery is at first under cover of the abductor hallucis, but afterward li in the interval between that muscle and the flexor digitorum brevis. It is covered by the sk and superficial fascia, but not by the plantar aponeurosis, since it lies between the central a medial portions of that structure.

FIG. 542.—DEEP PLANTAR ARTERIES. (After Henle.)



The **branches of the medial plantar** are:—(1) The deep and (2) the superfic

(1) The **deep** branch [ramus profundus], which at once divides—or it may come of several branches—to supply the muscles, articulations, and integument of the medial side o sole. Some of these branches form an anastomosis around the medial margin of the foot, branches of the dorsalis pedis.

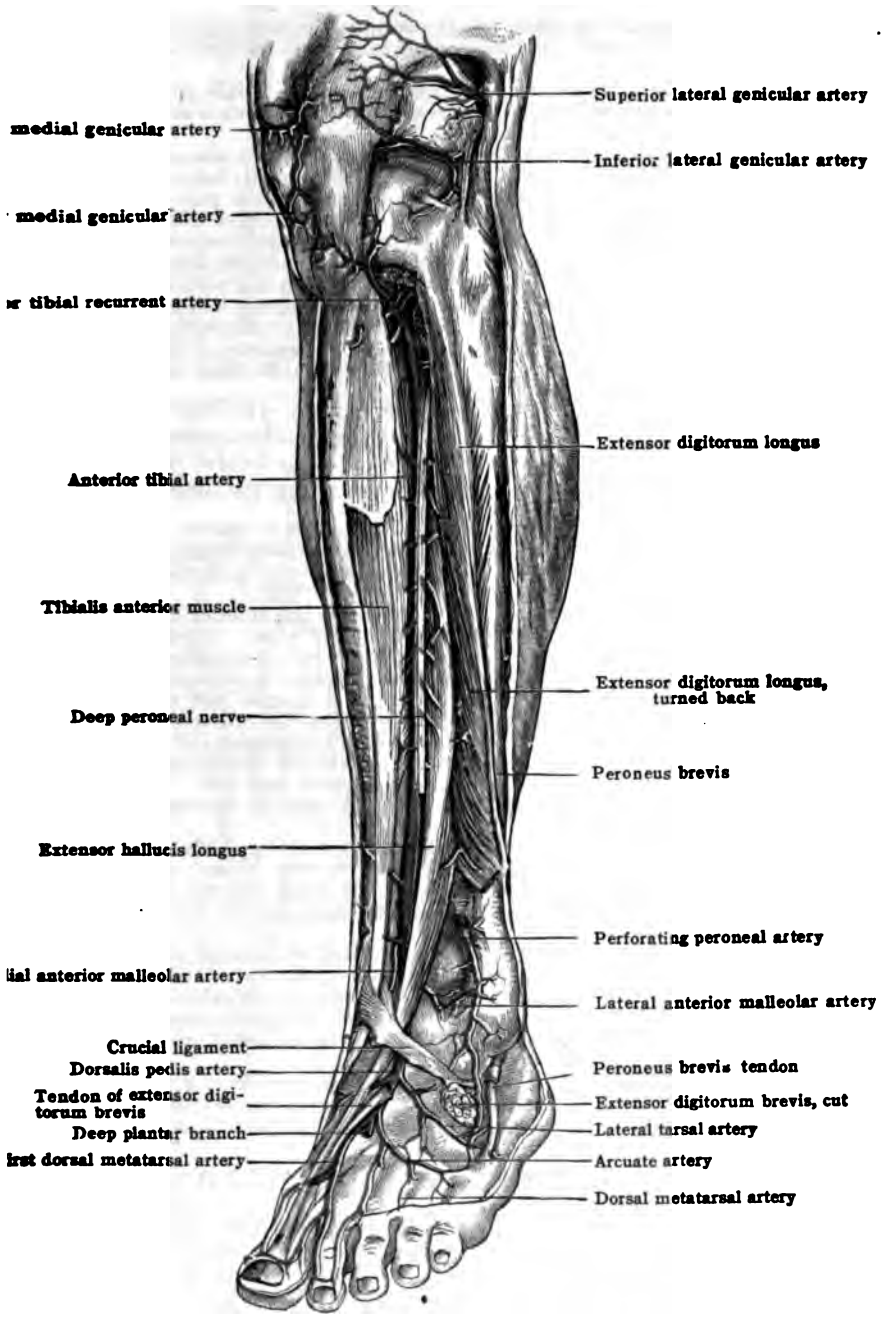
(2) The **superficial** branch [ramus superficialis] breaks up into very small twigs whic company the digital branches of the medial plantar nerves, and anastomose with the pl metatarsal arteries in the first, second, and third spaces. At times a twig from one of branches joins the lateral plantar artery to form a superficial plantar arch.

THE ANTERIOR TIBIAL ARTERY

The **anterior tibial** artery [a. tibialis anterior] (fig. 543)—the smaller of two branches into which the popliteal artery divides at the distal border of popliteus muscle—at first courses forward between the two heads of origi the tibialis posterior, and, after passing between the tibia and fibula abov proximal part of the interosseous membrane, runs on the front and lateral as

g, between the anterior muscles, as far as the front of the ankle-joint. the joint the artery is known as the dorsalis pedis. The course of the indicated by a line drawn from the front of the head of the fibula to a dway between the two malleoli.

—THE ANTERIOR TIBIAL, DORSALIS PEDIS AND PERFORATING (ANTERIOR) PERONEAL ARTERIES.



artery is accompanied by two veins which communicate with each other ient intervals across it. It is also accompanied in the distal three-fourths ourse by the deep peroneal nerve. The nerve, which winds round the head ibula, and pierces the extensor digitorum longus, first comes into contact e lateral side of the artery about the proximal third of the leg; in the middle

On its lateral side it is in contact in its proximal third with the extensor digitorum muscle; in its middle third with the extensor hallucis longus; but, as this muscle cro the medial side of the artery, the vessel usually for a very short part of its course come into contact with the extensor digitorum longus. At the proximal and distal thirds of its on the front of the leg the artery has the deep peroneal (anterior tibial) nerve to its later

In front the artery is covered by the skin, superficial and deep fascia. In its proxim thirds it is deeply placed in the cellular interval between the tibialis anterior on the side and the extensor digitorum longus and extensor hallucis longus on its lateral sid in its distal third it is crossed in the lateromedial direction by the tendon of the extensor l longus, and lies beneath the cruciate (anterior annular) ligament of the ankle-joint. Th peroneal nerve is usually in front of the artery in the middle third of the leg.

The **branches of the anterior tibial artery** are:—(1) The posterior tibial rent; (2) the anterior tibial recurrent; (3) the medial anterior malleolar; a the lateral anterior malleolar. In addition, ten or twelve muscular branch given off irregularly to the adjacent muscles along the artery.

(1) The **posterior tibial recurrent** artery is occasionally absent. It passes betwe popliteus muscle and the popliteal ligament of the knee-joint, supplying these structu the tibiofibular joint. It anastomoses with the inferior lateral genicular branch of the po and to a less extent with the inferior medial genicular branch.

(2) The **anterior tibial recurrent** is given off from the anterior tibial artery imm after that vessel has passed above the interosseous membrane. It winds tortuously t the substance of the tibialis anterior muscle, over the lateral condyle (tuberosity) of th close to the bone; and, perforating the deep fascia, ramifies on the lower and lateral par capsule of the knee-joint. It anastomoses with the inferior and superior lateral g branches of the popliteal, with the descending branch of the lateral circumflex, and so less freely with the medial genicular branches of the popliteal and with the genu s (anastomotica magna). It gives off small branches to the tibialis anterior, the extens torum longus, the knee-joint, and the contiguous fascia and skin. It forms one of lateral channels by which the blood is carried to the part of the limb beyond an ob popliteal artery (fig. 543).

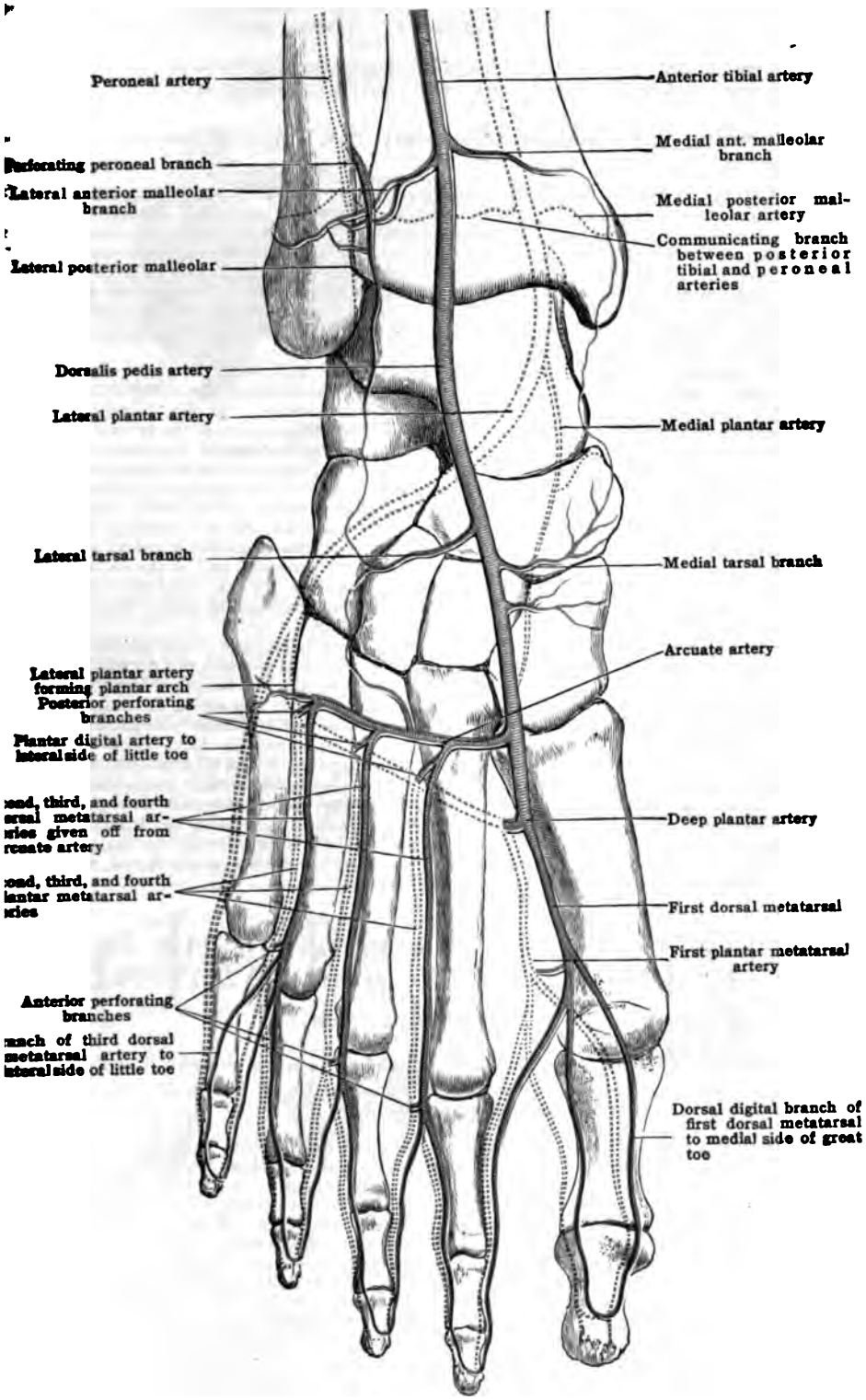
(3) The **medial anterior malleolar**, the smaller of the two malleolar branches, arises f distal part of the anterior tibial artery, usually near the place at which the tendon of the e hallucis longus crosses the anterior tibial artery. It winds over the medial malleolus, beneath the tibialis anterior, and joins the **medial malleolar rete anastomosing with t** from the posterior tibial artery.

(4) The **lateral anterior malleolar** artery, larger than the medial, arises from the lat of the anterior tibial artery, usually beyond the level of the medial malleolar. It winds and laterally round the lateral malleolus, passing beneath the extensor digitorum lon peroneus tertius, and joins the **lateral malleolar rete** by anastomosing with the per peroneal, the termination of the peroneal, and the lateral tarsal branch of the dorsa (figs. 543, 544).

The anastomosis between the lateral malleolar and perforating peroneal is some considerable size, supplying the blood to the dorsal artery of the foot; the anterior tib much reduced in size, usually ends at the place of origin of the lateral malleolar.

FIG. 544.—SCHEME OF THE DISTRIBUTION AND ANASTOMOSES OF THE ARTERIES OF THE RIGHT FOOT. (Walsham.)

(The plantar arteries are shown in dotted outline; the dorsal in solid red.)


Peroneal artery
Anterior tibial artery
Perforating peroneal branch
Medial ant. malleolar branch
Lateral anterior malleolar branch
Medial posterior malleolar artery
Communicating branch between posterior tibial and peroneal arteries
Lateral posterior malleolar
Dorsalis pedis artery
Lateral plantar artery
Medial plantar artery
Lateral tarsal branch
Medial tarsal branch
Arcuate artery
Lateral plantar artery forming plantar arch
Posterior perforating branches
Plantar digital artery to lateral side of little toe
Deep plantar artery
First dorsal metatarsal
First plantar metatarsal artery
Anterior perforating branches
Dorsal digital branch of first dorsal metatarsal to medial side of great toe

the dorsal ligaments uniting the second cuneiform to the first cuneiform. It is more o bound down to the bones by aponeurotic fibers derived from the deep fascia.

Above, the artery is covered by the crucial (anterior annular) ligament, sometimes b extensor hallucis longus, by the skin, the superficial and deep fascia, and, just before its t nation, by the tendon of the extensor hallucis brevis. The angle formed by this tendon wi extensor hallucis longus is the best guide to finding the artery in the process of ligature (fig.

To its **lateral side** is the most medial tendon of the extensor digitorum longus, and distally the tendon of the extensor hallucis brevis. The deep peroneal (anterior tibial) is also to its lateral side.

To its **medial side** is the extensor hallucis longus, except at times for the distal hal where the tendon of the extensor hallucis brevis, having crossed the artery, may lie betw and this tendon.

The **branches of the dorsalis pedis artery** (figs. 543, 544) are:—(1) The ti (2) the arcuate; and (3) the deep plantar.

(1) The **tarsal branches** may be divided into (*a*) the lateral and (*b*) the medial. (*a*) **lateral tarsal** artery [a. tarsea lateralis] runs laterally over the navicular and cuboid bon neath the extensor digitorum brevis. It supplies branches to that muscle, and to the bon the articulations between them, and anastomoses with the lateral malleolar and perfo (anterior) peroneal, with the arcuate (metatarsal) and, over the lateral border of the with the anastomotic branches of the lateral plantar artery. (*b*) The **medial tarsal a** [aa. tarseæ mediales] consist of a few small branches which run over the medial side of the supplying the skin and articulations, and anastomose with the medial malleolar arteries with branches of the medial plantar.

(2) The **arcuate (metatarsal)** artery [a. arcuata] (figs. 543, 544) runs laterally acro foot, in a slight curve with the convexity forward, over the bases of the metatarsal bone beneath the extensor tendons and the extensor digitorum brevis. At the lateral border foot it anastomoses, with the lateral tarsal artery, and with branches of the lateral planta

From the convexity of the arch it gives off four **dorsal metatarsal** (interosseous) ar which run forward on the dorsal interosseous muscles in the center of the four interosseous s to the cleft of the toes, where they bifurcate for the supply of the contiguous sides of th The artery to the first space is large, and gives off the digital artery to the medial side of the toe. This vessel continues the direction of the dorsalis pedis and is commonly known a **dorsalis hallucis** artery. The most lateral of the interosseous branches gives off a small for the supply of the lateral side of the little toe. At the proximal end of the second, thi fourth interosseous spaces each artery receives a perforating branch from the lateral p artery, and, immediately before they bifurcate, a second perforating artery through the end of the interosseous space from the corresponding digital.

The **dorsal digital** arteries [aa. digitales dorsales], into which the dorsal metatarsal a divide at the cleft of the toes, run along the side of each toe toward the dorsal aspect, tomosing with each other across the dorsum of the toes and by frequent branches wi digital branches of the plantar metatarsal arteries, which also run along the sides of th but nearer the plantar surface. At the end of the toes they anastomose with each other a the quick of the nail.

(3) The **deep plantar** branch [ramus plantaris profundus] comes off from the dorsali with the first dorsal metatarsal (into which arteries indeed the dorsalis pedis may be s divide). At the proximal end of the first interosseous space it dips into the sole between t heads of the first dorsal interosseous muscle, and communicates with the termination lateral plantar artery, completing the plantar arch, in a manner similar to that in wh radial artery, passing through the first dorsal interosseous muscle in the hand, compl anastomosing with the ulnar the deep palmar arch.

MORPHOGENESIS AND VARIATIONS OF THE ARTEI

A. ARTERIES OF THE HEAD AND TRUNK

1. MORPHOGENESIS

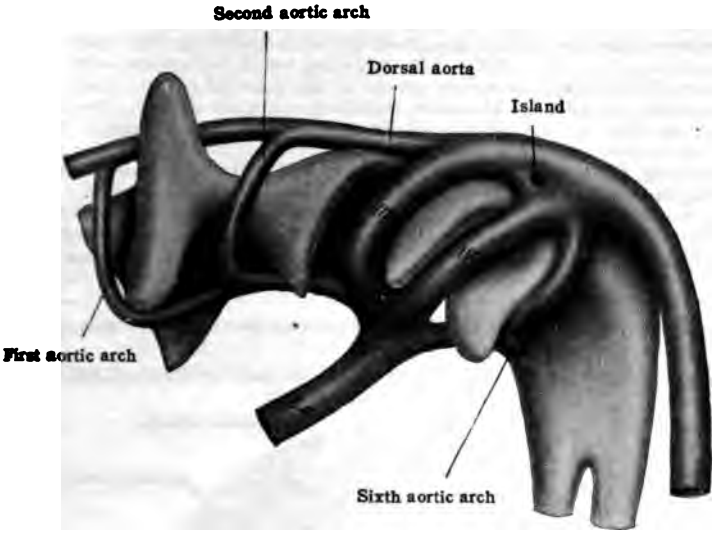
In conformity with the branchiomeric and metameric development of th and trunk (see p. 13) the arteries are developed in two sets, the branchi (aortic arches) and metameric (segmental arteries).

(1) **The system of aortic arches** consists of five pairs of arteries which spring from tral aorta, or aortæ, and pass around the pharynx in the branchial arches to join th dorsal aortæ. Some of the arches are very transitory, but all of those that give rise to nent vessels are present in embryos about five millimeters in length. Fig. 545 shows t tribution and relations to the pharyngeal pouches at this stage. The fifth pair in the usually regarded as representing the sixth of the lower vertebrates. The true fifth ar probably not always developed, but may occur as imperfect and transitory structure dorsal aortæ, originally paired throughout, later become united in the median line near forward as the last pair of aortic arches.

During the separation of the heart into right and left halves (p. 558), the primitive aorta is divided by the aortic septum into two vessels, the *main pulmonary artery* and *ending aorta* of the adult. The pulmonary trunk becomes connected with the sixth arches only; the other arches then communicate, by means of the ventral aorta, with ventricle. The further changes which occur in the arches to bring about the condition

adult are shown diagrammatically in fig. 546. The right and left *pulmonary arteries* arise he corresponding sixth arches. The portion of the sixth arch between the pulmonary and the dorsal aorta disappears on the right side, while on the left it persists until birth *ductus arteriosus* (lig. arteriosum of the adult). The fourth arch, including the short l stem between the fourth and sixth arch, becomes the permanent *aortic arch* on the left nd the *innominate* and proximal portion of the subclavian upon the right. The dorsal

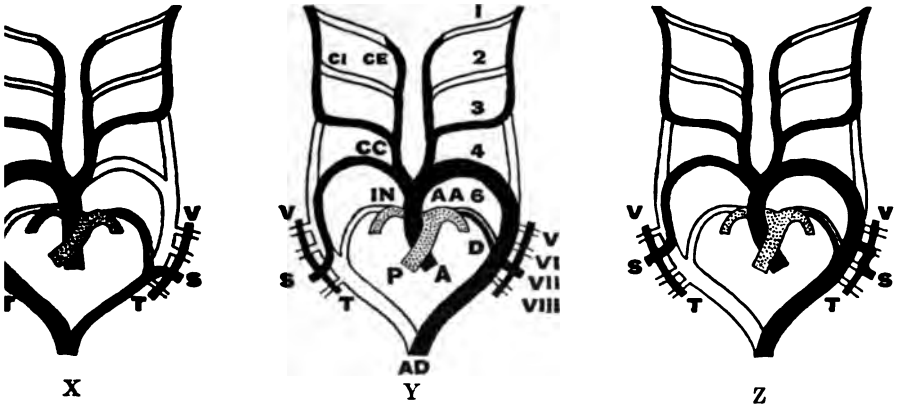
15.—Model of the Pharynx and Aortic Arches of a Human Embryo 5 mm. Long. (Tandler, ×75.)



lisappears on both sides between the third and fourth arches. The part of the left dorsal between the fourth and sixth arches enters into the composition of the aortic arch, while rresponding part of the right dorsal aorta forms part of the right subclavian artery. The ıder of the dorsal aorta of the left side forms part of the descending thoracic aorta of the while that of the right side usually disappears entirely. A trace of the latter vessel ınally persists in the adult as a small vessel (*a. aberrans*) connecting the dorsal aorta,

46.—Diagrams showing the Method of Normal Development of the Aortic Arches, and Indicating the Mechanism of some Variations.

imitive aortic arches (1–6), and some of the cervical dorsal segmental arteries are shown all the diagrams but numbered in Y only. Y., normal; X., abnormal: the aortic arch is ı the right; the left subclavian takes the dorsal course; the right vertebral arises directly ɔm the aortic arch. *Z.*, abnormal: the right subclavian arises from the sixth cervical ırsal segmental; the left from the sixth in part only. A, ascending aorta; AA, aortic ch; AD, dorsal aorta; CC, common carotid; CE, external carotid; CI, internal carotid; , ductus arteriosus; IN, innominate; S, subclavian; T, costocervical; V, vertebral.



r or indirectly, with the right subclavian artery (p. 609). The ventral stems between the and third arches form the *common carotids;* those between the third and first become the l *carotids*. The *internal carotid* arteries are formed by the third arches and by the parts lorsal aortæ between the third and first arches. The distal part of the internal carotid ı, the circulus arteriosus and the cerebral arteries are developed from the primitive vascu- uses of the forebrain and midbrain.

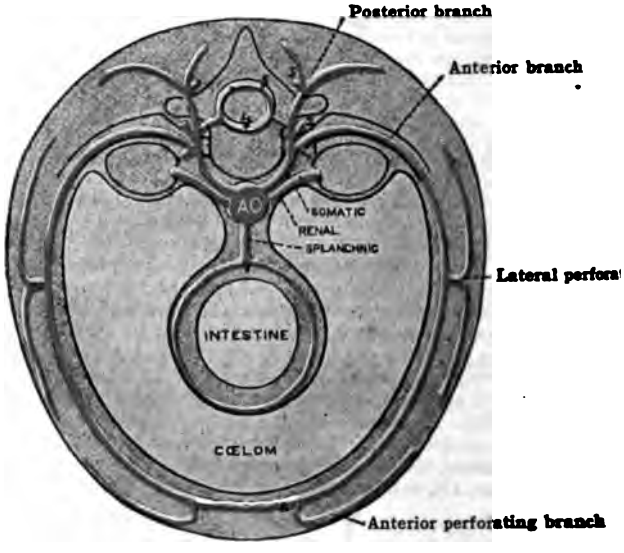
In early development the segmental arteries are caudally placed with regard to arch vessels. The latter, however, become shifted as the heart migrates from the ne thorax.

Little is known of the share taken by the first and second aortic arches in the forma branches of the internal and external carotid arteries. It has been shown by Tandl *internal maxillary* is primarily a branch of the internal carotid (the first and sec taking a share in its formation). The primitive vessel is known as the *stapedial* sinc between the crura of the developing stapes. It gives off supraorbital, infraorbital, and lar branches; the latter two arising from the main artery by a common trunk. Th trunk is later joined by a branch from the external carotid and, together with the su becomes the *middle meningeal*. An anastomosis between the supraorbital and the o persists so that in the adult the anterior branch of the meningeal frequently takes a co share in the blood-supply of the orbit. The stapedial trunk undergoes retrogress represented in the adult by the *caroticotympanic* of the internal carotid and by th *tympanic* of the middle meningeal. The infraorbital branch of the stapedial becomes t and third parts of the internal maxillary and gives off branches accordingly. The m branch becomes the *inferior alveolar* of the adult.

(2) The **segmental system** (figs. 547, 548) consists of arteries primarily arising aorta in three longitudinal series, dorsal, lateral, and ventral on either side. The arrangement is much less perfect in the ventral and lateral groups than in the dorsal so, in fact, that the term segmental is used for the ventral and lateral groups rather a of convenience than as indicating a strict numerical correspondence between segm vessels.

FIG. 547.—SCHEME OF THE TYPICAL ARRANGEMENT OF THE BRANCHES OF THE AORTA Quain.)

Longitudinal anastomoses: 1, precostal; 2, postcostal; 3, postvertebral; 4, preneura neural; 6, mammary.



The **dorsal segmental arteries** primarily supply the central nervous system bu off two sets of vessels to the body wall: these persist in the adult as the *anterior* a *main branches of the intercostal and lumbar arteries*. The termination of the orig segmental arteries is represented in the adult by the *spinal ramus* which accor corresponding nerve root through the intervertebral foramen. The tendency to for mental anastomoses between these vessels (and their branches) gives rise to many o tant longitudinal stems of adult anatomy. Thus, the spinal ramus gives rise to postneural anastomosing channel on either side, the (primarily paired) *anterior a spinal arteries*. The anterior branches have each a longitudinal precostal anasto as they grow forward with the developing body wall, their ends are connected to for mary anastomosis. Between the posterior rami, a postcostal and a postvertebral may be formed (fig. 547).

Two dorsal segmental arteries have been recognized in the occipital region; t appears and the second, the *hypoglossus artery*, follows the hypoglossal nerve to the face of the brain where it is connected with a longitudinal anastomosis out of which *artery* is formed.

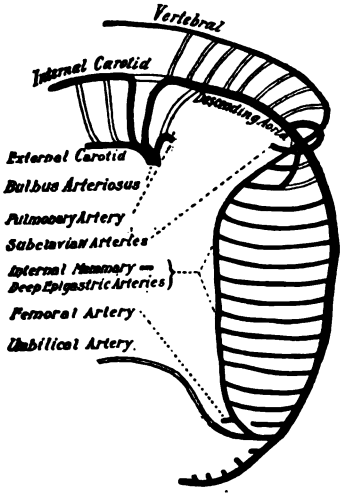
In the *cervical region*, the spinal ramus of segmental cervical I forms the third, o tal, part of the *vertebral artery*. Cervical segmentals I to VI lose their connection wi and a postcostal anastomosis between them forms the second part of the same ve first part of the vertebral is formed by the posterior ramus of cervical VI and by th anastomosis of that artery with the subclavian (fig. 548).

The *subclavian artery* does not seem to belong to the dorsal segmental series. T part of the right subclavian originates from the aortic arch system. The distal po

nd the entire vessel of the left side, represents the only persistent artery out of the e number originally entering the primitive arm-bud. It usually comes to occupy etween cervical arteries VI and VIII of the dorsal segmental series.
anterior ramus of cervical VIII is connected with the subclavian artery by a pre- nosis which becomes the *costocervical* trunk. The posterior ramus becomes the *ep cervical*, and, by a postvertebral anastomosis with the other posterior cervical the occipital, forms the remainder of the deep cervical and the *descending branch artery.*
acic and lumbar regions, the embryonic conditions very largely persist (fig. 548). rami of thoracic segmentals I and II, however, lose their connection with the y a precostal anastomosis with cervical VIII, become secondarily connected costocervical trunk) with the subclavian. The *superior intercostal* of the adult is
Dorsal segmental arteries III to XII of the thoracic, and I to IV of the lumbar e to the *aortic intercostals* and the *lumbar arteries*, respectively.
on iliac artery, like the subclavian, does not appear to belong to the dorsal seg-
Branches from several of the segmental arteries, in addition to lateral branches , enter the lower limb-bud and break up into a plexus which probably gives rise to ic (internal iliac), the internal pudendal, and the axial artery of the lower limb. of the anterior rami of all the thoracic and the upper four lumbar segmentals l, as they grow out with the body wall, to form the longitudinal mammary anas- 48). This anastomosis is connected above with the subclavian artery by means *l mammary* and with the common iliac by means of the *inferior (deep) epigastric liac arteries.*

IAGRAM TO SHOW THE DEVELOPMENT OF THE ARTERIES OF THE TRUNK FROM THE AORTIC ARCHES AND THE DORSAL SEGMENTAL ARTERIES.

vhich persist are black; those which degenerate are in outline; those newly formed are shaded. (After Mall.)



ral region, the arteries of the dorsal segmental series arise from the middle sacral to the anterior vertebral foramina, but before doing so are connected with one precostal anastomosis. This anastomosis forms part of the *lateral sacral artery;* e greater part of its blood from the hypogastric.
l segmental arteries take origin from the aorta in series, intermediate in position lorsal and ventral segmentals. They reach their fullest development in embryos n., when they extend from the seventh cervical to the twelth thoracic segment and esonephros. At this stage Broman found twenty arteries on each side, many of on-segmental. As the suprarenals and gonads develop, they each receive branches mesonephric arteries. The latter arteries now undergo rapid retrogression and l and gonadic branches are shifted caudally through the mesonephric series to l (non-segmental) arteries opposite the upper lumbar segments. Finally there suprarenal arteries opposite the twelfth thoracic and first and second lumbar l a gonadic artery (*ovarian or internal spermatic* of the adult) opposite the third nt. All of these vessels now appear to be direct branches from the aorta. Of the nal branches, the upper and lower each gives a large branch to the diaphragm and tively and become the *inferior phrenic* and *renal arteries* of the adult. The middle *middle suprarenal* of the adult. Felix regards the lateral segmental arteries as from longitudinal anastomoses connecting the ventral segmental series. He rent interpretation upon the vessels which persist in the lumbar region after the e of the thoracic mesonephric arteries. He finds in an embryo of 18 mm. nine ther side, extending from the ninth thoracic to the third lumbar segment, all of s upon as mesonephric. These arteries he classifies into three groups: Cranial, he mesonephros by passing dorsally to the suprarenal; caudal which pass ventrally enal, and middle which pass through it. Inasmuch as the arteries anastomose

in the mesonephros there is great liability to variation in the number and position of the stems which persist in the adult. The suprarenal arteries are usually derived from the caudal group, the renals from the caudal or middle and the spermatics from the middle. When accessory renals or spermatics occur in the adult their place of origin and course indicate the group from which they have been derived.

The **ventral segmental arteries** appear very early. In an embryo of seven somites (1.5 mm.) described by Dandy there is a right and a left series of twelve arteries, each arising from the still ununited dorsal aortæ, the artery at the caudal end of each series being the umbilical, and the remainder vitelline arteries. In an embryo of 4.9 mm. (35 somites) described by Ingalls the originally paired vitelline arteries have united (as have the dorsal aortæ in part) to form unpaired vessels. There are unpaired ventral segmental arteries as follows: one opposite the seventh cervical segment (celiac); five opposite the first four thoracic (omphalomesenterics, united by a longitudinal anastomosis), and one vessel of doubtful significance opposite the fifth and sixth thoracic segments. The paired umbilical arteries are opposite the first lumbar segment.

It has been found from more fully developed stages that the inferior mesenteric artery is distinguishable at a stage of 8 mm. opposite the second lumbar segment. Also that the ventral segmental vessels undergo a process of apparent migration until they reach their definite positions, the *celiac* opposite the twelfth thoracic segment; the *superior mesenteric* opposite the first, the *inferior mesenteric* opposite the third, and the umbilicals opposite the fourth lumbar segments, respectively. The esophageal arteries of the adult do not belong to this series: but seem to be vessels of later formation.

The *umbilical arteries* become connected by anastomosis with the common iliac-hypogastric trunks. The original (or ventral) roots of the umbilical arteries soon disappear and the umbilical arteries are subsequently supplied through the common iliac-hypogastric trunks alone.

2. VARIATIONS

Aorta and pulmonary artery.—The variations met with in the arch of the aorta are usually to be explained as persistent fetal conditions, and are often associated with abnormalities of the heart. Many of the variations are due to different modes of transformation of the primitive system of aortic arches. Since the aorta and pulmonary artery develop from a common conus and truncus arteriosus, irregular and imperfect development of the aortic septum may also be productive of variations.

It has been seen that at one stage of development two fourth arches, a right and a left, are present, and such a condition is occasionally persistent in the adult. In such cases, the right arch passes from right to left behind the esophagus, which thus seems to perforate the aortic arch.

Another variation occasionally seen is the occurrence of an aortic arch curving to the right instead of the left. This may be due to a persistence of the lower portion of the right dorsal longitudinal stem and the disappearance of the left, as shown in fig. 546; or it may be associated with transposition of the viscera (*situs inversus*).

If the lower portion of the right dorsal longitudinal trunk should persist, and the part of it which normally forms the proximal part of the right subclavian should disappear, the right subclavian would arise from the descending portion of the aortic arch. It is to be noted that in such cases the subclavian passes behind the esophagus and below the right inferior laryngeal nerve. Partial persistence of the lower portion of the right dorsal longitudinal trunk is represented in the arteria aberrans (see p. 609).

Another group of variations is based on abnormal persistence of the ductus arteriosus, which is a derivative of the sixth aortic arch. With this group belong the cases in which the pulmonary artery arises from the aorta; that is, where the blood of the pulmonary arteries passes from the aorta through the ductus arteriosus.

Variations in the number and the position of the vessels arising from the aortic arch are numerous and important. Many of these conditions are found normally in other mammals or birds. There may be from one to six branches. The case of one branch is the normal in the horse. It involves the fusion of the two aortic stems and the shortening of the fourth arch so that the left subclavian joins with the common stem. The avian form with two innominate arteries is extremely rare. A more common form is the one found in most apes, in which the innominate and left carotid form one branch; in rare instances the three branches are the two subclavians with a single common carotid artery. When there are more than three branches the vertebral arteries are added, or the extra branch may be the thyroidea ima (fig. 487). The commonest form with four vessels is the one in which the left vertebral arises between the left carotid and subclavian. In a rarer form the order is right subclavian, right carotid, left carotid, and left subclavian. Where there are five arteries, the extra ones are the right subclavian and left vertebral. The case of six branches is due to the separate origin of both vertebrals and both subclavians. The manner in which the vertebral artery may arise from the adult aortic arch is indicated in fig. 546.

The **innominate artery** may be absent, or may give off additional branches (see AORTA). It may be longer than usual and, bending to the left, ascend in front of the trachea (or more rarely behind the trachea and esophagus) to turn again to the right. The *thyroidea ima* has been referred to (p. 573).

Carotid arteries.—The *common carotid* may be absent or bifurcate at a higher or a lower level than usual. It may not bifurcate at all, in which case the branches usually arising from the external carotid are derived from the common. The ascending pharyngeal and superior thyroid occasionally arise from an otherwise normal common carotid. Unusual origin of the common carotid arteries has been referred to (see AORTA).

Branches of the carotid arteries.—The superior thyroid, lingual and external maxillary

sometimes have a common stem of origin. The *superior thyroid* artery varies in size inversely with the inferior. The *external maxillary* occasionally terminates in its submental branch. In such cases the main supply of the face is taken over by an abnormally large dorsal nasal branch of the ophthalmic, or transverse facial branch of the temporal artery. The *occipital* sometimes arises from the internal carotid or from the ascending cervical. The *ascending pharyngeal* is very variable in its place of origin from the external carotid, it may arise from the common or internal.

Out of 447 arteries examined, the second portion of the *internal maxillary* passed laterally to the external pterygoid muscle in 55 per cent., and medially to it in 45 per cent. of cases. When it passes to the medial side of this muscle the internal maxillary sometimes passes medially to the inferior alveolar and lingual nerves and occasionally between them. The variability in the course of this artery appears to depend on a tendency to reduplication of the infraorbital branch of the *stapedial artery* (p. 670) in the neighborhood of the mandibular nerve. Such a condition was found by Thyng in a 17 mm. human embryo. When the internal maxillary passes medially to the external pterygoid there is often a parallel anastomosing channel between the posterior deep temporal and buccal branches.

The *ophthalmic artery* may arise, wholly or in part, from the middle meningeal, or *vice versa*. This is due to the anastomosis between the supraorbital branch of the stapedial and the ophthalmic in the embryo.

Subclavian artery.—Irregularities of origin have been referred to (see AORTA).

The branches of the subclavian artery are very variable in their place of origin (p. 597). The *vertebral* may arise directly from the arch of the aorta (p. 672) or take an unusual course in the neck. It may enter the foramen transversarium of the fourth or fifth cervical vertebra instead of the sixth; this arises from substitution of an embryonic precostal anastomosis in these segments for the usual postcostal. By a converse substitution it may enter the seventh; or the pre- and postcostal anastomoses may coexist. The *aa. transversa colli and scapulæ* vary inversely in size. The *arteria aberrans* connecting the right subclavian with the dorsal aorta has been referred to (p. 672).

The thoracic aorta.—Transposition, and the arteria aberrans have been referred to above.

Branches of the thoracic aorta.—The *intercostal arteries* are liable to numerical variation, evidently owing to the occurrence of precostal intersegmental anastomoses between the embryonic dorsal segmentals. A common longitudinal stem may even take over the vessels of both sides. The arrangement of the *bronchial arteries* is liable to much variation; this has not received adequate explanation.

The abdominal aorta sometimes divides as low as the fifth lumbar vertebra, occasionally a little higher than usual, depending usually upon the position of origin of the common iliac. (p. 671). Cases are on record of accessory pulmonary arteries arising by a single stem from the abdominal aorta, which passes into the thorax along the esophagus. The aorta and vena cava inferior may be transposed either as a part of *situs inversus* or as an abnormality of the venous system.

Branches of the abdominal aorta.—The *lumbar arteries* are subject to the same type of variation as occurs in the intercostals. There may be a loop connecting the *celiac* and *superior mesenteric* arteries. Any or all of the branches of the celiac may arise from the superior mesenteric (celiomesenteric in the latter case) or directly from the aorta. The instability of the celiac and superior mesenteric branches is favored by the rapid craniocaudal migration of the two trunks; intersegmental anastomosis, in some cases, may be a factor also. There is very great variation in the number of branches given off by the superior mesenteric and in the details of their arrangement. This is a natural result of the number of possible routes which may be taken by the blood, which resemble, in their variety, those which occur in an embryonic plexus. The region of supply of the *inferior mesenteric artery* is sometimes taken over entirely or in part (e.g., middle colic) by the superior mesenteric. An *omphalomesenteric* artery, in rare cases, arises from the superior mesenteric or one of its branches. It passes to the navel and anastomoses with inferior epigastric and with the small arteries accompanying the round ligament of the liver or the urachus.

Accessory renal arteries are very common; as many as six on a side have been recorded. These may arise from the aorta, middle sacral, inferior phrenic, middle suprarenal or internal spermatic. According to Felix, they are to be regarded as persistent mesonephric arteries. Those arising above the regular renal frequently enter the kidney on the dorsal side of the hilum. Those below it are more apt to be ventrally placed.

Nearly all possible variations of origin are met with in the *inferior phrenic, middle suprarenal, internal spermatic* and *accessory renal* arteries which find explanation in the caudal migration of, and anastomosis between, the embryonic representatives of these vessels. The occasional origin of the inferior phrenic from the celiac (or from one of its branches) or from the superior mesenteric; of the internal spermatic or the middle suprarenal from the lumbar arteries, or of an accessory renal from the inferior mesenteric must be taken as indicating embryonic anastomoses between the dorsal, lateral, or ventral segmental arteries, as the case may be.

The iliac and hypogastric arteries.—The length of the *common iliac* depends upon the site of aortic bifurcation (p. 674); also upon the site of division of the common iliac into external iliac and hypogastric. Many of the variations of the *common iliac* and *hypogastric* arteries are, in reality, anomalies of position of the *external iliac*. Failure in the separation of the common iliac from the hypogastric may be due to origin of the external iliac from the aorta (Cruveilhier, Walsham) or to its origin from the distal region of the hypogastric (Ellis, Ledwich, Luschka, Vonviller). In the latter case the hypogastric has been erroneously reported absent.

The *branches of the hypogastric artery* may not combine so as to form the typical anterior and posterior divisions. The marked tendency to variation in the branches of the a. hypogastrica does not appear to have been satisfactorily explained. The *obturator artery* may arise by the union of a stem from the hypogastric with another arising from the external iliac or from the inferior epigastric, or it may arise solely from any one of these arteries.

B. ARTERIES OF THE EXTREMITIES

1. MORPHOGENESIS

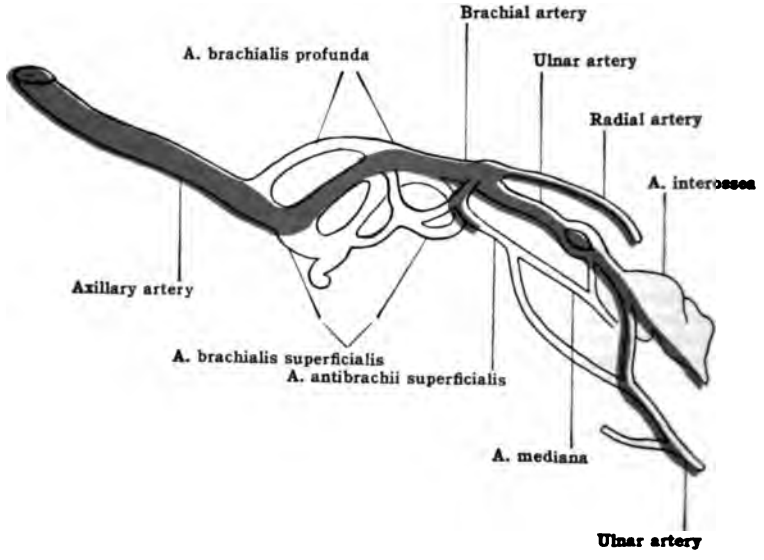
The developing extremities are at first supplied by lateral branches of the aorta and by branches of the neighboring dorsal segmental arteries, which form a plexus drained by the umbilical and postcardinal veins.

The further development of the *arteries of the upper extremity* has been described by both DeVriese (Arch. de Biol., T. 18, 1902), and Müller (Anat. Hefte, 1903). The accounts given by the two authors differ, however, very considerably in detail. According to DeVriese there is an axial artery of the embryonic extremity, which follows the median nerve in the arm and the volar interosseous nerve in the forearm. It breaks up to supply the volar surface of the hand, and sends a perforating carpal branch to supply the dorsum. Embryonic arteries of secondary formation follow the radial and the ulnar nerve in the arm and forearm and the median nerve in the forearm. For further details on the ensuing changes, see the original article.

Müller describes a plexus which traverses the axis of the limb at the stage of 8.3 mm. At the stage of 11.7 mm. the plexus reaches its full development and centers about a main trunk which corresponds to the axillary, the brachial and to the volar interosseous arteries of the adult. Some of the other elements of the plexus of the stage of 11.7 mm. are recognizable as the remaining arteries of the normal adult; others consist of anastomosing channels which would be instrumental, if they were to persist, in the production of various anomalies (fig. 549).

FIG. 549.—DIAGRAM INDICATING THE METHOD OF DEVELOPMENT OF THE ARTERIES OF THE LEFT UPPER EXTREMITY. (After E. Müller.)

(The embryonic arteries are outlined in black, and labelled in Latin. The normal adult arteries are colored red and labelled in English).



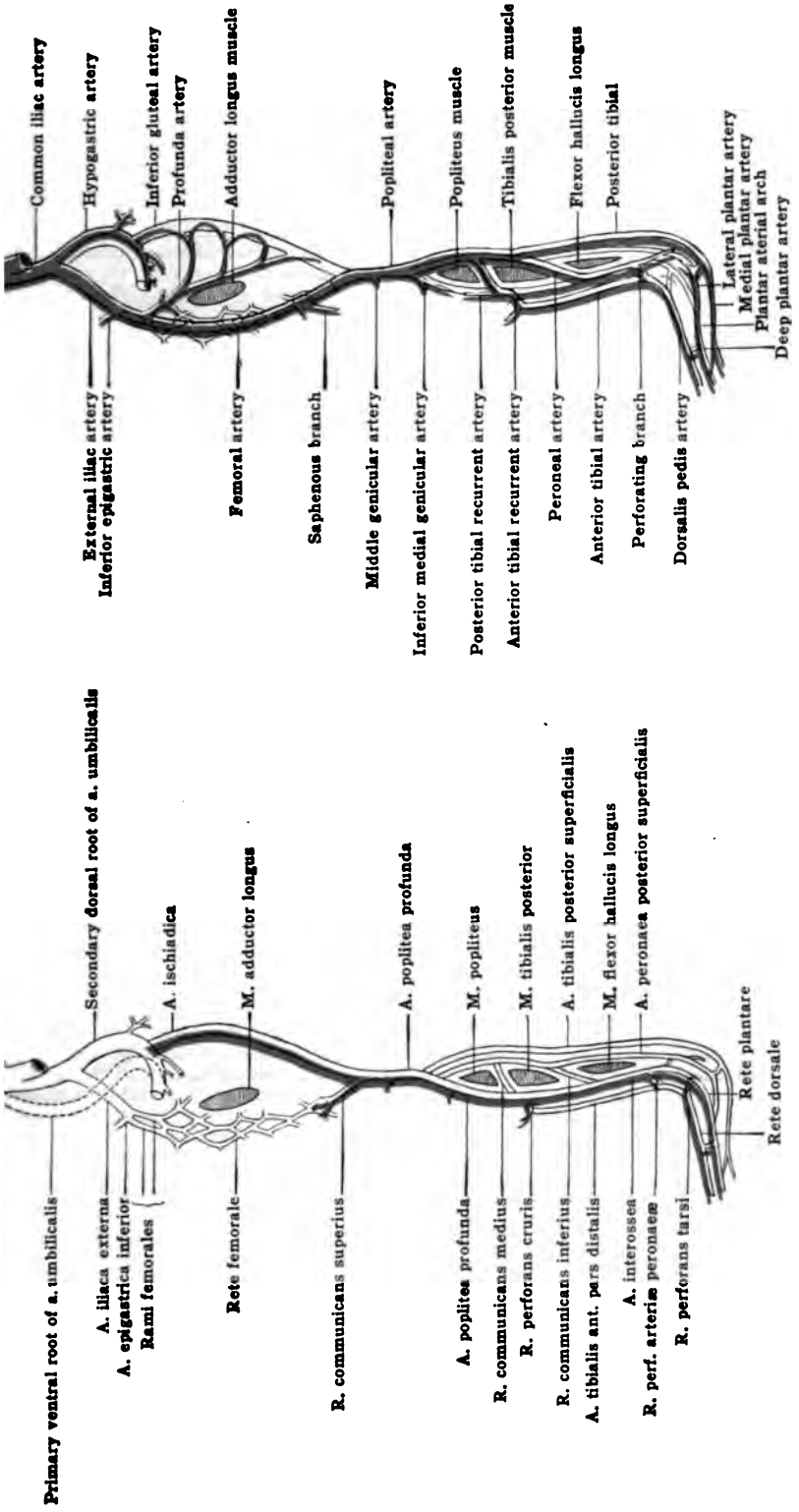
The further history of development consists in the loss of existing arterial channels which have no place in the normal upper extremity. By the stage of 20.2 mm. the definitive arrangement has been established.

In the *lower extremity* (fig. 550) the arterial part of the vascular plexus of the early limb-bud gives place to the common iliac-hypogastric trunk which replaces the original, or ventral, root of the umbilical artery, and to an artery which traverses the axis of the limb. In the thigh the axial artery accompanies the tibial nerve; and is called the a. ischiadica. In the proximal part of the leg it passes between the popliteus muscle and the tibia, on which account it takes the name of a. poplitea profunda; it then follows the posterior surface of the interosseous membrane, as the a. interossea, to the medial malleolus. Passing below the malleolus it breaks up into an arterial plexus (rete) for the supply of the sole and sends a branch, the r. perforans tarsi, through the sinus tarsi to the dorsum of the foot. The axial artery is represented in the adult by the inferior glutaeal artery and by the part of the popliteal artery above the popliteus muscle. Smaller parts of it persist in the postfemoral anastomosis; in the inferior medial genicular artery; in the posterior tibial recurrent and in the part of the anterior tibial artery from which the latter arises, also in the part of the peroneal artery which lies in contact with the interosseous membrane (fig. 550).

The external iliac is an artery of new formation which is connected, by means of the rete femorale, with a recurrent branch of the axial artery, the r. communicans superius; the femoral artery is developed from the rete femorale and ramus communicans, as are all of its branches. The distal part of the popliteal artery, and the part of the posterior tibial artery above the origin of the peroneal, are formed by the blending of two embryonic arteries. One of these, the superficial posterior tibial, still further persists in the distal part of the posterior tibial artery and in

-DIAGRAM INDICATING THE METHOD OF DEVELOPMENT OF THE ARTERIES OF THE RIGHT LOWER EXTREMITY. (After E. Müller.)

onic arteries are outlined in black, In *A*, the axial artery of the developing limb, and of its branches are colored red; the original, or ventral, root of the umbilical artery cated by a broken line. In *B*, the adult arteries are colored red.



the medial plantar. The other, the superficial posterior peroneal, is united with the axial artery by means of the r. communicans inferius to form a combination of which a part persists as the peroneal artery of the adult. The distal part of the anterior tibial artery arises as a communication between the rete dorsale of the foot and the ramus perforans cruris, which is a branch of the axial artery. The proximal part consists of the ramus communicans medius, a branch which connects the axial with the popliteal artery. The lateral plantar artery is derived from the terminal bifurcation of the embryonic superficial posterior peroneal artery which forms a connection between the superficial posterior tibial and the plantar rete of the foot. All the deeper arteries of the foot are developed from the embryonic retia.

2. VARIATIONS

Variations of the *arteries of the upper extremity* are very common. The most important group of major variations centers about persistence of the embryonic *superficial brachial* artery This vessel crosses in front of the median nerve instead of behind it; it may partly, or entirely, replace the normal, or deep, brachial, or both vessels may occur together. In the latter case the superficial brachial may end in, or communicate with, the deep brachial artery near the bend of the elbow, forming an *arteria aberrans;* or it may pass without communication, into the forearm. In the latter case it most commonly follows the course of the radial artery (high origin of radial); while the deep brachial is continued as the ulnar. The superficial brachial artery may, however, be continued into the forearm as the embryonic *superficial antibrachial* artery. This vessel may combine, with the distal part of the ulnar, or with the median artery, to form the *superficial ulnar* or *median*, as the case may be, or it may combine with both. When the persisting superficial antibrachial artery enters into combinations of this kind, the ulnar nerve is not accompanied by an artery in the middle of the forearm, and the radial artery, the continuation of the deep brachial, gives origin to the common interosseus and to the ulnar recurrent arteries. When the deep and superficial brachial arteries occur together the superficial brachial frequently arises in the distal third of the arm. It may arise from the proximal third, however, or from the axillary; it seldom arises in the middle third. In cases in which the superficial brachial artery altogether replaces the deep brachial and the distal portion of the axillary, the branches of the third part of the axillary artery arise by a common stem, the *a. profunda axillaris*. The latter vessel takes the same course, with regard to the medial root of the median nerve, as does the normal axillary artery. The deep axillary artery may give origin to the a. profunda brachii and the superior ulnar collateral in addition to the branches which usually arise from the third part of the axillary. The embryological basis for these variations, according to DeVriese and Müller is stated above (fig. 549).

Apart from the variations mentioned above, the radial or ulnar artery may be small or absent, compensation usually occurring through enlargement of the median. The volar interosseous artery may be sufficiently large to take part in the supply of the deep volar arch. Many variations less commonly encountered have been recorded by Barkow, Gruber, Quain, Tiedemann and others.

Arterial variations are much less common in the *lower extremity* than in the upper. In the absence of the embryonic r. communicans superius the *ischiadic artery* may persist in the adult. The femoral is small in such cases, and ends either as the a. genu suprema or as the a. profunda femoris. Partial *reduplication of the femoral artery* may result from the formation of a double channel, instead of the usual single one, through the elements of the rete femorale. The *profunda artery* is quite commonly represented by several branches of the femoral. This seems to result from the fact that the circumflex arteries, and the common stem of the aa. perforantes, make their appearance separately at different periods of development, and that their proximal ends may fail to combine in the formation of a single stem. The perforating arteries may even arise individually or in two or more groups from the femoral (Hepburn, Ruge, Young). In consequence of the failure of the proximal part of the embryonic a. peronaea posterior superficialis to unite with the corresponding part of the a. tibialis posterior superficialis, the *popliteal artery may divide at the upper border of the popliteus muscle* into the posterior tibial and a trunk which gives origin to the peroneal artery and to the anterior tibial. In the absence of the embryonic r. communicans medius, part of the a. poplitea profunda persists as the proximal portion of the *anterior tibial artery*, which crosses the anterior surface of the popliteus muscle. The *posterior tibial artery* is occasionally absent; in such cases the distal part of the embryonic a. peronaea posterior superficialis persists and the peroneal artery, through it, supplies the sole. The *peroneal artery* is constantly present; through the abnormal persistence of the embryonic a. interossea (Hyrtl) or of the a. peronaea posterior superficialis (Barkow, Hyrtl) it may appear to be reduplicated. The distal part of the anterior tibial artery is often small, and may be altogether absent. In such cases the *dorsal artery of the foot* receives its blood-supply through the perforating branch of the peroneal.

The *a. saphena magna* is occasionally present, also the *a. suralis magna*, and either of them may be large enough to take part in the arterial supply of the foot. These arteries do not appear regularly in the embryo; the occurrence of either of them, whether in the embryo or in the adult, appears to afford an example of individual variations.

3. THE SYSTEMIC VEINS

The systemic veins are naturally divided into three groups—(1) the veins of the heart; (2) the vena cava superior and its tributaries, namely the veins of the head, neck, upper extremity, and thorax; and (3) the vena cava inferior and its tributaries, namely, the portal system, and the veins of the abdomen, pelvis, and lower extremity.

I. THE VEINS OF THE HEART

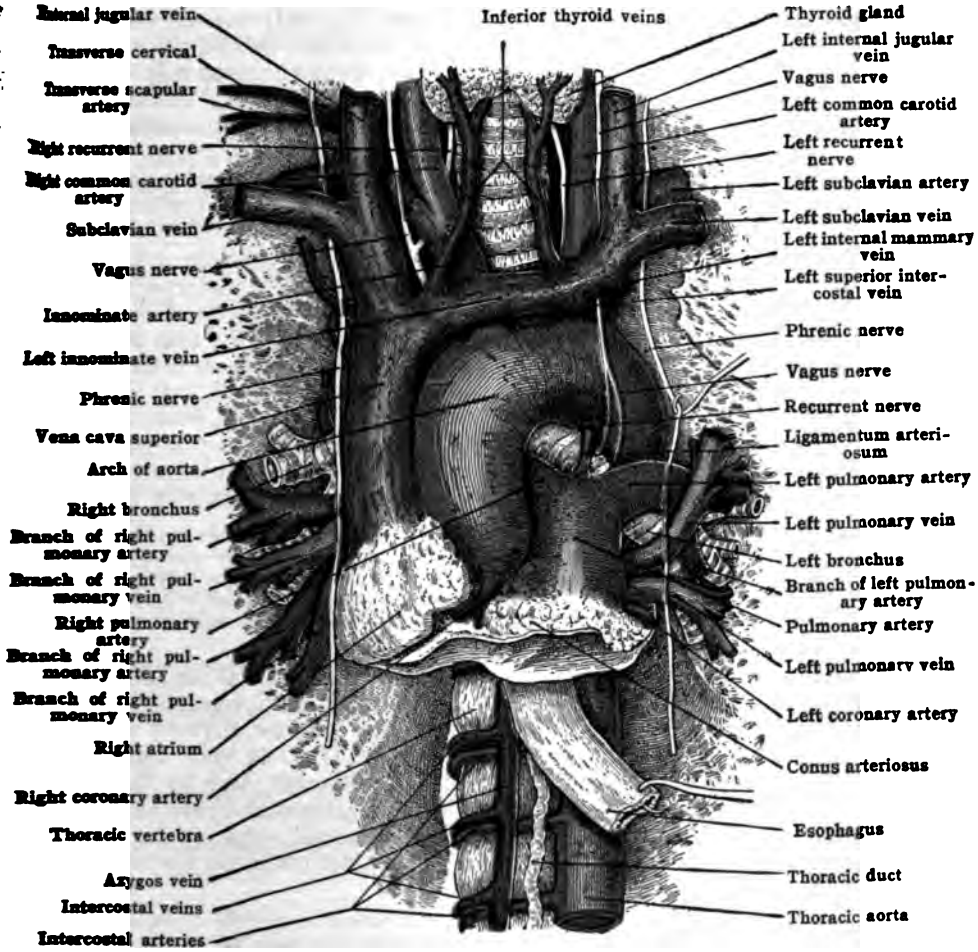
The veins of the heart have already been described (p. 561).

II. THE VENA CAVA SUPERIOR AND ITS TRIBUTARIES

THE VENA CAVA SUPERIOR

The **vena cava superior** (fig. 551) carries to the heart the blood returned from the head and neck and upper extremities through the right and left innominate veins, and from the walls of the thorax, either directly through the azygos vein, or indirectly through the innominate veins. It is formed by the confluence of the right and left innominate veins behind the first right sternochondral

FIG. 551.—THE VENA CAVA SUPERIOR AND THE INNOMINATE VEINS.
(Modified from a dissection in St. Bartholomew's Hospital Museum.)



articulation. Descending from its origin in a gentle curve with its convexity to the right and in a direction slightly backward behind the sternal end of the first and second intercostal spaces and second costal cartilage, it terminates in the right atrium of the heart on a level with the third right costal cartilage in front and the seventh thoracic vertebra behind. It measures about 7 to 8 cm. (3 in.) in length. A little more than its lower half (4 cm.) is contained within the pericardium, the serous layer of that membrane being reflected obliquely over it immediately below the spot where it is joined by the vena azygos, and on a lower level than the reflection of the pericardium on the aorta. The vena cava superior contains no valves.

Relations.—In front, in addition to the first and second intercostal spaces and the second costal cartilage, **it is covered by** the remains of the thymus gland, the intrathoracic fascia, and the pericardium, **and is overlapped** by the right pleura and lung.

Behind are the vena azygos (major), the right bronchus, the right pulmonary artery, and the superior right pulmonary vein; and below, the fibrous layer of the pericardium. The serous layer is reflected over the front and sides of the vessel, but not over its posterior part.

To the **right side** are the right lung and pleura and the phrenic nerve.

To the **left side** are the innominate artery and the ascending aorta.

Tributaries.—In addition to the right and left innominate veins and the vena azygos it receives small veins from the mediastinum and pericardium.

THE INNOMINATE VEINS

The **innominate** veins [vv. anonymæ] return the blood from the head and neck and upper extremity. They are formed on each side by the confluence of the internal jugular and subclavian veins behind the sternal end of the clavicle. They terminate behind the first costal cartilage on the right side by uniting to form the vena cava superior. The innominate veins have no valves.

The **right innominate** vein [v. anonyma dextra] (fig. 551) measures about 2 to 3 cm. (1 to 1½ in.) in length, and descends from its origin behind the sternal end of the clavicle, very slightly forward and medially, along the right side of the subclavian and innominate arteries, to its junction with the left vein behind the first costal cartilage close to the sternum. It is superficial to the innominate artery.

Relations.—**In front** are the origins of the sternohyoid and sternothyroid muscles, the clavicle, the first costal cartilage, and the remains of the thymus gland. **Behind** are the pleura and lung. To the **right** are the right pleura and lung and the phrenic nerve. To the **left** are the right subclavian artery, the innominate artery, the right vagus nerve, and the trachea.

The **left innominate** vein [v. anonyma sinistra] (fig. 551) measures 6 to 7.5 cm. (2½ to 3 in.) in length, and extends from its origin behind the sternal end of the left clavicle obliquely across the three main branches of the arch of the aorta to unite with the right innominate vein behind the cartilage of the first rib close to the sternum to form the vena cava superior. In this course it runs from left to right with an inclination downward and slightly backward. A line drawn obliquely across the upper half of the manubrium of the sternum, from the sternoclavicular articulation on the left side to the lower border of the first costal cartilage at its junction with the sternum on the right side, will indicate its course. The left innominate vein is on a level with the top of the sternum at birth.

Relations.—**In front,** in addition to the manubrium of the sternum, it has the origins of the sternohyoid and sternothyroid muscles, and the remains of the thymus gland, the sternal end of the left clavicle, and the sternoclavicular articulation. **Behind** are the three chief arteries arising from the arch of the aorta, the trachea, and the left phrenic and left vagus nerves. **Below** it is the arch of the aorta. **Above** it are the cervical fascia, the inferior thyroid, and thyroidea ima veins.

Tributaries.—In addition to the internal jugular and subclavian veins, by the confluence of which the innominate veins are formed, each vein receives on its upper aspect the vertebral, the deep cervical, and inferior thyroid veins; and on its lower aspect the internal mammary vein. The left vein, moreover, is joined by the thyroidea ima, the left superior intercostal, and by the thymic, tracheal, esophageal, superior phrenic, anterior mediastinal, and pericardiac veins. At the confluence of the internal jugular and subclavian veins on the right side the three lymphatic trunks or the right lymphatic duct open; on the left side the thoracic duct.

THE VEINS OF THE HEAD AND NECK

The **veins of the head and neck** may be divided for purposes of description into the **superficial,** which return the blood from the external parts of the head and neck; and the **deep,** which return the blood from the deeper structures. All the veins, whether superficial or deep, terminate in the internal jugular or subclavian, or open directly into the innominate veins at the root of the neck. Through the latter all the blood from the head and neck ultimately passes on its way to the heart.

THE SUPERFICIAL VEINS OF THE HEAD AND NECK

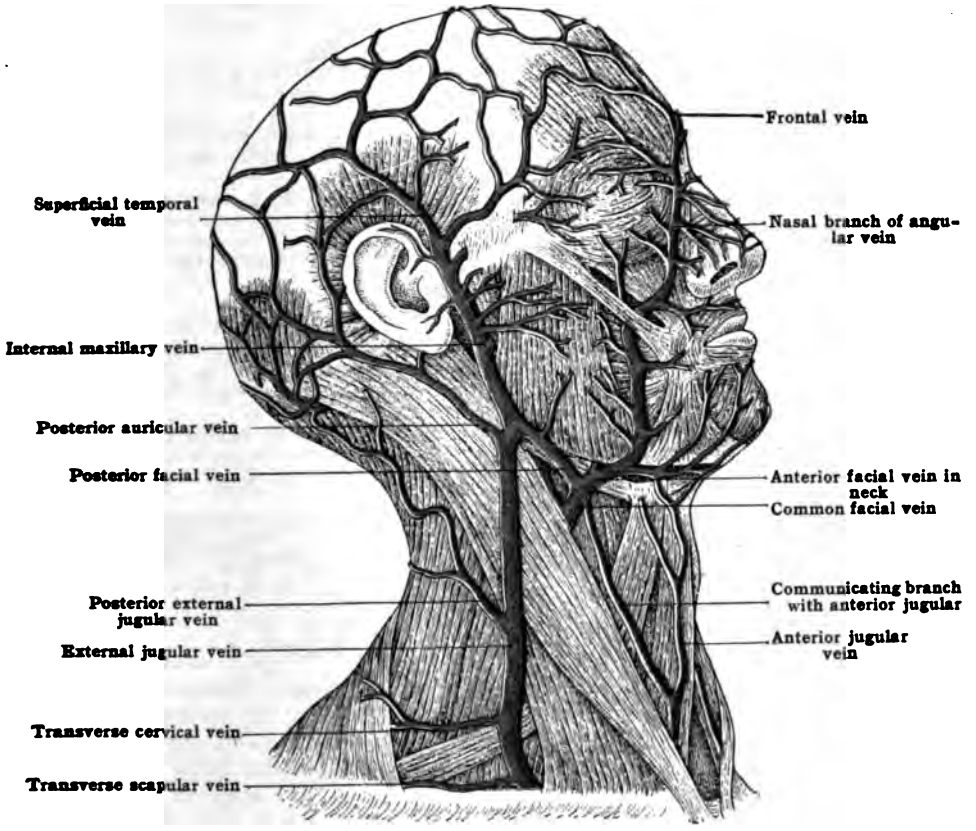
The venous blood from the anterior part of the scalp and integument of the face is returned, through the **anterior and posterior facial veins, to the common**

cial, a tributary of the internal jugular vein. From the posterior part of the **calp and from the integument of the neck venous blood is returned, through the external jugular** and its tributaries, to the subclavian vein.

A. The Anterior Facial Vein

The **anterior facial** vein [v. facialis anterior] (fig. 552) begins a little below the medial end of the eyebrow where it is formed by the union of the frontal and supraorbital veins. It descends near the medial angle of the orbit, and then by the side of the nose to the cheek, which it crosses obliquely, to the anterior edge of the masseter muscle. Thence it passes through the digastric triangle to the upper border of the hyoid bone, where it terminates in the common facial vein. In this course it is reinforced by numerous collateral veins, and gradually increases in size. It has, moreover, numerous communications with the deep veins.

Fig. 552.—The Superficial Veins of the Face and Scalp. (After Quain.)



The portion of this vein above the lower margin of the orbit is called the **angular** [v. angularis]. In the remainder of its course over the face and neck it is termed the **anterior facial** vein.

The angular vein skirts around the medial margin of the orbit, lying with the angular artery on the frontal (nasal) process of the maxillary bone slightly medial to the lacrimal sac. Branches pass from the posterior part of the angular vein into the orbit to join the ophthalmic.

The angular, the facial, and the ophthalmic veins contain no valves. The blood, therefore, can pass either forward from the ophthalmic into the angular, or backward through the facial and angular into the ophthalmic, and so on to the cavernous and other venous sinuses of the cranium.

The anterior facial vein runs in a more or less direct line behind its corresponding artery, the external maxillary (facial), which itself pursues a tortuous course. It usually passes deep to the zygomatic muscle, the zygomatic head of the quadratus labii superioris, and the risorius, but superficial to the other muscles At the anterior edge of the masseter it meets the external maxillary artery, lying

immediately posterior to it. In the neck it lies beneath the platysma and cervical fascia, and is usually separated from the external maxillary artery by the submaxillary gland and the stylohyoid and posterior belly of the digastric muscle, below which it is joined by the posterior facial, to form the **common facial vein**.

Tributaries.—It receives, from above downward:—(a) the frontal vein; (b) the supraorbital vein; (c) the superior palpebral veins; (d) the external nasal veins; (e) the inferior palpebral veins; (f) the superior labial vein (g) the inferior labial vein; (h) the masseteric veins; (i) the anterior parotid veins; (j) the palatine vein and (k) the submental vein.

(a) The **frontal** vein [v. frontalis] (figs. 552, 562) begins about the level of the coronal suture in a venous plexus which communicates with the anterior division of the temporal vein. Soon forming a single trunk, it passes vertically downward over the frontal bone, a short distance from the middle line and parallel with its fellow of the opposite side, to the medial end of the eyebrow where it terminates in the angular vein.

(b) The **supraorbital** vein [v. supraorbitalis] begins over the frontal eminence by intercommunication with the middle temporal vein. It receives tributaries from the forehead and eyebrow, and, running obliquely, medially and downward, opens into the termination of the frontal vein to form the angular. It communicates with the ophthalmic vein, and receives the frontal vein of the diploë as the latter vein issues from the bone at the bottom of the supraorbital notch.

(c) The **superior palpebral** veins [vv. palpebrales superiores] arise in the upper eyelid and open into the lateral side of the angular vein. They communicate with the middle temporal vein.

(d) The **external nasal** veins [vv. nasales externæ] form three or four stems on either side. The upper veins run upward into the angular and the lower, from the ala, pass more horizontally into the anterior facial vein.

(e) The **inferior palpebral** veins [vv. palpebrales inferiores] arise in the lower eyelid, and, passing medially and downward over the cheek from which they receive tributaries, open into the lateral side of the anterior facial vein. They communicate with the infraorbital vein.

(f) The **superior labial** vein [v. labialis superior] and (g) the **inferior labial** vein [v. labialis inferior] arise from venous plexuses in the upper and lower lips. They run laterally to open into the medial side of the facial vein.

(h) The **masseteric** veins [vv. massetericæ] and (i) the **anterior parotid** veins [vv. parotidæ anteriores], of small size, drain the cheek over the masseteric and parotid regions.

(j) The **palatine** vein [v. palatina] accompanies the ascending palatine or tonsillar artery from the venous plexus about the tonsil and soft palate, and joins the anterior facial vein just below the body of the mandible.

(k) The **submental** vein [v. submentalis] lies on the mylohyoid muscle superficial to the submental artery. Running back in the submental triangle, it joins the anterior facial vein just after the latter has passed over the body of the mandible. It communicates with the anterior jugular vein.

Communications.—The tributaries of the anterior facial vein communicate freely with the anterior and middle temporal, ophthalmic, infraorbital and anterior jugular veins. The main trunk has a large communicating branch with the pterygoid plexus. This vein, sometimes known as the deep facial, opens into the anterior facial below the zygomatic bone under cover of the zygomaticus muscle.

B. The Posterior Facial Vein

The **posterior facial** (temporomaxillary) vein [v. facialis posterior] (figs. 552, 562) is formed in the region of the root of the zygoma by the union of the superficial and middle temporal veins. It passes downward behind the ramus of the mandible through the substance of the parotid gland—here lying lateral to the superficial temporal and external carotid arteries. At the angle of the mandible it runs medially and somewhat forward, and, passing either deep or superficial to the stylohyoid and digastric muscles, joins the anterior facial to form the common facial vein.

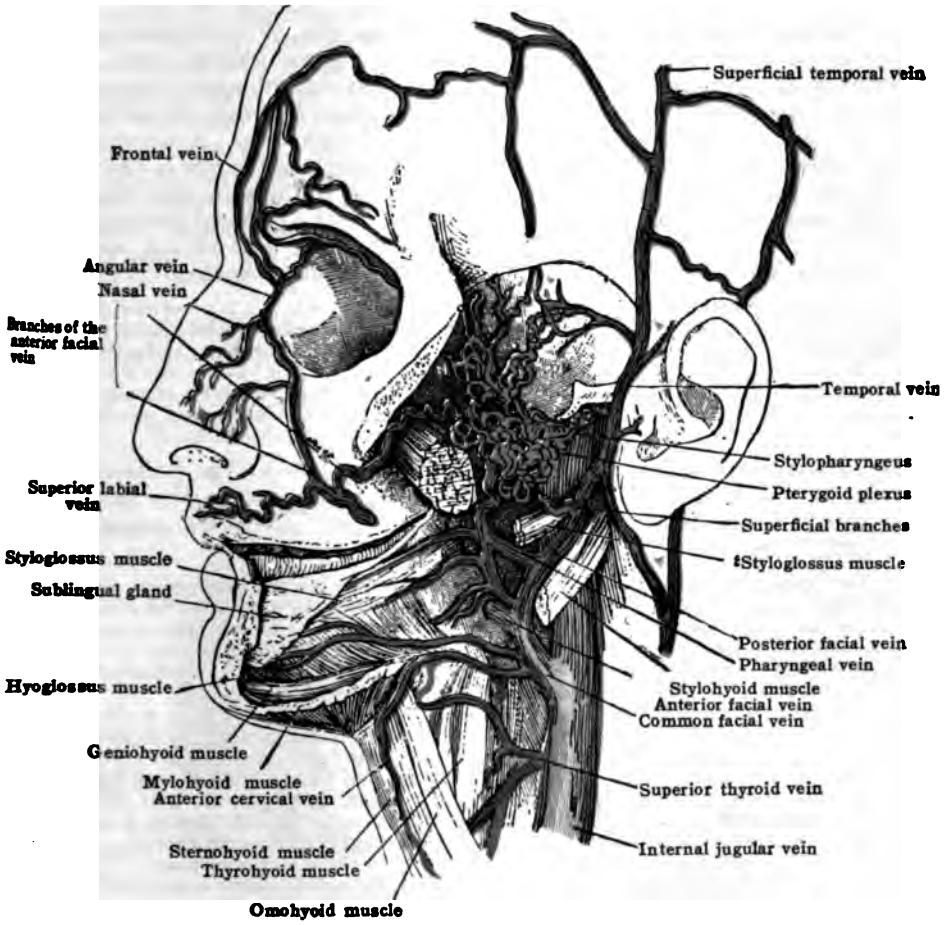
The **tributaries** received by the posterior facial vein are:—(a) the superficial temporal veins; (b) the middle temporal vein; (c) the transverse facial vein; (d) the articular veins; (e) the posterior parotid veins; (f) the anterior auricular veins; (g) the stylomastoid vein; and (h) the internal maxillary vein through which occurs the principal drainage of the pterygoid plexus.

(a) The **superficial temporal** vein [v. temporalis superficialis] returns the blood from the parietal region of the scalp. It is formed by the union of an anterior and a posterior branch: the former communicates with the supraorbital and frontal veins; the latter with the posterior auricular and occipital veins and the temporal vein of the opposite side. These branches lie superficial to the corresponding branches of the superficial temporal artery, which they roughly though not accurately follow. Like the artery, they lie between the skin and the galea aponeurotica, and descend over the temporal fascia to unite a little above the zygoma, and just in front of the auricle, to form the superficial temporal trunk. The vein thus formed continues its course downward with the trunk of the temporal artery, and opposite the zygoma is joined by the middle temporal vein to form the common temporal vein.

(b) **The middle temporal** vein [v. temporalis media] corresponds to the orbital branch of the temporal artery, and communicates in front with the ophthalmic vein, the external palpebral veins, and the infraorbital veins, and then runs backward between the layers of the temporal fascia to join the superficial temporal vein. The middle temporal vein communicates with the deep temporal veins, and through them with the pterygoid venous plexus.

(c) **The transverse facial** vein [v. transversa faciei] corresponds to the transverse facial artery. (d) **Articular** veins [vv. articulares mandibulæ] form the plexus around the temporomandibular joint; this plexus receives the **tympanic** veins [vv. tympanicæ], which, together with the corresponding artery, passes through the petrotympanic fissure. (e) **Posterior parotid** veins [vv. parotideæ posteriores] emerge from the substance of the parotid gland. (f) **Anterior auricular** veins [vv. auriculares anteriores], from the auricle. (g) **Stylomastoid** vein [v. stylomastoidea] from the facial canal. (h) The **internal maxillary** vein accompanies the first part of the internal maxillary artery. It begins at the posterior confluence of the veins forming the pterygoid pelxus, and passes backward between the stylomandibular ligament and the neck of the mandible. It ends by joining the posterior facial vein.

FIG. 553.—THE INTERNAL JUGULAR VEIN. (After Henle.)



The pterygoid plexus [plexus pterygoideus] is formed by the veins which correspond to the branches of the internal maxillary artery. It is situated, partly on the medial surface of the internal pterygoid muscle, and partly around the external pterygoid muscle. The veins entering into this plexus are:—the two **middle meningeal** veins [vv. meningeæ mediæ], which accompany the artery of that name; the **posterior superior alveolar** (dental); the **inferior alveolar** (dental); the **masseteric; the buccal;** the pterygoid veins from the pterygoid muscles; the **deep temporal** veins [vv. temporales profundæ], by which the plexus communicates with the temporal plexus; the **sphenopalatine** vein; the **infraorbital;** the **superior palatine;** a branch of communication with the lower branch of the **ophthalmic** vein, which courses through the inferior orbital (sphenomaxillary) fissure; and the **rete foraminis ovalis** and **Vesalian** vein, through which the plexus communicates with the cavernous sinus. The plexus ends posteriorly in the internal maxillary vein, which joins the posterior facial vein, and anteriorly in a communicating vessel (the deep facial vein), which passes forward and downward between the buccinator and masseter muscles to join the anterior facial vein.

The above-mentioned veins, forming by their confluence the pterygoid plexus correspond in their course so nearly with that of their companion arteries that a detailed description is not

necessary. Although for convenience described with the superficial veins, they are all deeply placed.

Near the angle of the mandible there is almost always a communicating branch between the posterior facial and the external jugular veins. When large, this branch may drain the greater part of the blood from the posterior facial.

C. The Common Facial Vein

The **common facial** vein [v. facialis communis] (fig. 552) is a short thick stem contained within the carotid triangle. It is formed, just below the angle of the mandible, by the union of the anterior and posterior facial veins. It ends opposite the hyoid bone, by opening into the internal jugular vein. In addition to the vessels which form it, sometimes it receives the superior thyroid, the pharyngeal, and the lingual or the sublingual veins.

D. The External Jugular Vein

The **external jugular** vein [v. jugularis externa] (fig. 52) is formed by the confluence of the posterior auricular and a short communicating trunk from the posterior facial near the angle of the mandible. It runs obliquely downward and backward across the sternomastoid muscle to a point opposite the middle of the clavicle, where it terminates as a rule in the subclavian vein. A line drawn from a point midway between the mastoid process and angle of the jaw to the middle of the clavicle will indicate its course. It is covered by the skin, superficial fascia, and platysma, and is crossed by a few branches of the cervical plexus, the great auricular nerve running parallel with it at the upper part of the neck. It is separated from the sternomastoid by the anterior layer of the deep cervical fascia.

Just above the clavicle it perforates the cervical fascia, by which it is prevented from readily collapsing, the fascia being attached to its walls. It then opens into the subclavian vein, occasionally into the internal jugular, or into the confluence of the subclavian and internal jugular veins. It contains a pair of valves about 2.5 to 5 cm. (1 to 2 in.) above the clavicle, and a second pair where it enters the subclavian vein. Neither of these valves is sufficient to prevent the blood from regurgitating, or injections from passing from the larger vein into the external jugular.

Tributaries and communications.—These include:—(a) The posterior auricular vein; (b) the occipital vein; (c) a branch of communication with the posterior facial vein; (d) the posterior external jugular vein; (e) the transverse scapular vein; and (f) the anterior jugular vein.

(*a*) The **posterior auricular** vein [v. auricularis posterior] begins in a venous plexus on the posterior part of the parietal bone. This plexus communicates with the vein of the opposite side across the sagittal suture, and with the posterior branch of the superficial temporal vein in front, and with the occipital vein behind. It descends over the back part of the parietal bone and the mastoid process of the temporal bone, lying with its artery behind the ear, and joins a branch from the posterior facial vein to form the external jugular.

(*b*) The **occipital** vein [v. occipitalis] begins at the back of the skull in a venous plexus which anastomoses with the posterior auricular and the posterior branch of the superficial temporal veins. It passes downward over the occipital bone, and usually perforates the trapezius with the occipital artery, to join a plexus drained by the deep cervical and vertebral veins. It also communicates with the posterior auricular, and in many cases this forms the chief path of drainage. One of its branches, usually the most lateral, receives a mastoid emissary vein [emissarium mastoideum] which issues through the mastoid foramen of the temporal bone, and in this way forms a communication with the transverse sinus.

(*c*) The branch of **communication with the posterior facial** vein occurs a short distance below the point at which the posterior facial receives the internal maxillary vein. It is very constant and is placed immediately behind the angle of the mandible. Through it the external jugular usually receives a considerable proportion of the blood returning from the temporal and pterygoid regions.

(*d*) The **posterior external jugular** vein (fig. 552) descends from the upper and back part of the neck, receiving small tributaries from the superficial structures and muscles. At times it communicates with the occipital, or may appear as a continuation of that vein. It opens into the external jugular as the latter vein is leaving the sternomastoid muscle.

(*e*) The **transverse scapular** vein [v. transversa scapulæ] corresponds to the transverse scapular (suprascapular) artery. If double, these venæ comitantes usually form one trunk before they open into the external jugular vein. They contain well-marked valves.

(*f*) The **anterior jugular vein** [v. jugularis anterior] begins below the chin by communicating with the mental, submental, inferior labial, and inferior hyoid veins. It descends a little lateral to the middle line, receiving branches from the superficial structures at the front and side of the neck, and occasionally a branch from the larynx and thyroid body. Just above the clavicle it turns laterally, and, piercing the fascia, passes beneath the sternomastoid muscle and opens into the external jugular vein just before the latter joins the subclavian; at times it opens into the subclavian vein itself. In its course down the neck it communicates with the

external jugular; and, as it turns laterally beneath the sternomastoid, sends a branch across the trachea, between the layers of cervical fascia, to join the anterior jugular of the opposite side. This communicating vein, the **jugular venous arch** [arcus venosus juguli], may open directly into the external jugular or into the internal jugular vein; occasionally one or both ends may open into the subclavian or innominate vein. It may be divided in the operation of tracheotomy, and is then often found greatly engorged with blood. Another branch, often of considerable size, courses along the anterior margin of the sternomastoid and joins the anterior facial vein. When the anterior jugular vein is large, the external jugular is small, and *vice versa*. It is usually also of large size when the corresponding vein on the opposite side is absent, as is frequently the case. It contains no valves.

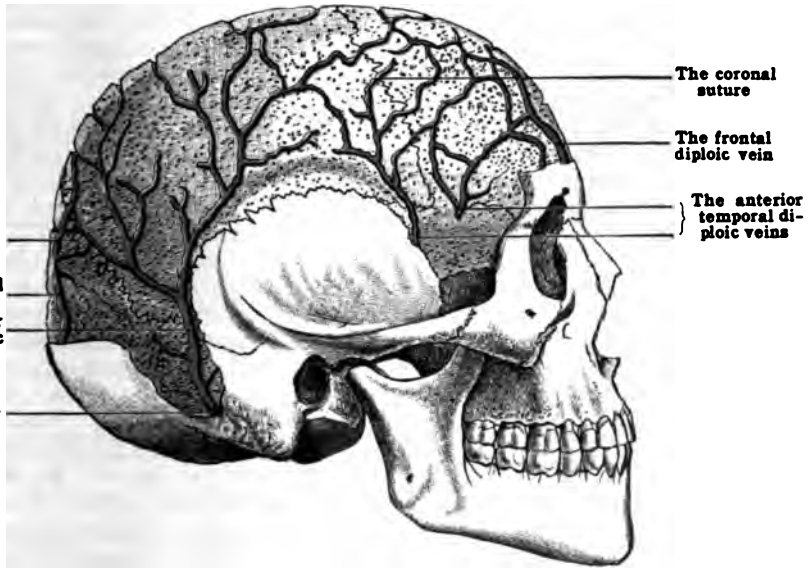
THE DEEP VEINS OF THE HEAD AND NECK

The **deep veins of the head and neck** may be divided into:—(1) the veins of the diploë; (2) the venous sinuses of the dura mater encephali; (3) the veins of the brain; (4) the veins of the nasal cavities; (5) the veins of the ear; (6) the veins of the orbit; (7) the veins of the pharynx and larynx; and (8) the deep veins of the neck. The veins of the diploë terminate partly in the superficial veins already described, partly in the venous sinuses of the cranium, and partly in the deep veins of the neck. The venous sinuses open into the deep veins of the neck. The veins of the brain terminate in the venous sinuses. The veins of the nasal cavities terminate partly in the deep, and to some extent in the superficial veins. The veins of the ear join both the superficial and deep veins and the venous sinuses. The veins of the orbit terminate partly in the superficial veins, but chiefly in the venous sinuses. The veins of the pharynx and larynx enter the deep veins of the neck.

1. THE VEINS OF THE DIPLOË

The **veins of the diploë** [venæ diploicæ] (fig. 554) are contained in bony channels in the cancellous tissue between the external and internal laminæ of the

FIG. 554.—THE VEINS OF THE DIPLOË
(From a specimen in St. Bartholomew's Hospital Museum).



cranium. They are of comparatively large size, with very thin and imperfect walls, and form numerous irregular communicating channels. They have no valves. They terminate in four or five main and descending channels, which open, some outward through the external cranial lamina into some of the superficial and deep veins of the head and face, and some inward through the internal lamina into the venous sinuses. They are divided into the frontal, anterior temporal, posterior temporal, and occipital.

The **frontal diploic veins** are contained in the anterior part of the frontal bone. They converge anteriorly to a single vein [v. diploica frontalis] which passes downward, perforates the

external table through a small aperture in the roof of the supraorbital notch, and terminates in the supraorbital vein. They also communicate with the superior sagittal sinus.

The **anterior temporal diploic veins** [v. diploica temporalis ant.] are contained in the posterior part of the frontal and in the anterior part of the parietal bone. They pass downward, and end, partly in the temporal veins by perforating the greater wing of the sphenoid bone, and partly in the sphenoparietal sinus.

The **posterior temporal diploic vein** [v. diploica temporalis post.] ramifies in the parietal bone, and coursing downward to the posterior inferior angle of that bone, passes either through a foramen in its inner table, or through the mastoid foramen into the transverse sinus.

The **occipital diploic vein** [v. diploica occipitalis] ramifies chiefly in the occipital bone, and opens into the occipital vein or into the transverse sinus.

The diploic veins freely anastomose with one another in the adult; but in the fetus, before the bones have united, each system of veins is distinct.

2. THE VENOUS SINUSES OF THE DURA MATER

The **venous sinuses of the dura mater** [sinus duræ matris] are endothelial-lined blood-spaces, situated between the periosteal and meningeal layers of the dura mater. They are the channels by which the blood is conveyed from the cerebral veins, and from some of the veins of the meninges and diploë, into the veins of the neck. The sinuses at the base of the skull also carry the chief part of the blood from the orbit and eyeball to the jugular veins. In certain places the sinuses communicate with the superficial veins by small vessels known as the emissary veins, which run through foramina in the cranial bones.

The venous sinuses are sixteen in number, six being median and unpaired, the remaining ten consisting of five lateral pairs. The median sinuses are:—(1) the superior sagittal; (2) the inferior sagittal; (3) the straight; (4) the occipital; (5) the circular; and (6) the basilar plexus. The lateral and paired sinuses are:—(7) the two transverse; (8) the two superior petrosal; (9) the two inferior petrosal; (10) the two cavernous; and (11) the two sphenoparietal. Occasionally there are two additional sinuses, the two petrosquamous.

(1) The **superior sagittal** (or longitudinal) **sinus** [sinus sagittalis superior] (fig. 556) lies in the median groove on the inner surface of the cranium along the attached margin of the falx cerebri. It extends from the foramen cecum to the internal occipital protuberance. It grooves from before backward the frontal bone, the contiguous sagittal margins of the parietal bones, and the squamous portion of the occipital bone. In the fetus, and occasionally in the adult, it communicates (through the foramen cecum) with the nasal veins. It communicates throughout life with each superficial temporal vein by means of a **parietal emissary** vein [emissarium parietale] which passes through the parietal foramen. It is triangular on section, the base of the triangle corresponding to the bone. Crossing it are a number of fibrous bands known as the *chords of Willis*, and projecting into it in places are the arachnoidal (Pacchionian) granulations. The parts of the sinus into which the arachnoidal granulations project are irregular lateral diverticula from the main channel known as the *lacunæ laterales* (fig. 558). In front the sinus is quite small, but it increases greatly in caliber as it runs backward. It receives at intervals the superior cortical cerebral veins and the veins from the falx. The former, for the most part, open into it in the direction opposite to that in which the blood is flowing in the sinus. They pass for some distance in the walls of the sinus before opening into it. Posteriorly, at the internal occipital protuberance, the superior sagittal sinus usually turns sharply to the right, and ends in the right transverse (lateral) sinus. In such cases the straight sinus usually terminates in the left transverse (lateral) sinus.

Occasionally, however, the superior sagittal sinus ends in the left transverse sinus, the straight then passing into the right. At the angle of union between the superior sagittal sinus and the transverse sinus into which it empties there is a dilation, the **confluens sinuum** or torcular Herophili. At this point there is a communication between the right and left transverse sinuses. In some cases the communication is so free that the blood from the sagittal sinus flows almost equally into each transverse sinus. The confluens may communicate with the occipital vein through the occipital emissary vein [emissarium occipitale], which, when present passes through a minute foramen in the occipital protuberance.

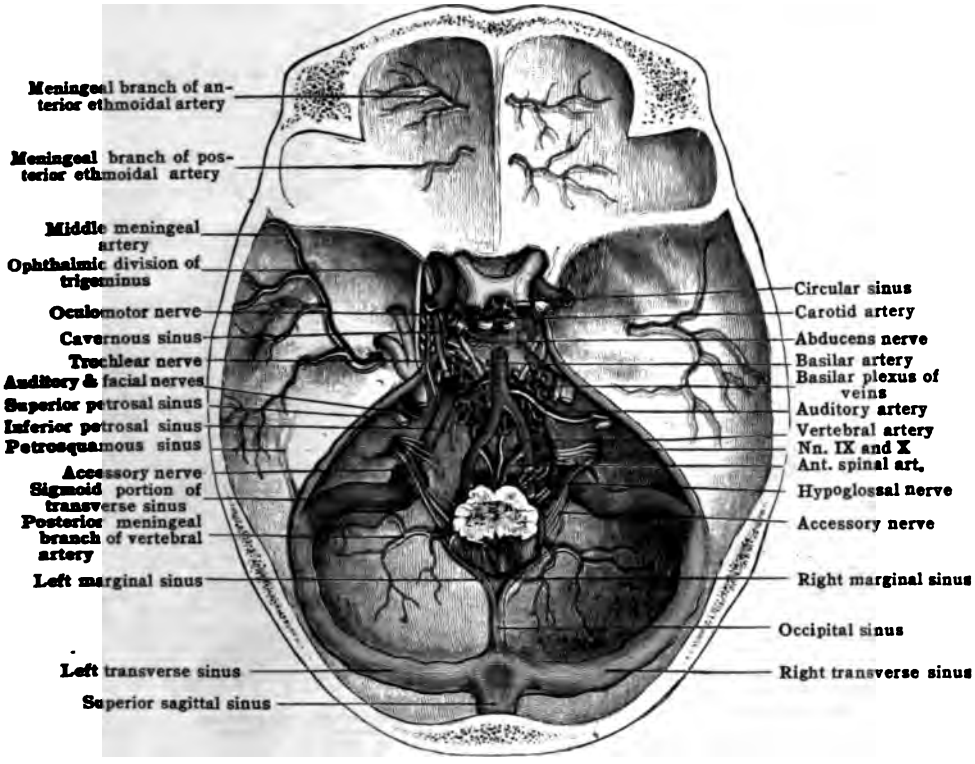
(2) The **inferior sagittal** (or longitudinal) **sinus** [sinus sagittalis inferior] (fig. 556) is situated at the free margin of the falx cerebri. Beginning about the junction of the anterior with the middle third of the falx, it is continued backward along the concave or lower margin of that process to the junction of the falx with the tentorium, where it ends in the straight sinus. The sinus is cylindrical in

shape and of small size, and receives some of the inferior frontal veins of the brain, some of the veins from the medial surface of the brain, and some of the veins of the falx.

(3) The **straight sinus** [sinus rectus] (fig. 556) lies along the junction of the falx cerebri with the tentorium cerebelli. It is formed by the union of the great cerebral vein (of Galen) and the inferior sagittal sinus. It receives in its course branches from the tentorium cerebelli and from the upper surface of the cerebellum. It runs downward and backward to the internal occipital protuberance, where it ends in the transverse sinus opposite to that joined by the superior sagittal sinus. On section it is triangular in shape, with its apex upward.

(4) The **occipital sinus** [sinus occipitalis] (fig. 555) ascends at the attached margin of the falx cerebelli, along the lower half of the squamous portion of the occipital bone from near the posterior margin of the foramen magnum to the internal occipital protuberance. It usually begins in a right and a left branch, known as the **marginal sinuses.**

FIG. 555.—THE VENOUS SINUSES IN THE CRANIAL FLOOR
(From a dissection by W.J. Walsham in St. Bartholomew's Hospital Museum)



These proceed from the termination of each transverse sinus, run around the foramen magnum where they communicate with the venous vertebral retia, and unite at a variable distance from the internal occipital protuberance to form the single occipital sinus. Sometimes they remain separate as far as the occipital protuberance, then forming two occipital sinuses. At the point where the marginal sinuses unite to form the single occipital sinus, there is a communication with the venous vertebral retia. The occipital sinus ends in the confluens sinuum. It receives in its course veins from the tentorium cerebelli, and from the inferior surface of the cerebellum. It communicates through the plexus of veins which surrounds the hypoglossal nerve [**rete canalis hypoglossi**] in the hypoglossal (anterior condyloid) canal with the vertebral vein and the longitudinal vertebral venous sinuses.

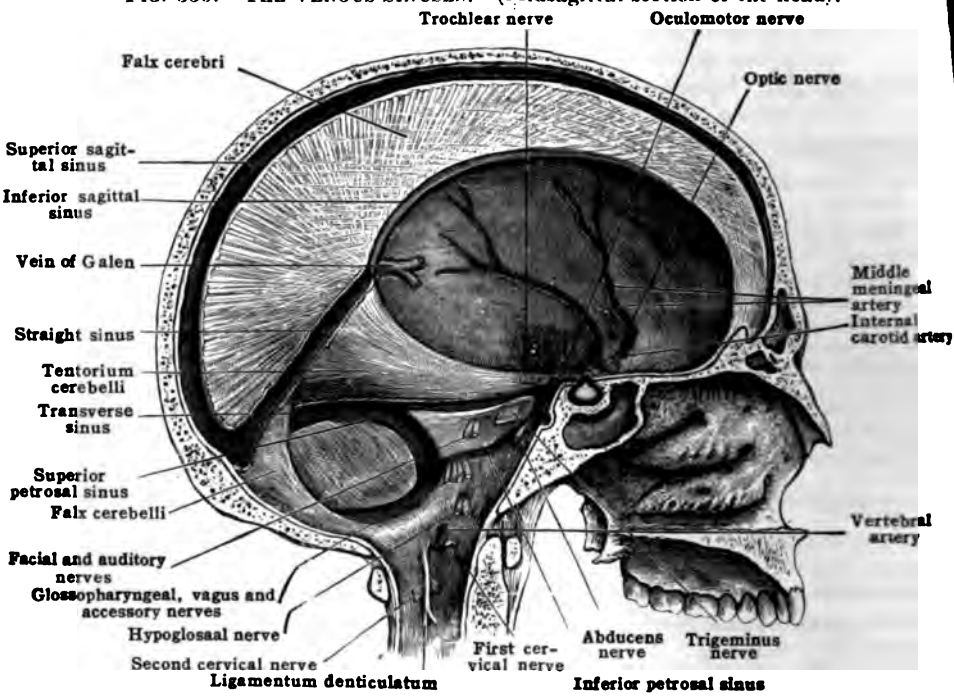
(5) The **circular sinus** [sinus circularis] (fig. 557) encircles the hypophysis cerebri. It consists of the two cavernous sinuses and their communications across the median line by means of the **anterior and posterior intercavernous sinuses.** The intercavernous sinuses are small and cross the median line in front of and behind the hypophysis, respectively.

(6) The **basilar plexus** [plexus basilaris] is a venous plexus in the substance of the dura mater over the basilar part of the occipital bone. It extends from

the cavernous sinus to the margin of the foramen magnum below. It communicates laterally with the inferior petrosal sinus, and inferiorly with the internal vertebral venous plexuses. One of the larger of the irregular venous channels forming the plexus passes transversely from one inferior petrosal sinus to the other. This venous plexus is serially homologous with the longitudinal vertebral venous sinuses on the posterior surfaces of the bodies of the vertebræ.

(7) The **transverse** (or lateral) **sinus** [sinus transversus] (figs. 555–557) extends from the internal occipital protuberance to the jugular foramen. In this course it lies in the corresponding groove along the squamous portion of the occipital bone, the mastoid angle of the parietal bone, the mastoid portion of the temporal bone, and the jugular process of the occipital bone. It at first runs laterally and forward horizontally between the two layers of the tentorium cerebelli, following the curve of the groove on the occipital and on the mastoid angle of the parietal bone. On reaching the groove in the mastoid portion of the temporal bone it leaves the tentorium and curves medially and downward and then forward over the jugular process of the occipital bone, and ends at the jugular fossa in the superior bulb of the internal jugular vein. The S-shaped part of the sinus which lies on the mastoid portion of the temporal and jugular portion of the occipital bone is sometimes known as the **sigmoid sinus.**

FIG. 556.—THE VENOUS SINUSES. (Midsagittal section of the head).



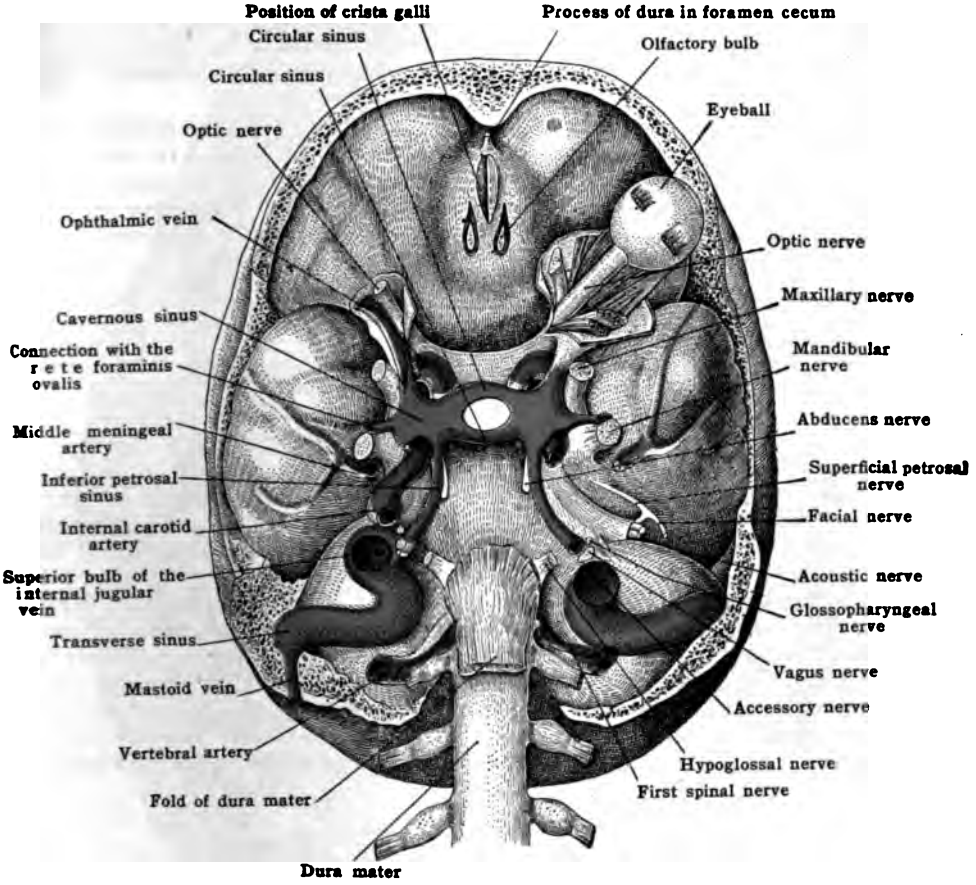
The transverse sinus receives from the labyrinth, the **internal auditory veins** [vv. auditivæ internæ] which emerge from the internal auditory meatus. It also receives veins from the temporal lobe of the cerebrum, some of the superior and inferior cerebellar veins, some of the veins of the medulla and pons, the occipital, and the posterior temporal and occipital veins of the diploë. At the point where it leaves the tentorium it drains the superior petrosal sinus and, when present, the petrosquamous sinus. It communicates with the occipital and vertebral veins through the mastoid and posterior condyloid foramina by means of the mastoid and condyloid emissary veins. As the transverse sinus lies between the layers of the tentorium it is on section prismatic in shape. The sigmoid portion is semicylindrical.

The right transverse sinus is usually the larger and the direct continuation of the superior sagittal sinus, and hence conveys the chief part of the blood from the cortical surface of the brain and vault of the skull. The left transverse sinus is usually the smaller and the direct continuation of the straight sinus, and hence returns the chief part of the blood from the central ganglia of the brain. The right and left sinuses communicate opposite the internal occipital protuberance.

The relation of the lateral sinus to the outside of the skull, especially to the mastoid process of the temporal bone, is of importance with reference to operations in this region. The course of the sinus corresponds to a line drawn from the external occipital protuberance to the base of the mastoid process, or to the asterion, and thence over the back of the mastoid process in a curved line toward its apex.

(8) The **superior petrosal sinus** [sinus petrosus superior] (figs. 555, 556) runs at the attached margin of the tentorium cerebelli, along the upper border of the petrous portion of the temporal bone. It connects the cavernous with the transverse sinus. Leaving the lateral and back part of the cavernous sinus just below the trochlear nerve, it crosses the trigeminus nerve, and, after grooving the petrous bone, ends in the transverse sinus as the latter turns downward on the mastoid portion of the temporal bone. It receives veins from the temporal lobe of the cerebrum, veins from the cerebellum, veins from the tympanum through the squamopetrosal fissure, and sometimes the anterior temporal veins of the diploë.

FIG. 557.—THE VENOUS SINUSES AT THE BASE OF THE BRAIN. The dura mater has not been removed. (After Toldt, 'Atlas of Human Anatomy', Rebman, London and New York).



(9) The **inferior petrosal sinus** [sinus petrosus inferior] (figs. 555–557) runs posteriorly from the cavernous sinus along the line of the petro-occipital suture, and passes through the jugular foramen to terminate in the commencement of the internal jugular vein. It is shorter than the superior petrosal, but considerably wider.

As it crosses the anterior compartment of the jugular foramen, it separates the glossopharyngeal from the vagus and accessory nerves. It receives veins from the inferior surface of the cerebellum, from the medulla and pons, and from the internal ear. The **vein of the cochlear canaliculus** [v. canaliculi cochleæ], issues through the canaliculus cochleæ and terminates in the lower part of the inferior petrosal sinus or the adjacent part of the internal jugular vein.

(10) **The cavernous sinus** [sinus cavernosus] (fig. 557) is an irregularly shaped venous space situated between the meningeal and periosteal layers of the dura mater on the side of the body of the sphenoid bone. It extends from the medial end of the superior orbital (sphenoidal) fissure in front to the apex of the petrous bone behind. Its lateral wall is the more distinct, and contains the oculomotor

and trochlear nerves, and the ophthalmic division of the trigeminus. The nerves take the above-mentioned order from above downward, and in the mediolateral direction. The internal carotid artery and the abducens nerve also pass through the sinus, being separated from the blood by the endothelial lining. The right and left cavernous sinuses communicate across the middle line with the opposite sinus in front and behind the hypophysis cerebri as before mentioned.

The cavernous sinus is traversed by numerous trabeculæ or fibrous bands, so that there is no central space, but rather a number of endothelial-lined irregular lacunar cavities communicating one another. Hence its name cavernous, from its resemblance to cavernous tissue. **In front** it receives the ophthalmic vein, with which it is practically continuous, and just above the third nerve, the sphenoparietal sinus. **Medially** it communicates with the opposite sinus, and **posteriorly** it ends in the superior and inferior petrosal sinuses. It also receives veins from the inferior surface of the frontal lobe of the brain, and some of the middle cerebral veins. Through the Vesalian vein, which occasionally perforates the greater wing of the sphenoid bone the sinus communicates with the pterygoid plexus of veins; through the **venous plexus around the petrosal portion of the internal carotid** [plexus venosus caroticus internus], with the internal jugular vein; and through a venous rete which leaves the cranium by the foramen ovale [rete foraminis ovalis] and by small veins passing through the foramen lacerum medium, with the pterygoid and pharyngeal plexuses.

(11) The **sphenoparietal sinus** [sinus sphenoparietalis] runs in a slight groove on the inferior surface of the lesser wing of the sphenoid bone. It originates in one of the meningeal veins near the apex of the lesser wing, and, running medially, passes through the sphenoidal fold of dura mater above the oculomotor nerve into the front part of the cavernous sinus. It generally receives the anterior temporal veins from the diploë.

The **petrosquamous sinus** is occasionally present. It lies in a groove which separates the anterior surface of the petrous from the cerebral surface of the squamous portion of the temporal bone. It opens posteriorly into the transverse sinus at the spot where the latter enters on its sigmoid course. In front it sometimes communicates, through a foramen between the mandibular fossa and the external acoustic meatus, with the deep temporal vein.

3. THE VEINS OF THE BRAIN

The **veins of the brain** present the following peculiarities:—(*a*) They do not accompany the cerebral arteries. (*b*) Ascending veins do not, as in other situations, run with descending arteries, but with ascending arteries, and *vice versa*. (*c*) The deep veins do not freely communicate. (*d*) The veins have very thin walls, no muscular coat, and no valves. (*e*) The veins opening into the sagittal and some of those opening into the transverse (lateral) sinus pour in their blood in a direction opposite to the current in the sinuses, so impeding the flow in both vein and sinus. (*f*) The flow of blood in the sinuses is further retarded by the trabeculæ stretching across their lumen, and in the sagittal sinus by the blood having to ascend, when the body is erect, through the anterior half of its course.

The veins of the brain may be divided into the **cerebral** and the **cerebellar.**

The Cerebral Veins

The **cerebral** veins, like the cerebral arteries, may be divided into the **cortical** and the **central.**

The **cortical** or **superficial** veins ramify on the surface of the brain and return the blood from the cortical substance into the venous sinuses. They lie for the most part in the sulci between the gyri, but some pass over the gyri from one sulcus to another. They consist of two sets: a superior and an inferior.

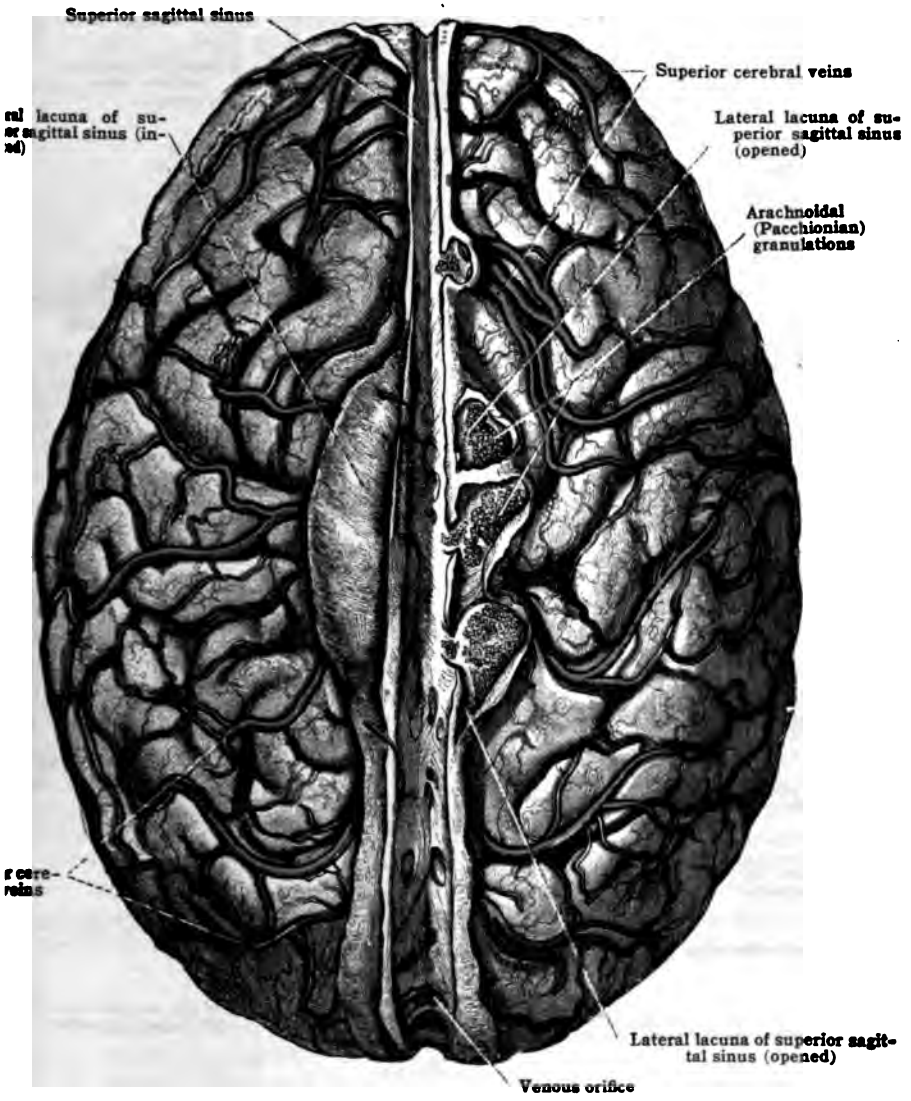
(1) The **superior cerebral** veins [venæ cerebri superiores] (fig. 558), some eight to twelve in number on each side, are formed by the union of branches from the convex and medial surfaces of the cerebrum. Those from the convex surface pass medially and forward toward the longitudinal fissure, where they are joined by the branches coming from the medial surface. After receiving a sheath from the arachnoid, they enter obliquely into the superior sagittal sinus, running for some distance in its walls. These veins freely communicate with each other, thus differing from the cortical arteries. They also communicate, with the inferior cortical veins. They may be roughly divided into (*a*) frontal; (*b*) paracentral; (*c*) central; (*d*) occipital.

(2) The **inferior cerebral** veins [venæ cerebri inferiores] (fig. 559), ramify on the base of the hemisphere and the lower part of its lateral surface. Those on the inferior surface of the frontal lobe pass, in part into the inferior sagittal sinus, and in part into the cavernous sinus. Those on the temporal lobe enter in part into the superior petrosal sinus, and in part into the transverse sinus, passing into the latter from before backward. A large vein from the occipital

winds over the cerebral peduncle and joins the great cerebral vein (of Galen) just before latter enters the straight sinus. One of the inferior cortical veins is called the **middle eral vein** [v. cerebi media], it runs in the lateral fissure (of Sylvius) and ends in the cavernous sinus. This vein is sometimes called the superficial Sylvian vein. Another, the great anastomosing vein of Trolard, establishes a communication between the superior sagittal and cavernous sinuses by connecting the middle cerebral veins with one of the superior cerebral veins. A second anastomotic vein, that of Labbé, is also a tributary of the middle cerebral, and connects the veins over the temporal lobe with the transverse sinus.

The small inferior cerebral vein, the **ophthalmomeningeal vein**, establishes a communication between the cerebral veins and those of the orbit. It communicates with the veins of the base

558.—THE VEINS OF THE BRAIN, SUPERIOR SURFACE. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York).


Superior sagittal sinus
Superior cerebral veins
Lateral lacuna of superior sagittal sinus (opened)
Arachnoidal (Pacchionian) granulations
Lateral lacuna of superior sagittal sinus (opened)
Venous orifice

usually drained by the superior ophthalmic vein. It occasionally opens into the superior **al sinus.**

he central or deep (ganglionic) veins return blood from the internal parts of erebrum, and converge to the great cerebral vein.

The internal cerebral veins [vv. cerebri internæ] are two large venous trunks (the venæ i) which leave the brain at the transverse fissure, that is, between the splenium of the **callosum** and the corpora quadrigemina. In this region they unite to form the **great al vein** [v. cerebri magna, Galeni], which opens into the anterior end of the straight

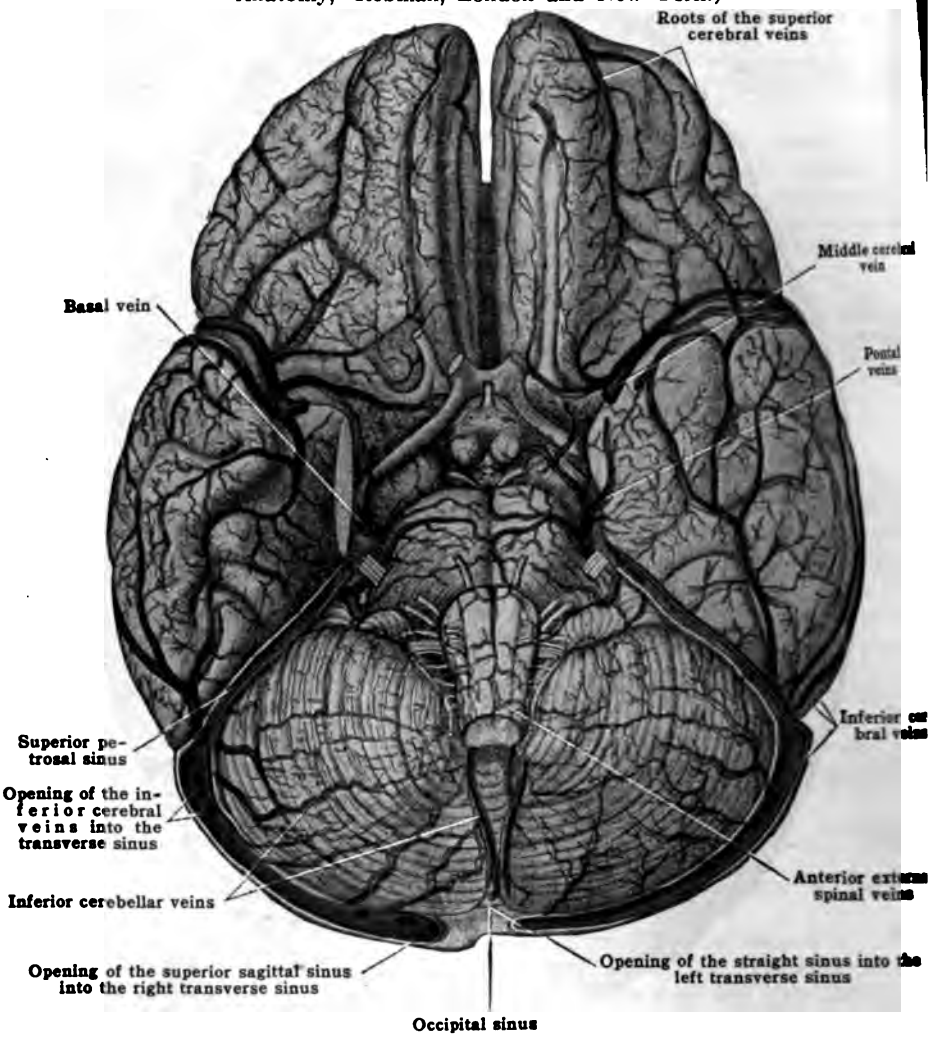
The internal cerebral veins are formed by the union of the choroid vein with the vena

terminalis near the interventricular foramen. From this spot they run backward parallel to each other, between the layers of the tela chorioidea, and terminate in the way above mentioned.

Tributaries of the internal cerebral veins.—In addition to the vena terminalis and the chorioidal, the internal cerebral veins also receive the basal vein, the veins of the thalamus, the veins of the choroid plexus of the third ventricle, and veins from the corpus callosum, the pineal body, the corpora quadrigemina, and posterior horn of the lateral ventricle. The united trunk or great cerebral vein, receives veins from the upper surface of the cerebellum, and one of the posterior inferior cerebral veins.

The **choroid** vein [v. chorioidea] runs with the chorioid plexus. It begins in the inferior cornu of the lateral ventricle, and ascends on the lateral side of the chorioid plexus along the margin of the tela chorioidea to the interventricular foramen, where it unites with the vena terminalis to form the internal cerebral vein. It receives tributaries from the hippocampus, corpus callosum, and fornix.

FIG. 559.—THE VEINS OF THE BRAIN, INFERIOR SURFACE. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)


Roots of the superior cerebral veins
Middle cerebral vein
Basal vein
Pontal veins
Inferior cerebral veins
Superior petrosal sinus
Opening of the inferior cerebral veins into the transverse sinus
Anterior external spinal veins
Inferior cerebellar veins
Opening of the superior sagittal sinus into the right transverse sinus
Opening of the straight sinus into the left transverse sinus
Occipital sinus

The **terminal** vein (or vein of the corpus striatum) [v. terminalis], formed by veins from corpus striatum and thalamus, runs forward in the groove between those structures, passes in its course beneath the stria terminalis, and joins the chorioid (choroid) vein at the interventricular foramen. **Tributaries.**—It receives, in addition to the veins from the corpus striatum, thalamus and fornix, the **vena septi pellucidi** which receives blood from the septum pellucidum, and anterior cornu of the lateral ventricle.

The **basal** vein [v. basalis], runs backward over the cerebral peduncle, and enters the internal cerebral vein near the union of that vessel with the vein of the opposite side.

Tributaries.—A vein, the deep Sylvian, from the insula and the opercular gyri; the inferior striate veins from the corpus striatum, which they leave through the anterior perforated substance; and the anterior cerebral veins from the front of the corpus callosum. It is also joined by interpeduncular veins from the structures in the interpeduncular space; ventricular veins from the inferior cornu of the lateral ventricle; and by mesencephalic veins.

The Cerebellar Veins

The cerebellar veins are divided into the **superior** and **inferior.**

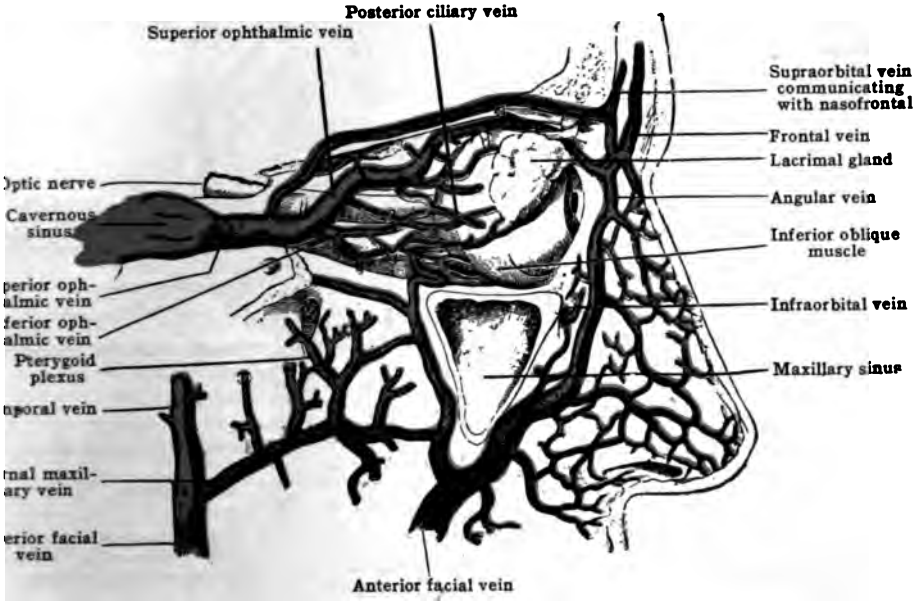
The superior [vv. cerebelli superiores] ramify on the upper surface of the cerebellum; some **them** run medially over the superior vermis to join the straight sinus and great cerebral ; others run laterally to the transverse and superior petrosal sinuses.

The inferior [vv. cerebelli inferiores], larger than the superior, run, some forward and **ally** to the inferior petrosal and transverse sinuses, and others directly backward to the **bital** sinus.

The Veins of the Medulla and Pons

The veins from the **medulla oblongata** and the **pons** terminate in the inferior **rosal** and transverse sinuses.

Fig. 560.—The Ophthalmic Veins. (After Quain).



4. THE VEINS OF THE NASAL CAVITIES

The venous plexuses on the inferior nasal concha (turbinate bone) and back **ne septum are described with the** Nose. The veins leaving the nasal cavities **ow roughly the** course of their corresponding arteries. Thus the spheno-**tine veins pass through** the sphenopalatine foramen into the pterygoid plexus; **anterior and posterior** ethmoidal veins join the ophthalmic. Small veins **ompany branches of** the external maxillary artery through the nasal bones and **ital processes of the maxillary** bones, and end in the angular and anterior facial **is; and other small veins pass** from the nose anteriorly into the superior labial, **thence to the anterior facial.**

5. THE VEINS OF THE EAR

The veins from the external ear and external acoustic meatus join the posterior **al and posterior auricular veins.** The veins from the tympanum open into **superior petrosal sinus and** posterior facial vein. The blood from the laby-**h flows chiefly through the internal auditory** veins [vv. auditivæ internæ], **ch accompany the internal** auditory artery in the internal acoustic meatus, and **ers the transverse or the** inferior petrosal sinus.

Some of the blood from the labyrinth, however, passes through the vestibular vein, which in the aqueductus vestibuli, into the inferior petrosal sinus. Some also passes through the canaliculi cochleæ which traverses the canal of the same name and empties into the commencement of the internal jugular vein or the terminal portion of the inferior petrosal sinus.

6. THE VEINS OF THE ORBIT

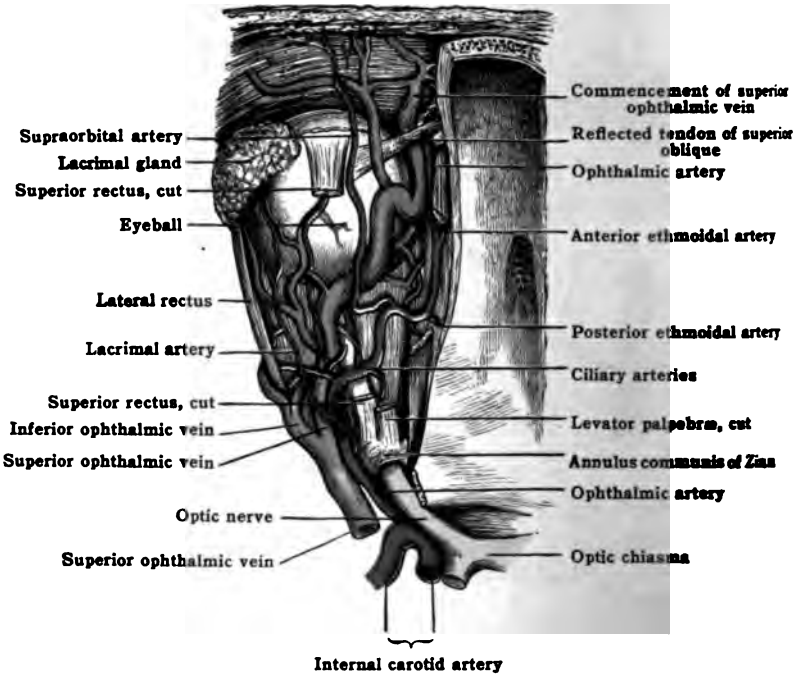
The blood from the eyeball and orbit is returned by the superior ophthalmic into the cavernous sinus. This vein and its tributaries have no valves, and

communicate with the frontal, supraorbital, inferior cerebral, and pterygoid veins (fig. 562).

Under certain conditions, as from pressure on the cavernous sinus, the blood may flow in the contrary direction to the normal—i.e., from behind forward into the frontal and supraorbital, and thence through the angular vein into the anterior facial; or upward into the cerebral venous system. In this way pressure on the retinal veins is quickly relieved, and little or no distension occurs in cases of obstruction in the cavernous sinus.

The **superior ophthalmic** vein [v. ophthalmica superior] (**fig. 561**) begins at the medial angle of the eyelid by a free communication with the frontal, supraorbital, and angular veins, and thence runs backward and laterally with the ophthalmic artery across the optic nerve to the medial end of the superior orbital (sphenoidal) fissure, where it is usually joined by the inferior ophthalmic vein. It then passes backward between the two heads of the lateral rectus muscle below the sixth nerve, leaves the orbit through the medial end of the superior orbital fissure and enters the anterior end of the cavernous sinus. In this course it is superficial to the ophthalmic artery.

FIG. 561.—THE VEINS OF THE ORBIT. (Superior View.)



Tributaries.—(1) The nasofrontal vein; (2) the superior muscular veins; (3) the veins of the lids and conjunctiva; (4) the ciliary veins; (5) the anterior and posterior ethmoidal veins; (6) the lacrimal vein; (7) the central vein of the retina; and (8) the inferior ophthalmic vein.

(1) The **nasofrontal** vein [v. nasofrontalis] begins by a free communication with the supraorbital vein and enters the orbit through the frontal notch or foramen. It frequently joins the superior ophthalmic vein quite far back in the orbit (see fig. 560).

(2) The **muscular** veins [vv. musculares] are derived from the levator palpebræ, superior rectus, superior oblique, and medial rectus.

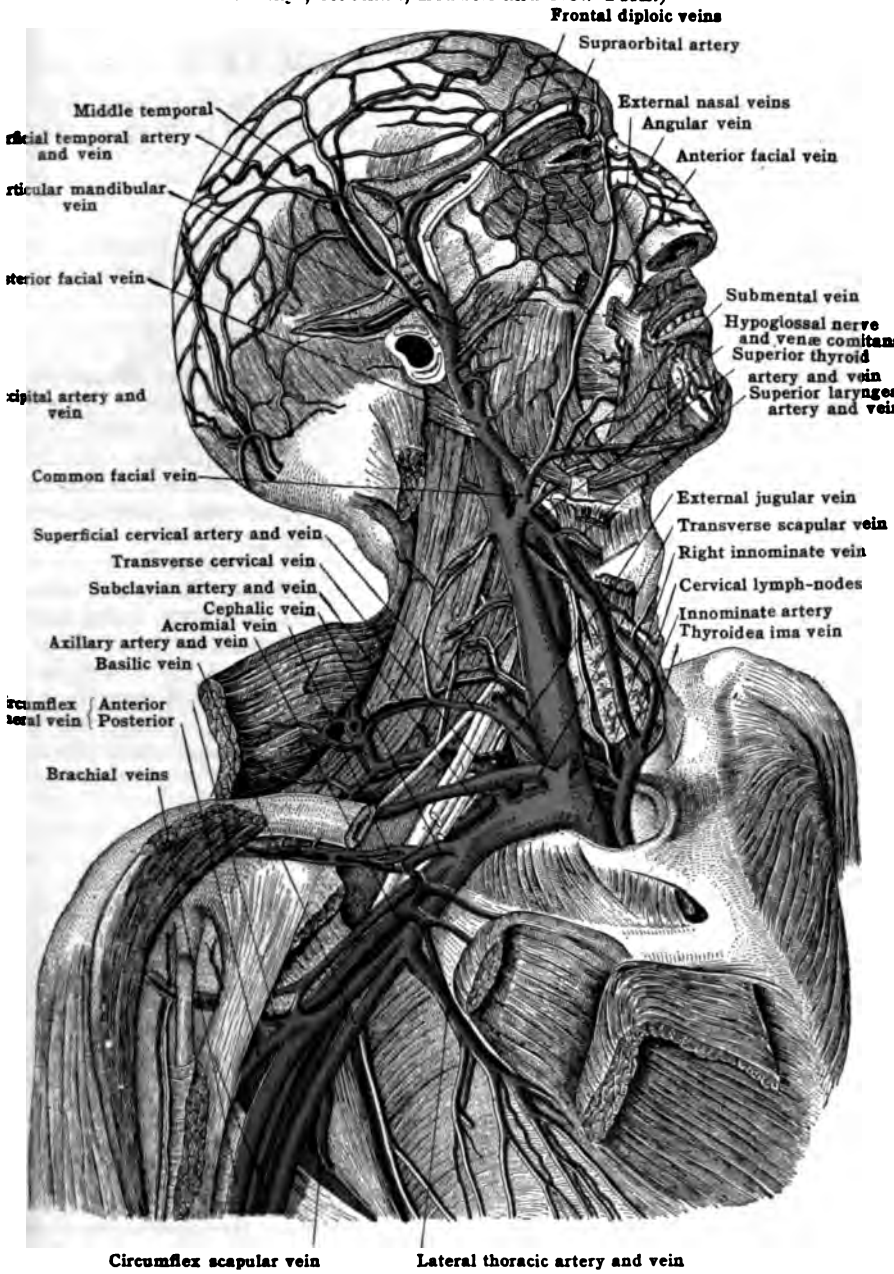
(3) The **palpebral** and **conjunctival** veins [vv. palpebrales; vv. conjunctivales ant. et post.], both anterior and posterior, open into the superior ophthalmic.

(4) The **ciliary** veins, the veins of the eyeball, are divided into anterior and posterior groups. The **anterior ciliary veins** [vv. ciliares ant.] emerge from the eyeball with the anterior ciliary arteries, and open into the muscular veins returning the blood from the four recti. They form a circumcorneal ring of episcleral veins [vv. episclerales]. The **posterior ciliary veins**, which drain the **venæ vorticosæ**, leave the globe midway between the cornea and the entrance of the optic nerve. The upper veins of this group end in the superior, and the lower in the inferior ophthalmic vein (fig. 560).

(5) The **anterior and posterior ethmoidal** veins [vv. ethmoidales ant. et post.], correspond in their course with the arteries of the same name. They enter the orbit through the anterior and posterior ethmoidal foramina, and join either the ophthalmic or one of superior muscular branches.

3) The **lacrimal** vein [v. lacrimalis] returns the blood from the lacrimal gland, and corre-
ds in its course to the lacrimal artery.
) The **central vein of the retina** [v. centralis retinæ] runs with the central artery in the
: nerve. It joins the superior ophthalmic at the back of the orbit.
8) The **inferior ophthalmic** vein [v. ophthalmica inferior], smaller than the superior, is
ed near the front of the orbit by the confluence of the inferior muscular with the lower

562.—The Veins of the Head, Neck, and Axilla. (After Toldt, 'Atlas of Human Anatomy', Rebman, London and New York.)



rior ciliary veins. It runs backward below the optic nerve, along the floor of the orbit **ither** joins the superior ophthalmic vein, or opens separately into the cavernous sinus. **ge** communicating branch passes downward through the inferior orbital (sphenomaxillary) **e** to join the pterygoid plexus of veins (fig. 560). It receives muscular twigs from the **or** and lateral rectus and from the inferior oblique, and some posterior ciliary veins.

7. THE VEINS OF THE PHARYNX AND LARYNX

The pharyngeal veins [vv. pharyngeæ] are arranged in the form of a plexus, **reen the constrictor** muscles and the prevertebral fascia. The **pharyngeal**

plexus receives branches from the mucous membrane, the pterygoid ca[nal] [vv. canalis pterygoidei] from the soft palate, the auditory (Eustachian) tube a[nd] the anterior recti and longus colli muscles. Above, it communicates with th[e] pterygoid plexus of veins; below it drains into the internal jugular vein.

The **veins of the larynx** end partly in the **superior laryngeal** vein [v. laryng[ea] superior], which opens into the internal jugular vein, and partly in the inferi[or] **laryngeal** vein [v. laryngea inferior], which terminates in the plexus thyroideus impar. The laryngeal plexus of veins communicates with the pharyngeal plexus.

8. THE DEEP VEINS OF THE NECK

The **deep veins of the neck** include the internal jugular, vertebral, deep cervical, inferior thyroid, thyroidea ima, thymic, tracheal, and esophageal veins.

The Internal Jugular Vein

The **internal jugular** vein [v. jugularis interna] begins at the jugular fossa, and is the continuation of the transverse sinus. It passes down the neck, in company first with the internal carotid artery and then with the common carotid artery, to a point a little lateral to the sternoclavicular articulation, where it joins the subclavian to form the innominate vein. At its commencement in the larger posterior and lateral part of the jugular foramen, it is somewhat dilated, forming the **superior bulb** of the jugular vein [bulbus v. jugularis superior]. This dilated part of the internal jugular vein lies in the jugular fossa of the temporal bone and is therefore in immediate relation to the floor of the tympanum. At first the internal jugular lies in front of the rectus capitis lateralis, and behind the internal carotid artery, from which it is separated by the hypoglossal, glossopharyngeal, and vagus nerves, and by the carotid plexus of the sympathetic. As it descends it passes gradually to the lateral side of the internal carotid, and retains this relation as far as the upper border of the thyroid cartilage. Thence it runs to its termination along the lateral side of the common carotid artery, being contained in the same sheath with it and the vagus nerve, but separated from these structures by a distinct septum. The vein generally overlaps the artery in front. About 2.5 cm. (1 in.) above its termination it contains a pair of imperfect valves below which a second dilation usually occurs in the vein. This, the **inferior bulb** [bulbus v. jugularis inferior], extends as low as the junction of the internal jugular with the subclavian. It not infrequently receives the termination of the external jugular vein.

Tributaries.—At the superior bulb the internal jugular vein receives the inferior petrosal sinus; the vein of the cochlear canaliculus (which may join the inferior petrosal sinus), and a meningeal vein; opposite the angle of the jaw, veins from the pharyngeal plexus, and often a communicating branch from the external jugular vein; opposite the bifurcation of the carotid it is joined by the common facial, and a little lower down by the lingual, sternomastoid, and the superior thyroid veins. At the level of the cricoid cartilage the internal jugular is joined by the middle thyroid when this vein is present.

The inferior petrosal sinus is described with the other sinuses of the brain (p. 687); the pharyngeal plexus with the veins of the pharynx (see p. 693); and the common facial vein with the superficial veins of the scalp and face (p. 682).

The **lingual** vein [v. lingualis], begins near the tip of the tongue, where it accompanies the arteria profunda linguæ. It lies at first beneath the mucous membrane covering the lower surface of the tongue. It then passes backward on the medial surface of the hyoglossus, in company with the lingual artery. After receiving the **sublingual vein** [v. sublingualis] and the **dorsal lingual** veins [vv. dorsales linguæ], which roughly correspond to their respective arteries, it is joined by the small **v. comitans nervi hypoglossi** which follows the upper border of the hypoglossal nerve. The trunk finally crosses the common carotid artery and opens into the internal jugular vein. The lingual vein communicates with the pharyngeal veins and with tributaries of the anterior facial. It occasionally terminates in the posterior or in the common facial vein. The **sternomastoid** vein [v. sternocleidomastoidea] accompanies the artery of the same name and empties into the internal jugular.

The **superior thyroid** vein [v. thyroidea superior] emerges from the upper part of the thyroid gland, in which it freely anastomoses with the other thyroid veins. This anastomosis, the **plexus thyroideus impar**, occurs both in the substance of the organ and on its surface beneath the capsule. The vein then passes upward and laterally into the internal jugular vein, crossing the common carotid artery in its course. At times it forms a common trunk with the common facial vein. Its tributaries are the sternohyoid, sternothyroid, and

roid veins from the muscles bearing those names; and the cricothyroid and superior al veins which correspond with the cricothyroid and superior laryngeal arteries ively. These require no special description.
eparate vein frequently passes out from the capsule of the thyroid gland near the lower the lateral lobe, crosses the common carotid, and opens into the main superior thyroid into the internal jugular vein a little below the cricoid cartilage. In the former case it ded as part of the superior thyroid vein system; in the latter it is generally known as the thyroid vein.

The Vertebral Vein

ie **vertebral** vein [v. vertebralis] does not accompany the vertebral artery in irth stage, that is, within the cranium, but begins in the posterior vertebral s plexus of the suboccipital triangle. It then enters the foramen in the erse process of the atlas, and passes with the vertebral artery through the ina in the transverse processes of the cervical vertebræ, forming a plexus d the artery. On leaving the transverse process of the sixth cervical verte- crosses in front of the subclavian artery and opens into the innominate vein. one or two semilunar valves at its entrance into the innominate vein. In iboccipital triangle it communicates with the internal vertebral venous es, with the deep cervical, and occipital veins, and is joined by veins from cti and oblique muscles and the pericranium.

utaries.—As it passes down the neck it receives (1) intervertebral veins, which issue with the cervical nerves, from the spinal canal; (2) tributaries from the anterior and or vertebral venous plexus from the bodies of the cervical vertebræ and their transverse es; and (3) tributaries from the deep cervical muscles. Just before it terminates in the nate it is joined by (4) the anterior vertebral vein, a small vein which accompanies the ing cervical artery, and, sometimes, by the deep cervical vein.

The Deep Cervical Vein

he **deep cervical** vein [v. cervicalis profunda], larger than the vertebral, s down the neck posterior to the cervical transverse processes. It corre- ls to the deep cervical artery from which it is separated by the semispinalis cis muscle.

begins in the posterior vertebral venous plexus and receives tributaries from the deep s of the neck. It communicates with, or entirely drains, the occipital vein by a branch perforates the trapezius muscle. The deep cervical vein then passes forward beneath ansverse process of the seventh cervical vertebra to open into the innominate vein near rtebral, or into the latter near its termination. Its orifice is guarded by a pair of valves.

The Inferior Thyroid and Thyroidea Ima Veins

he **inferior thyroid** veins [vv. thyreoideæ inferiores] descend from the lower of the *plexus thyroidea impar* which invests the surface of the thyroid gland. ight vein crosses the innominate artery just before its bifurcation, and ends right innominate vein a little above the vena cava superior or joins the left to a single vena thyroidea ima. It receives inferior laryngeal veins and veins from achea. The **left vein** passes obliquely over the trachea behind the sterno- id muscle, and opens into the left innominate vein. It also receives laryn- nd tracheal veins, and may be joined by the right inferior thyroid vein. uarded by valves where it opens into the innominate trunk.

e thyroidea ima vein [v. thyreoidea ima] can be said to exist only when the veins from ver part of the plexus thyroidea impar unite at once to form a single trunk which opens e left innominate vein, or when the right inferior thyroid vein joins the left before the lat- ich then becomes the v. thyroidea ima, opens into the left innominate.

The Thymic, Tracheal and Esophageal Veins

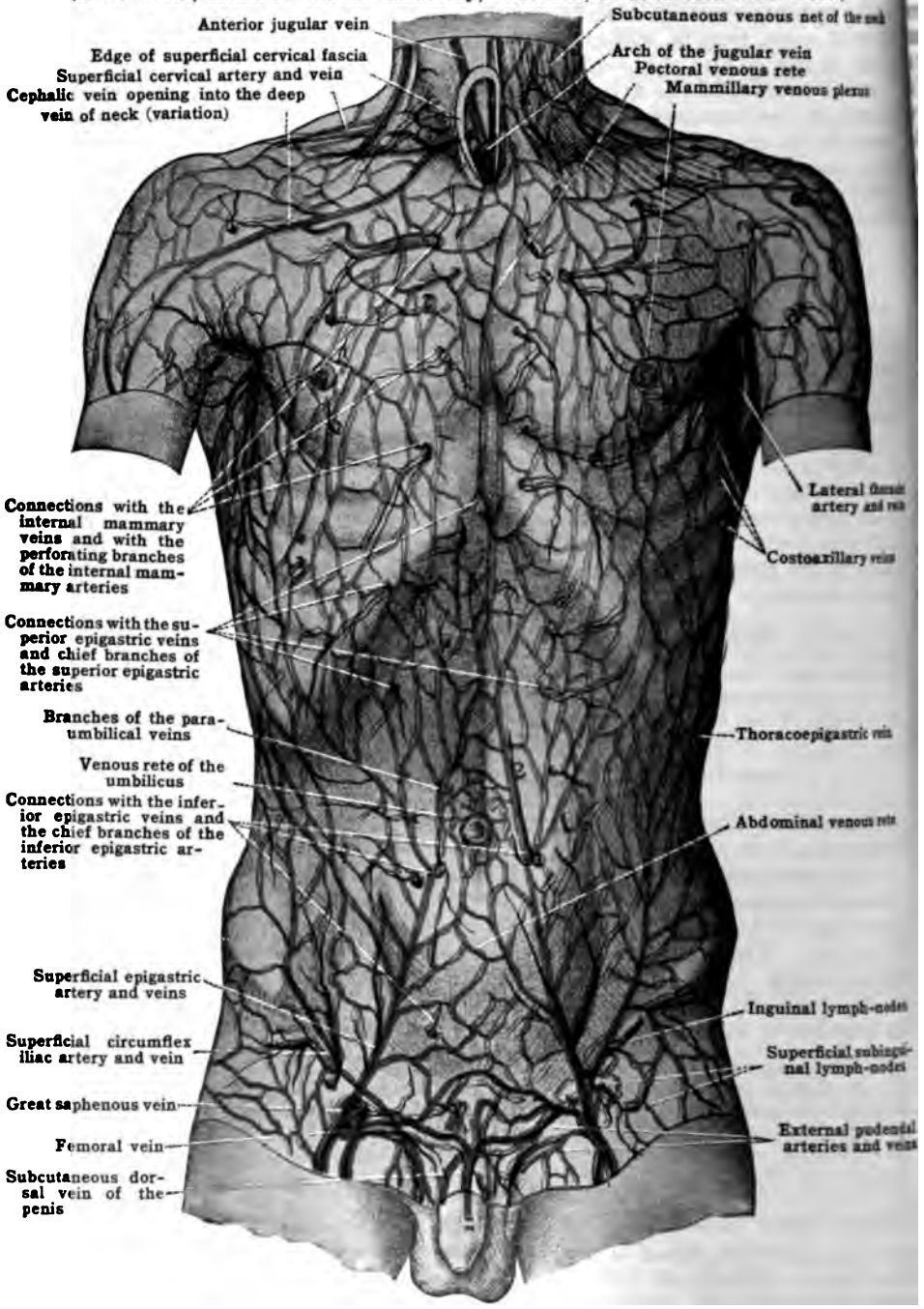
ese small veins usually open into the left innominate vein. The **thymic** [vv. thymicæ], small in the adult, open into the left innominate vein or into nferior thyroid or thyroidea ima. The **tracheal** veins [vv. tracheales] mose with the laryngeal and bronchial veins. The **esophageal** veins sophageæ] from the upper part of the esophagus, anastomose with the esophageal veins and with the pharyngeal plexus.

THE VEINS OF THE THORAX

THE SUPERFICIAL VEINS OF THE THORAX

The **superficial veins** of the front of the thorax can be seen in fig. 563. They form a plexus over the entire chest, of which the portion over the mammary gland

FIG. 563.—THE SUBCUTANEOUS ARTERIES AND VEINS OF THE ANTERIOR BODY WALL. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)


Anterior jugular vein
Edge of superficial cervical fascia
Superficial cervical artery and vein
Cephalic vein opening into the deep vein of neck (variation)
Subcutaneous venous net of the neck
Arch of the jugular vein
Pectoral venous rete
Mammillary venous plexus
Lateral thoracic artery and vein
Costoaxillary vein
Connections with the internal mammary veins and with the perforating branches of the internal mammary arteries
Connections with the superior epigastric veins and chief branches of the superior epigastric arteries
Branches of the paraumbilical veins
Thoracoepigastric vein
Venous rete of the umbilicus
Connections with the inferior epigastric veins and the chief branches of the inferior epigastric arteries
Abdominal venous rete
Superficial epigastric artery and veins
Inguinal lymph-nodes
Superficial circumflex iliac artery and vein
Superficial subinguinal lymph-nodes
Great saphenous vein
External pudendal arteries and veins
Femoral vein
Subcutaneous dorsal vein of the penis

is called the mammary plexus. The lateral thoracic vein drains the mammary plexus and the costoaxillary veins; it communicates with the thoracoepigastric

and terminates in the axillary vein (p. 705). The veins nearer the median ıre drained by the internal mammary vein and its anterior intercostal uperior epigastric tributaries. The veins over the entire thorax are in free ıunication with the superficial veins of the abdominal wall, which drain into reat saphenous and femoral veins and into the deeper veins of the abdomen.

THE DEEP VEINS OF THE THORAX

he **deep veins of the thorax** are:—the pulmonary veins, and the vena cava ior and its innominate and other tributaries. Of these veins, the pulmonary, ena cava superior, and the innominate veins have already been described, ve the tributaries of the latter arising in the neck.

he following veins are described below:—(1) The azygos and ascending ar veins, which discharge their blood into the vena cava superior; (2) the of the vertebral column, which are tributary to the azygos veins through the costals; (3) the internal mammary veins, and (4) the superior phrenic, an- r mediastinal and pericardiac veins, all of which open into the innominate

1. THE AZYGOS AND ASCENDING LUMBAR VEINS

he **azygos system** consists of a series of longitudinal collecting trunks for the *costal veins*. They lie along the sides of the thoracic vertebræ, and are the ard continuation of the **ascending lumbar veins** which take origin in the men. The **azygos** veins are three in number: the azygos (azygos major) ıe right side, and the hemiazygos (azygos minor) and accessory hemiazygos gos tertia) on the left.

he **azygos vein** [v. azygos] (figs. 564, 577) begins in the abdomen as the right ıding lumbar vein. It is in this way linked with the right common iliac right renal veins and has other connections with the vena cava inferior which become very important in cases of obstruction of the latter vessel. It up through the posterior mediastinum on the right side of the front of the es of the thoracic vertebræ as high as the fourth thoracic vertebra, in this part s course lying to the right of the aorta and thoracic duct; it then curves ard over the root of the right lung, and opens into the vena cava superior iediately before the latter pierces the pericardium.

he azygos vein usually contains an imperfect pair of valves at the point where it turns for- from the fourth thoracic vertebra to arch over the root of the lung; and still more imperfect s are found at varying intervals lower down the vein.

receives the intercostal veins of the right side, except the first two or three. These (usually excepting the first) are collected into a common trunk, the right superior inter- l vein, before joining the azygos. It also receives the hemiazygos and accessory hemiazy- he right posterior bronchial vein, and small esophageal and posterior mediastinal veins.

he **hemiazygos** vein [v. hemiazygos] (fig. 564) begins in the abdomen by nunicating, like the azygos vein, with the ascending lumbar vein of its own It courses up the posterior mediastinum to the left of the bodies of the r thoracic vertebræ as high as the eighth or ninth, where it turns obliquely to ight, and, crossing in front of the vertebral column behind the aorta and sophagus, opens into the vena azygos. In its course it crosses over three ur of the lower left intercostal arteries, and is covered by the pleura.

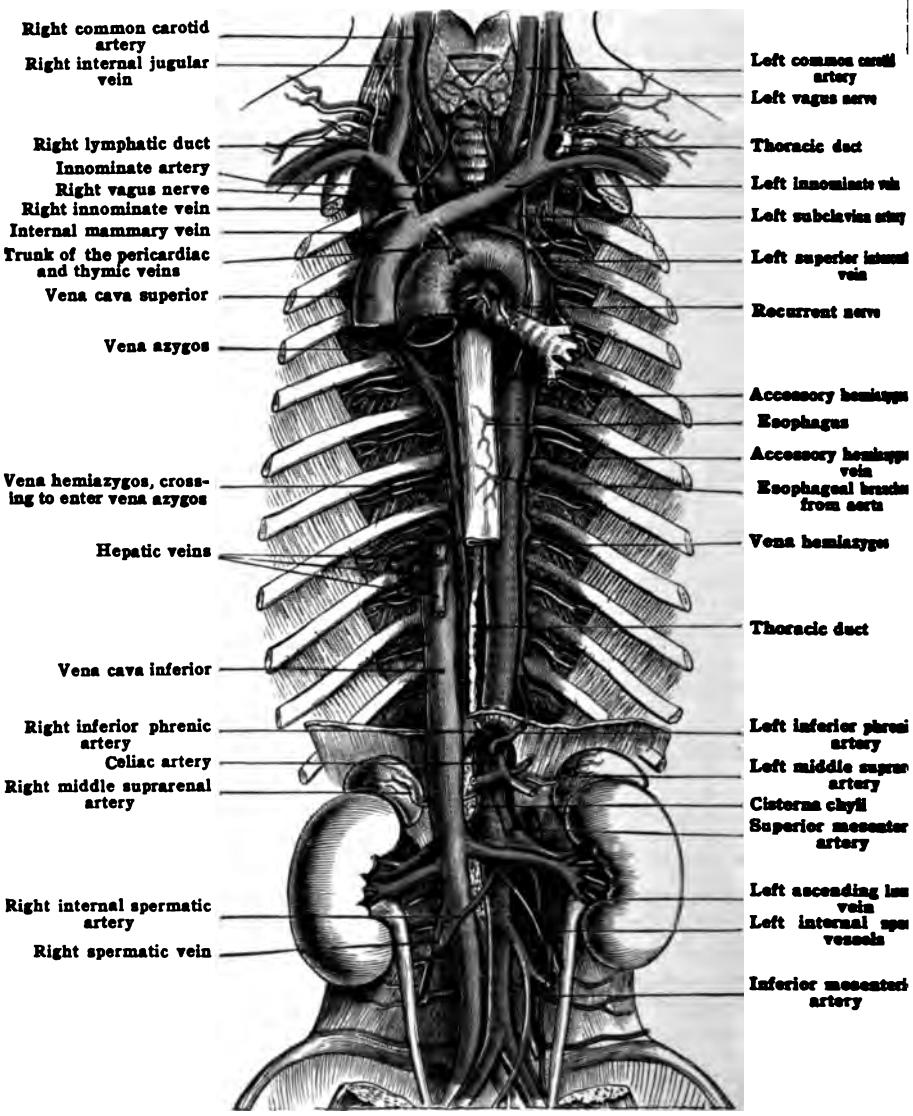
ıe hemiazygos receives the lower four or five left intercostal veins the lower end of the ıory hemiazygos vein (sometimes), the small left mediastinal veins, and the lower left ageal veins.

he **accessory hemiazygos** [v. hemiazygos accessoria] (fig. 564) varies much ıe, position, and arrangement, and is often continuous with, or drained by, eft superior intercostal vein. It lies in the posterior mediastinum by the ide of the bodies of the fifth, sixth, and seventh or eighth thoracic vertebræ, s more or less vertical in direction. It may communicate above with the ıperior intercostal vein, and below either joins the hemiazygos or passes uely across the seventh or eighth thoracic vertebra to join the azygos vein. sses the corresponding left intercostal arteries, and is covered by the pleura.

The accessory hemiazygos receives the fourth, fifth, sixth, seventh, sometimes the eighth intercostal veins, and the left posterior bronchial veins.

The **ascending lumbar** vein [v. lumbalis ascendens] (fig. 564) begins on each side in the neighborhood of the sacral promontory. It is here in free communication, by means of the anterior sacral plexus, with the middle and lateral sacral veins, and with the common iliac, hypogastric and iliolumbar veins. It ascends in front of the lumbar transverse processes communicating with the lumbar veins, the vena cava inferior and, usually, with the renal vein. The right

FIG. 564.—THE VENÆ CAVÆ SUPERIOR AND INFERIOR, THE INNOMINATE VEINS, AND THE AZYGOS VEINS.



enters the thorax between the aorta and the right medial crus of the diaphragm and is continued upward as the vena azygos. The left vein pierces the left medial crus and becomes the hemiazygos.

The intercostal veins [vv. intercostales].—The intercostal veins are twelve in number on each side, the last one being subcostal. They accompany the intercostal arteries, the vein lying above the artery whilst in the intercostal spaces. Each vein receives a dorsal tributary [ramus dorsalis] which accompanies the posterior ramus of an intercostal artery between the transverse processes of the vertebra and the neck of the rib. These dorsal branches not only return blood from the muscles of the back, but receive each a spinal branch [r. spinalis

from the vertebral venous plexuses and small tributaries from the bodies of the vertebræ.

The intercostal vein from the first space may join the superior intercostal vein, but commonly opens directly into the innominate or one of its tributaries, most frequently the vertebral. All the intercostal veins, usually excepting the first, lie posteriorly to the sympathetic trunk.

On the right side.—The second intercostal vein joins with the third or with the third and fourth to form the **right superior intercostal** vein [v. intercostalis suprema dextra]. This vein opens into the azygos vein as the latter is arching over the root of the right lung. The rest open in the azygos directly. The upper of these have well-marked valves where they join the azygos vein; in the lower veins these valves are imperfect. All the intercostal veins are provided with valves in their course between the muscles.

On the **left side** the second intercostal vein joins the third and fourth to form a single trunk, the **left superior intercostal** vein [v. intercostalis suprema sinistra]. This vein passes upward across the arch of the aorta and opens into the left innominate vein. The left superior intercostal frequently communicates at its lower end with the accessory hemiazygos vein, which is occasionally tributary to it. In most cases a small tributary runs up over the front of the aortic arch to join the superior intercostal vein; it is a vestige of the left common cardinal and from it a small fibrous cord can often be traced through the vestigial fold of the pericardium to the oblique vein of the left atrium (p. 564).

The left fifth, sixth and seventh intercostal veins commonly open into the accessory hemiazygos, and the eighth or ninth and succeeding veins into the hemiazygos. The method of termination of the intercostal veins of the left side is subject to such variation that a normal arrangement can scarcely be said to exist at all. The eighth may open directly into the azygos, as may the seventh and ninth or even more or all of the veins; the hemiazgyos and accessory hemiazygos veins may thus be very limited in extent or even altogether absent.

The **posterior bronchial** veins [vv. bronchiales posteriores] correspond to the bronchial arteries, but do not return the whole of the blood carried to the lungs by those vessels—that part which is distributed to the smaller bronchial tubes and the alveoli being brought back by the pulmonary veins. The posterior bronchial veins issue from the lung substance behind the structures forming the root of the lung. The right vein generally joins the vena azygos just before the latter vein enters the vena cava superior. The left vein opens into the accessory hemiazygos vein. The bronchial veins at the root of the lung receive small tributaries from the bronchial glands, from the trachea, and from the posterior mediastinum.

The **esophageal** veins [vv. œsophageæ] from the thoracic portion of the esophagus end in part in the vena azygos, and in part in the vena hemiazygos. They anastomose with the upper esophageal veins, which empty into the left innominate vein, and with the coronary vein of the stomach (fig. 572).

The **posterior mediastinal** veins, small and numerous, open into the azygos and hemiazygos veins.

2. THE VEINS OF THE VERTEBRAL COLUMN

The venous plexuses around and within the vertebral column extending from the cranium to the coccyx (fig. 565) may be divided into two categories:—(1) the **external** and (2) the **internal vertebral venous plexuses.** The external plexuses consist of two parts, the *anterior vertebral venous plexuses* situated on the anterior aspect of the vertebral bodies and the *posterior vertebral venous plexuses* ramifying over the posterior aspect of the vertebral arches, spines, and transverse processes. The internal plexuses consist of *two longitudinal venous sinuses* situated between the vertebræ and the posterior longitudinal ligament, and of two *vertebral venous retia* which ramify externally to the dura mater. The sinuses of the internal plexuses communicate freely with one another and with the internal retia and external plexuses. They receive the external spinal veins and the *basivertebral veins* from the bodies of the vertebræ. The venous circulation of the vertebral column is drained by the vertebral, intercostal, lumbar and sacral veins either directly or by means of (3) the **intervertebral** veins.

1. The **external vertebral venous plexuses** [plexus venosi vertebrales externi] include the following:—

(*a*) The **anterior vertebral venous plexuses** [plexus venosi vertebrales anteriores] (fig. 565) consist of small veins ramifying in front of the bodies of the vertebræ. These veins communicate with the basivertebral veins and are larger in the cervical region than elsewhere.

(*b*) The **posterior vertebral venous plexuses** [plexus venosi vertebrales posteriores] (fig. 565) are situated around the transverse, articular, spinous processes and laminæ of the vertebræ. Communications take place between the plexuses of each segment and with the veins of the neighboring muscles and integuments. Branches are also sent, through the ligamenta flava, to the internal vertebral venous plexuses, and, between the transverse processes, to the intervertebral veins.

2. The **internal vertebral venous plexuses** [plexus venosi vertebrales interni] (figs 565, 566):—

(*a*) The two **longitudinal vertebral sinuses** [sinus vertebrales longitudinales] run throughout the entire length of the vertebral canal. They are situated behind the bodies of the vertebræ on either side, between the bone and the posterior longitudinal ligament. The sinuses have extremely thin walls, and their interior is made irregular by numerous folds but no true valves are present. The caliber of the longitudinal sinuses is reduced by constrictions opposite the

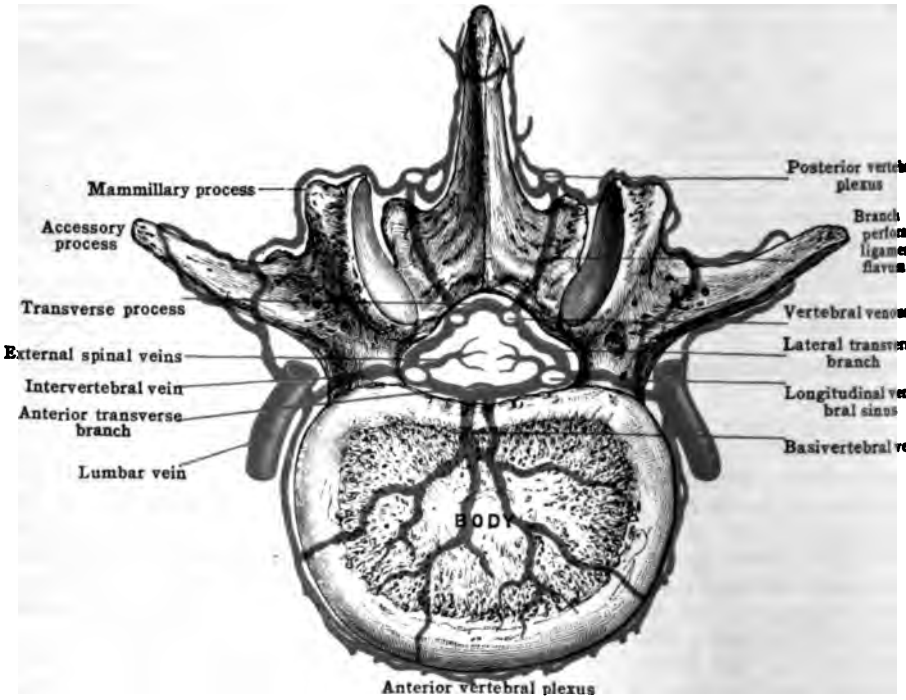
intervertebral disks; the constrictions alternating with dilatations opposite the vertebral bodies. At each dilatation there occurs a cross communication between the longitudinal sinuses on either side, and each receives a basivertebral vein from the corresponding vertebral body. Opposite every intervertebral foramen and anterior sacral foramen each longitudinal sinus is joined by the corresponding intervertebral vein. The longitudinal sinuses communicate very freely with one another, and with the vertebral retia. At the foramen magnum they communicate with the basilar plexus and, by means of the **rete canalis hypoglossi**, with the internal jugular vein.

(*b*) The **venous retia of the vertebræ** [retia venosa vertebrarum] (**fig. 565**) extend from the foramen magnum to the coccyx. They consist of two main retia situated posteriorly and laterally to the dura between the latter and the vertebral arch. They communicate very freely with one another across the median line; with the posterior external plexus by means of twigs perforating the ligamenta flava; and with the longitudinal vertebral sinuses by means of lateral branches. At the foramen magnum they communicate with the occipital sinus.

(*c*) The **external spinal** veins (fig. 565) consist of two sets—anterior and posterior—which are drained by means of veins following the nerve roots, into the internal vertebral venous plexus.

The **anterior external spinal** veins [vv. spinales externæ anteriores] form a tortuous anastomosing vessel in the region of the anterior median fissure.

FIG. 565.—THE VEINS OF THE VERTEBRAL COLUMN.



The **posterior external spinal** veins [vv. spinales externæ posteriores], smaller than the anterior run longitudinally on the posterior surface of the cord.

The external spinal veins form a wide-meshed plexus in the pia mater which drains into the **internal spinal** veins [vv. spinales internæ] (see SPINAL CORD).

(*d*) The **basivertebral** veins [vv. basivertebrales] (fig. 565) collect the blood from the cancellous tissue of the bodies of the vertebræ, and consist of a tunica intima only. They take a radial direction converging to the transverse vessels connecting the longitudinal vertebral sinuses. They communicate with the anterior external plexus and with the intercostal veins.

3. The **intervertebral** veins [vv. intervertebrales] (figs. 565, 566), emerge from each longitudinal sinus and pass out through the intervertebral or anterior sacral foramina. They open into the vertebral, intercostal, lumbar or sacral veins according to region and receive numerous tributaries from the anterior and posterior external vertebral venous plexuses. They are instrumental in draining the venous system of the vertebral column and spinal cord.

3. THE INTERNAL MAMMARY VEIN

The internal mammary vein [v. mammaria interna] (**fig. 506**) **is formed by** the union of the venæ comitantes corresponding to the **superior epigastric** and musculophrenic arteries. The right and left internal **mammary veins pass** upward, in company with the corresponding arteries, to open **into the right and** left innominate veins, respectively.

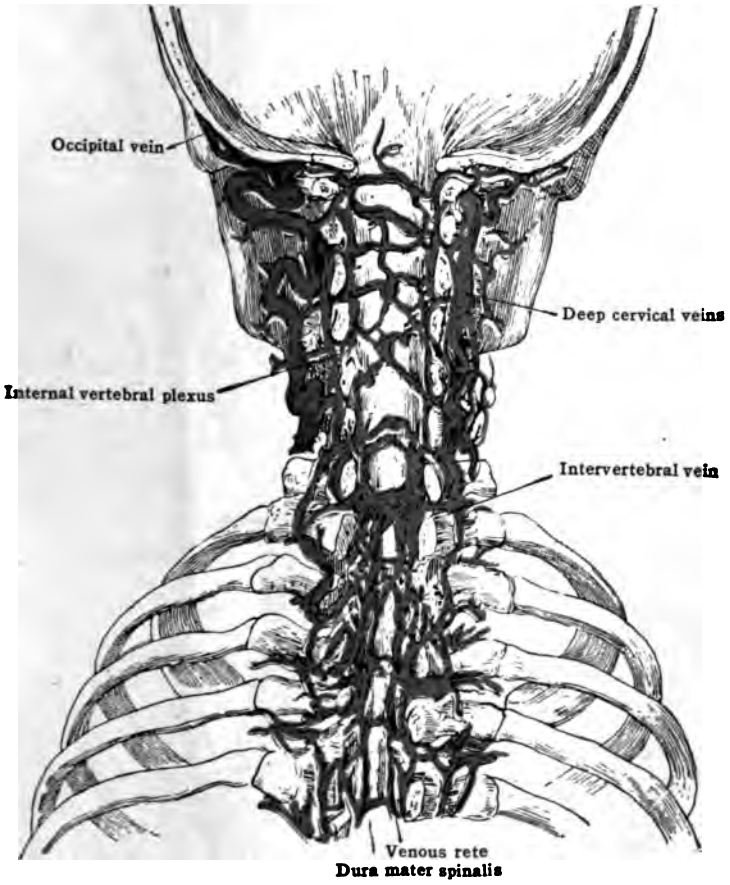
ributaries.—In addition to the superficial veins of the thorax, the internal mary veins receive the anterior intercostal, anterior bronchial and peri- iac veins.

he superior epigastric vein [v. epigastrica superior] assists in the drainage of the subcu- us abdominal veins [vv. subcutaneæ abdominis].
he anterior bronchial veins [vv. bronchiales anteriores] arise in the bronchial walls and unicate with the tracheal and posterior bronchial veins.

THE SUPERIOR PHRENIC, ANTERIOR MEDIASTINAL, AND PERICARDIAC VEINS

he superior phrenic [vv. phrenicæ superiores], the **anterior mediastinal** [vv. mediastinales iores], and **pericardiac** [vv. pericardiacæ] veins are small vessels, corresponding to the ar- of those names. They pass over the arch of the aorta and open into the lower and an- part of the left innominate.

FIG. 566.—THE VERTEBRAL VENOUS PLEXUSES. (After Henle.)



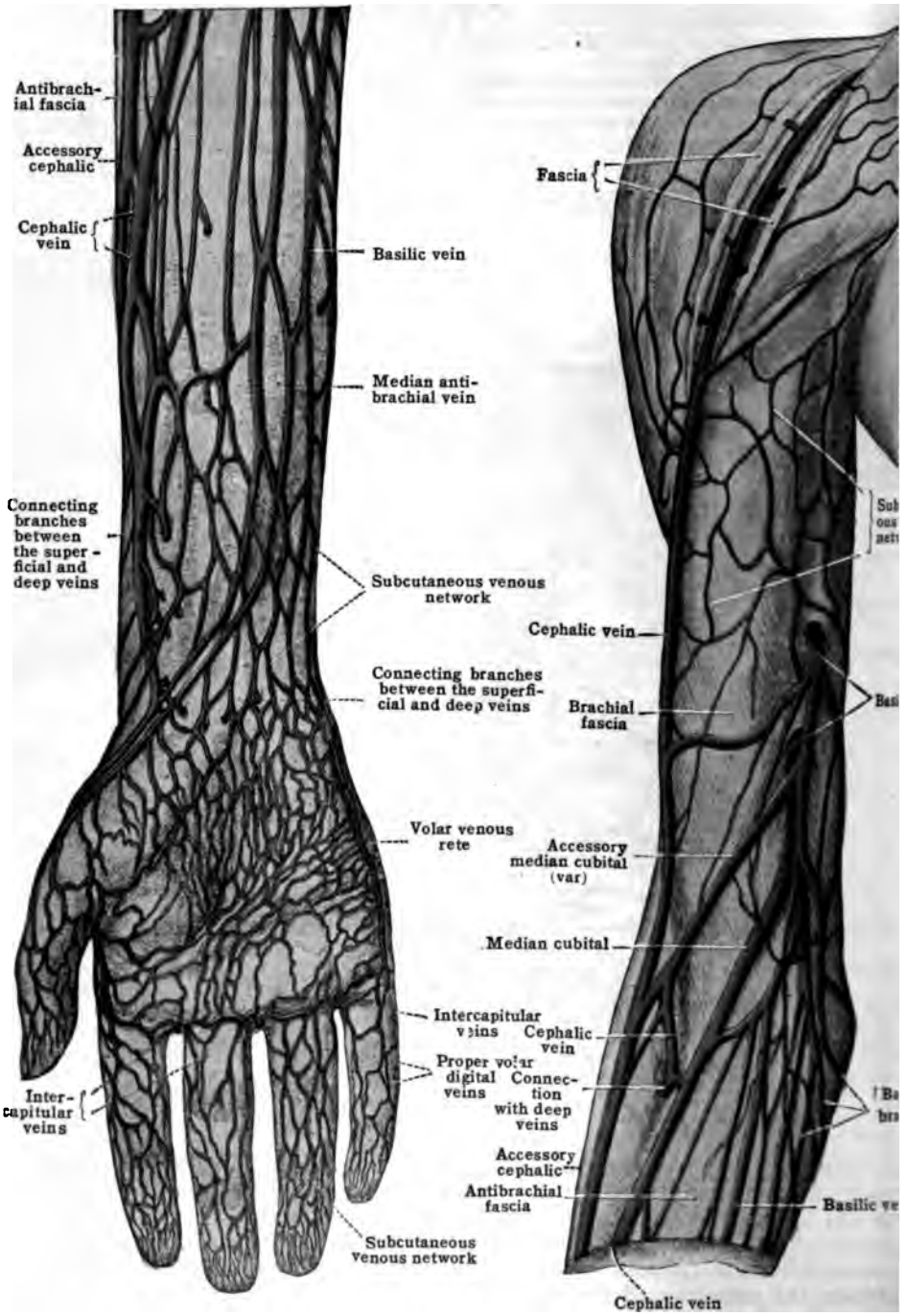
THE VEINS OF THE UPPER EXTREMITY

he veins of the upper limb consist of two sets—a **superficial** and a **deep.** uperficial veins ramify in the subcutaneous tissue above the deep fascia, and do not accompany arteries. The deep veins accompany the arteries, and practically the same relations as those vessels. The superficial and deep communicate at frequent intervals through the intermuscular veins which etween the muscles and perforate the deep fascia. Both sets of veins are ded with valves, but the valves are more numerous in the deep than in the ficial. There are usually valves where the deep veins join the superficial. uperficial veins are larger than the deep, and take the greater share in ning the blood.

A. THE SUPERFICIAL VEINS OF THE UPPER EXTREMI

The **superficial veins** begin in two irregular plexuses, one in the palm and other on the back of the hand. The plexus in the palm is much finer, and c

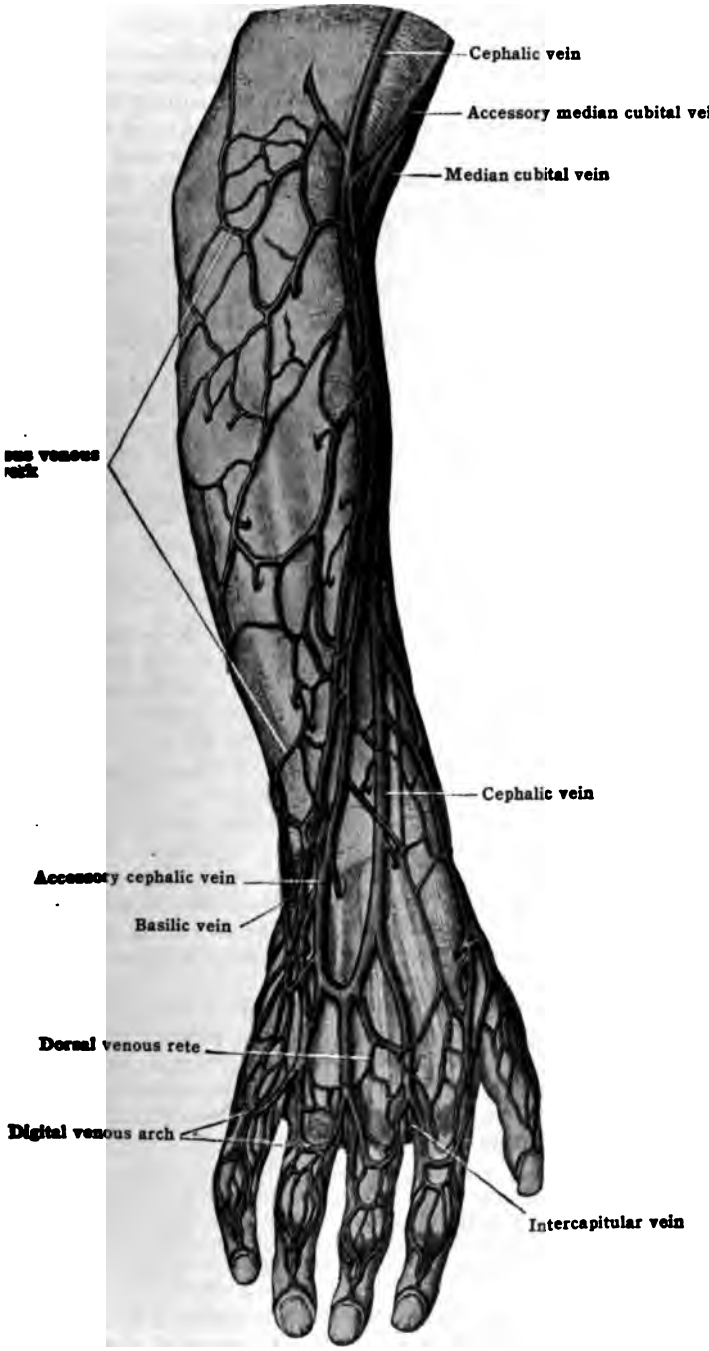
FIG. 567.—THE SUPERFICIAL VEINS OF THE ARM AND FOREARM. (After Toldt, 'Atla Human Anatomy,' Rebman, London and New York.)



municates with the superficial volar veins of the fingers. **The latter disc** their blood into the dorsal venous rete by means of the **veins of the folds be** the fingers, or the **intercapitular** veins [vv. intercapitulares] **(fig. 567).**

eins of the back of the hand begin in a longitudinal plexus over the d at the bases of the fingers the veins of the adjacent digits are con- **digital venous arches** [arcus venosi digitales], from which arise the

VEINS OF THE BACK OF THE FOREARM. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



tacarpal veins [vv. metacarpeæ dorsales]; these form upon the back **d a dorsal venous rete** [rete venosum dorsale manus] (fig. 568).

veins of the arm, two stand out prominently, the basilic and the Both of these arise from the veins of the back of the hand, curve the volar surface of the forearm, and pass to the arm (fig. 567).

below the clavicle it turns into the depth, and empties into the axillary v

At the elbow there is usually an oblique connecting branch, the **cubital** vein [v. mediana cubiti] (figs. 567, 569) (formerly termed median which, beginning from the cephalic a little distally to the crease of the ends in the basilic just proximally to the elbow.

NOTE.—In the limb shown in fig. 567 the direct venous channel on the radial sid forearm, the accessory cephalic (formerly radial) vein, is continued directly into the above the elbow. The cephalic in the forearm (formerly median) is mainly drained basilic through the median cubital. The vein opposite the bend of the elbow, wh ally forms the segment of the cephalic formerly known as the median cephalic vein, small channel draining into an accessory median cubital. The basilic vein of the (formerly posterior ulnar) is represented largely by a plexus of small venous channels.

There are several longitudinal or oblique tributaries of the basilic and cephalic ve the volar surface of the forearm. One of these, the **accessory cephalic** (formerly th vein, lies on the medial side of the cephalic, into which it opens a short distance prox the crease of the elbow; the others are not named.

B. THE DEEP VEINS OF THE UPPER EXTREMI

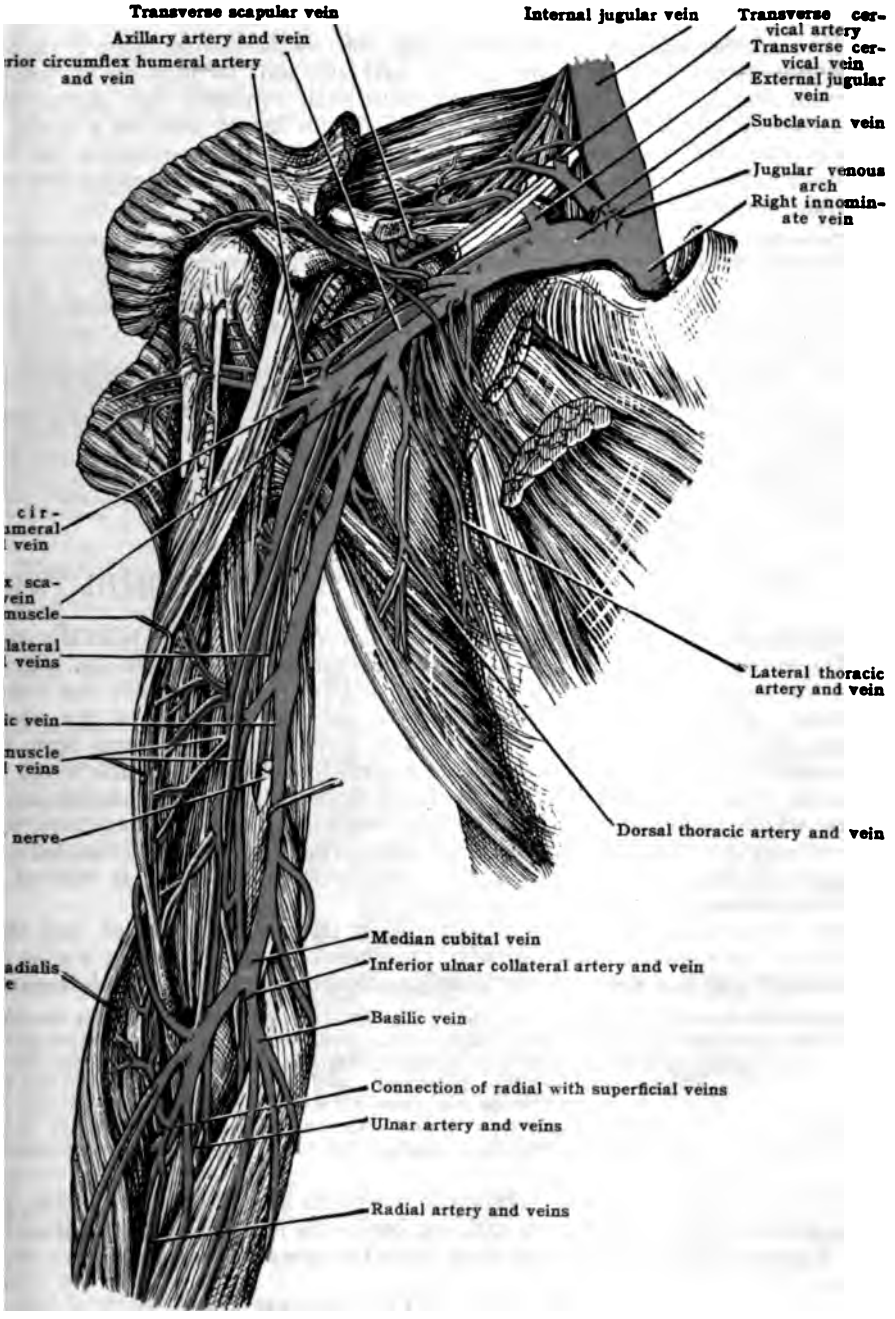
The **deep veins of the upper extremity** accompany their corres arteries. Distal to the axilla, each artery is accompanied by two veins as the venæ comitantes. The deep veins all contain numerous valv communicate at frequent intervals through intermuscular veins with th ficial vessels.

Beginning at the fingers, two minute **proper volar digital veins** [venæ volares propriæ], accompany each digital artery along the sides of the and uniting at the cleft, form **common volar digital veins** [vv. digitales communes], which join the venæ comitantes of the arteries, forming th ficial volar arch. In like manner the veins accompanying the arteries the deep arch receive tributaries, **the volar metacarpal veins** [vv. met volares], corresponding to the branches of that arch. **A superficial and volar venous arch** [arcus volaris venosi, superficialis et profundus] are thu accompanying the arterial arches. The venæ comitantes from the ulna the superficial and deep arches unite at the spot where the ulnar artery into the superficial and deep branch to form two **ulnar venæ comitan** ulnares]; whilst those on the radial side of the superficial and deep arch ac the superficial volar artery and the termination of the radial artery resp and unite at the spot where the superficial volar is given off from the radi to form the **radial venæ comitantes** [vv. radiales].

venæ comitantes of the arteries of the arm anastomose with one another **uent** cross branches.

axillary vein [v. axillaris], is formed by the junction of the medial brachial **omitans** with the basilic vein at the lower border of either the teres major

).—Deep Veins of the Arm and Axilla. (Ater Toldt, 'Atlas of Human Anatomy, Rebman, London and New York.)



scapularis muscle. It is a vessel of large size, conveying as it does nearly **ole** of the blood returning from the upper extremity. It accompanies the **y artery through** the axillary fossa, lying to its medial side and, at the upper **the space, on a slightly** posterior plane. At the lateral border of the first **hanges its name to** the subclavian. It has one or two axillary lymphatic

5

nodes in close connection with it. The vein contains a pair of valves, usually placed near the lower border of the subscapularis muscle.

Tributaries of the axillary vein are as follows:—(1) The **subscapular** veins which accompany the subscapular artery; (2) the **circumflex** veins accompanying the circumflex arteries; (3) the **lateral thoracic** vein [v. thoracalis lateralis] a large vein which accompanies the lateral thoracic artery and receives numerous **thoracoepigastric** veins [vv. thoracoepigastricæ] from the epigastric and lower thoracic regions; (4) the **costoaxillary** veins [vv. costoaxillares] the radicles of which arise in the pectoral region from the **mammary plexus** [plexus venosus mamillæ]; and (5) the **cephalic** vein.

The **subclavian** vein [v. subclavia] (fig. 569), is the continuation of the axillary. It begins at the lateral border of the first rib, and terminates by joining the internal jugular to form the innominate vein opposite the sternoclavicular articulation. It lies anterior to the subclavian artery and on a lower plane, and is separated from the artery in the second part of its course by the scalenus anterior muscle. The subclavian vein, just before it is joined by the external jugular, contains a pair of valves.

Tributaries.—The subclavian vein receives the thoracoacromial vein near its distal end, and the external jugular vein near the lateral border of the sternomastoid muscle. The transverse cervical veins terminate in the subclavian near the external jugular, or in the latter vein, or in a plexiform arrangement formed between the transverse scapular, transverse cervical and external jugular veins. The external jugular vein is described with the superficial veins of the head and neck (p. 682).

The **thoracoacromial** vein [v. thoracoacromialis], receiving tributaries corresponding to the branches of the artery of the same name, terminates near the lateral border of the first rib.

The **transverse cervical** veins [vv. transversæ colli] receive tributaries corresponding in distribution to the branches of the transverse cervical artery. They emerge from beneath the trapezius muscle, cross the posterior triangle, and usually terminate in the subclavian vein. They usually terminate as a single vein the orifice of which is guarded by a pair of valves. Occasionally the cephalic vein, or a branch from the cephalic (the **jugulocephalic**), passes over the clavicle to the subclavian.

C. THE VENA CAVA INFERIOR AND ITS TRIBUTARIES

All the veins of the abdomen, pelvis, and lower extremities, with the exception of the superior epigastric (p. 682), and ascending lumbar vein (p. 698), which join the superior caval system, enter directly or indirectly into the vena cava inferior. The veins corresponding to the parietal branches of the abdominal aorta, except the middle sacral vein, open directly into the vena cava inferior; the middle sacral vein only indirectly through the left common iliac vein. Of the visceral veins corresponding to the visceral branches of the abdominal aorta, those which return the blood from the stomach, intestines, pancreas, and the spleen end in a common trunk called the portal vein. The portal vein breaks up into capillaries (sinusoids) in the liver, whence the blood is carried by the hepatic veins to the vena cava inferior.

Of the other visceral veins, both renals, the right suprarenal, and the right spermatic or ovarian open directly into the vena cava inferior; whilst the left suprarenal and left spermatic or ovarian are drained through the left renal.

Two of the superficial veins of the lower part of the anterior abdominal wall, the superficial epigastric and superficial circumflex iliac, enter the great saphenous vein; and two of the deep veins from the like situation, the inferior epigastric and deep circumflex iliac, enter the external iliac vein. The blood in these vessels, however, can flow upward as well as in the normally downward direction. In obstruction of the vena cava inferior they become greatly enlarged, and form, with the superior epigastric vein and with other superficial veins of the thorax with which they anastomose, one of the chief channels for the return of the blood from the lower limbs.

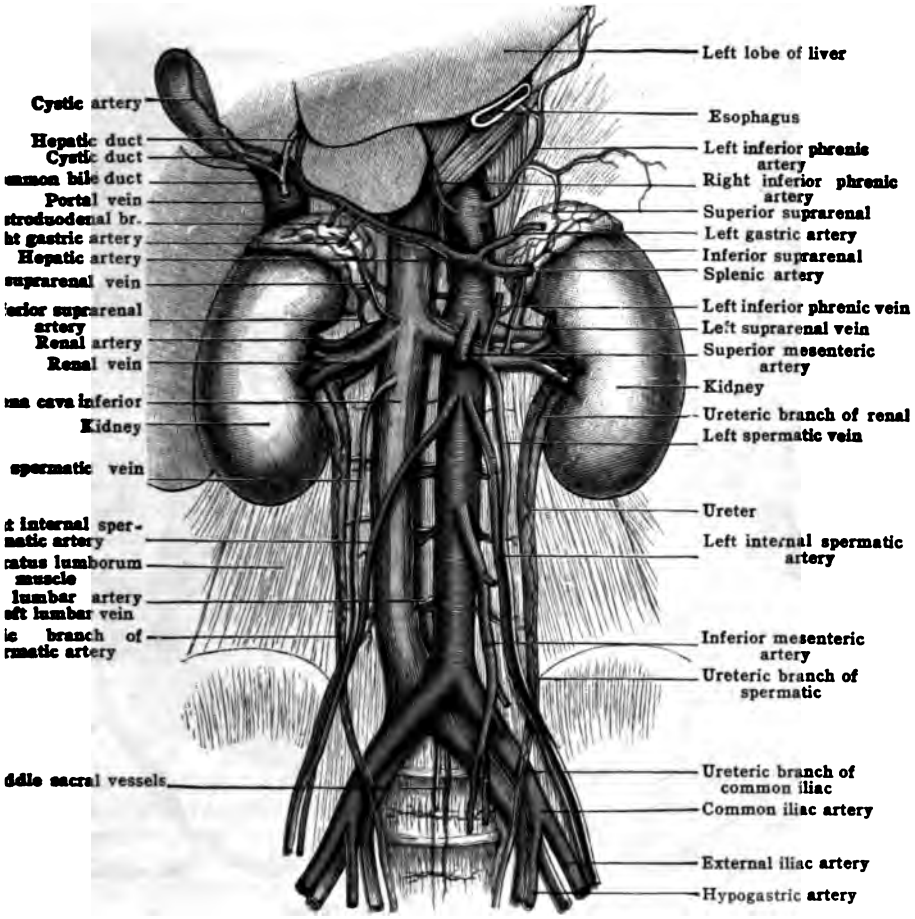
Most of the veins of the pelvis, the perineum and the gluteal region, join the hypogastric vein. The hypogastric on each side joins the external iliac to form the common iliac, and these in turn unite to form the vena cava inferior.

THE VENA CAVA INFERIOR

The **vena cava inferior** (fig. 570) is the large vessel which returns the blood from the lower extremities and the abdomen and pelvis. It is formed by the confluence of the right and left common iliac veins opposite the body of the fifth lumbar vertebra, ascends in front of the lumbar vertebra to the right of the abdominal aorta, passes through the caval opening in the diaphragm, and ends in

lower and back part of the right atrium of the heart usually about the level ne ninth thoracic vertebra. At its origin it lies behind the right common artery on a plane posterior to the aorta, but as it ascends it passes slightly ard and to the right, reaching a plane anterior to the aorta, and becomes rated from that artery by the right medial crus of the diaphragm and the ate lobe of the liver. While in contact with the liver it lies in a deep groove a venæ cavæ] on the posterior surface of that organ, the groove being often erted into a distinct canal by a thin portion of the hepatic substance bridging ss it. As it passes through the diaphragm its walls are attached to the inous margins of the caval opening, and are thus held apart when the muscle racts. On the thoracic side of the diaphragm it lies for about 1.2 cm. (½ in.) in the pericardium, the serous layer of that membrane being reflected over g. 480).

FIG 570.—THE ABDOMINAL AORTA AND VENA CAVA INFERIOR.



lations.—**In front** it is covered by the peritoneum, and crossed by the right spermatic , branches of the aortic plexus of the sympathetic, the transverse colon, the root of the tery, the duodenum, the head of the pancreas, the portal vein, and the liver. The lumbar lymphatic nodes are also in front of it below, and at its commencement the right on iliac artery rests upon it. **Behind,** it lies on the lumbar vertebræ, the right lumbar e, the right renal artery, the right celiac (semilunar) ganglion, and the right medial crus diaphragm. To the **right** are the peritoneum, liver, and psoas muscle. To the **left** is rta, and higher up the right medial crus of the diaphragm.

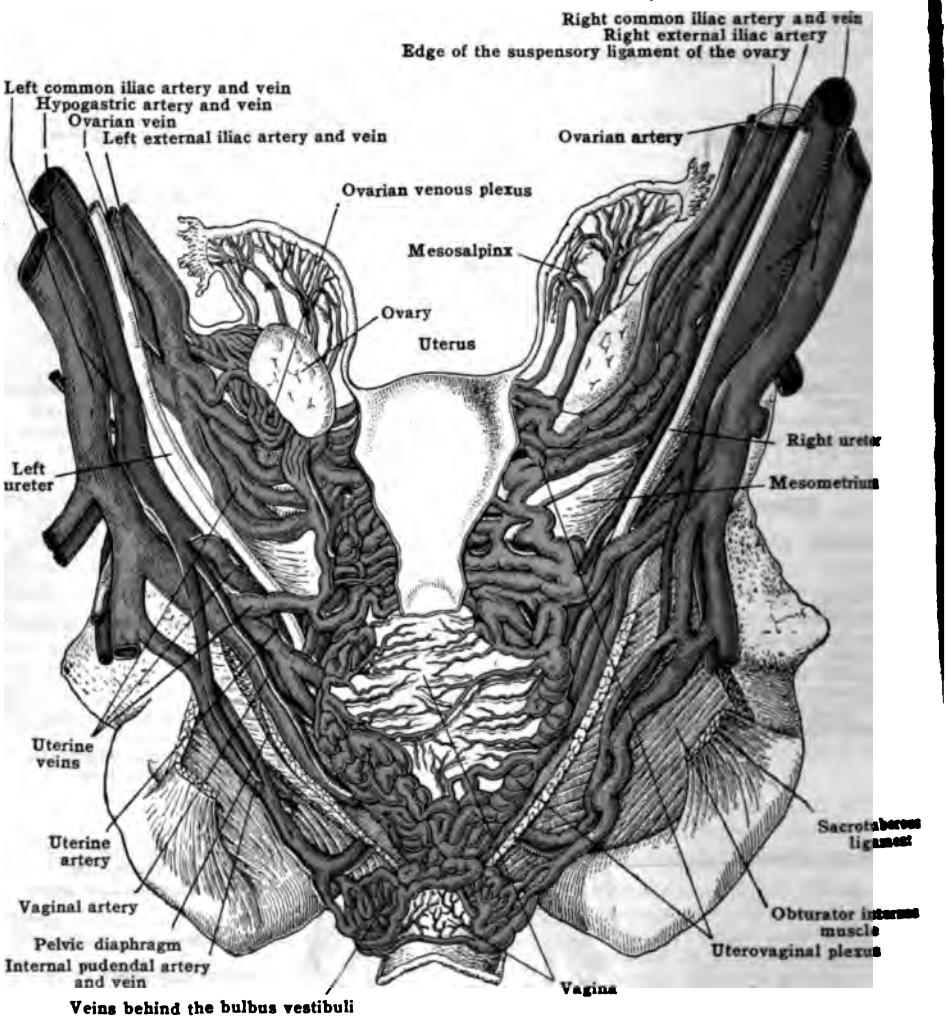
ributaries.—The vena cava inferior receives the following veins:—(1) the veins; (2) the right suprarenal vein; (3) the right spermatic or the right an vein; (4) the lumbar veins; (5) the inferior phrenic veins; (6) the hepatic (which indirectly receive blood from the portal); and (7) the right and ommon iliac veins.

) The **renal** veins [vv. renales] (fig. 570) return the blood from the kidneys.

They are short but thick trunks, and open into the vena cava nearly at right angles to that vessel. The vein on the left side, like the kidney, is a little higher than on the right, and is also longer, in consequence of its having to cross the aorta.

Each renal vein lies in front of its corresponding artery. The left vein crosses in front of the aorta, just below the origin of the superior mesenteric artery. It is covered by the inferior portion of the duodenum, and receives the left spermatic, or the left ovarian in the female, and usually the left suprarenal, and sometimes the left phrenic. There are rudiments of valves in each vein where it joins the vena cava. Those on the right side, however, are less well marked.

FIG. 571.—THE VEINS OF THE FEMALE PELVIS. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



(2) **The suprarenal** veins [vv. suprarenales] (fig. 570).—**There is usually only** one suprarenal vein on each side to return the blood **brought to the suprarenal** body by the three suprarenal arteries. On the **right side the vein opens directly** into the vena cava, above the opening of the right renal vein. **On the left side,** it opens into the left renal.

(3) The **spermatic** veins [vv. spermaticæ] (fig. 570) **return the blood from** the testes. They begin by the confluence of small branches **from the body of the** testis and epididymis. As they proceed up the spermatic cord, **in front of the** internal spermatic artery and ductus deferens, they **become dilated and plexiform,** constituting the **pampiniform plexus** [plexus pampiniformis] **(fig. 582).**

Veins. Along with the artery the veins pass up beneath the peritoneum, and on the left side also beneath the sigmoid colon, across the psoas muscle and ureter. They receive small tributaries from the ureter and peritoneum, and proceed as a single trunk, on the right side to the vena cava inferior, and on the left side to the left renal vein. There are commonly a number of imperfect valves in the spermatic plexus and a perfect pair at the termination of each spermatic vein. On the left side, however, the terminal valve may be wanting.

The **ovarian** veins [vv. ovaricæ] begin at the plexus pampiniformis near the ovary, between the layers of the broad ligament (figs. 525, 526, 571). This plexus is larger than in the male and communicates freely with the uterovaginal plexus of veins, and with the plexus of veins which extends from the hilus of the ovary into the ovarian ligament.

After passing from between the layers of the broad ligament, the plexus unites to form at first two vessels and then a single vessel, which accompanies the ovarian artery, following a course similar to that of the spermatic veins in the male. The right ovarian veins open into the vena cava inferior, the left into the left renal. They usually contain imperfect valves in their plexiform part, and a perfect valve where they join the vena cava and renal vein respectively.

(4) The **lumbar** veins [vv. lumbales], four to five on either side accompany the lumbar arteries and collect venous blood from the muscles of the back and abdomen.

They terminate by passing beneath the tendinous arches of the psoas major, along the sides of the lumbar vertebræ, and opening into the vena cava inferior. The veins of the left side are longer than those of the right and pass behind the aorta. Each vein receives a dorsal tributary corresponding in distribution to the dorsal branch of the lumbar artery. Between the dorsal tributaries and the posterior vertebral venous plexus there occurs a free communication. There is also an anastomosis between the main lumbar veins and the anterior vertebral venous plexus around the bodies and transverse processes of the lumbar vertebræ. By means of these communications the intervertebral veins, the internal and external vertebral and spinal plexuses are partly drained. In addition to these anastomoses the lumbar veins are connected with one another and with common iliac, hypogastric, iliolumbar, renal, azygos and hemiazygos veins by means of the *ascending lumbar veins* (p. 682).

(5) The **inferior phrenic** veins [v. phrenica inferior] follow the course of the inferior phrenic arteries; the right opens into the vena cava direct; the left into the suprarenal, the left renal, or the vena cava.

(6) The **hepatic** veins [vv. hepaticæ], the largest visceral tributaries of the vena cava, return the blood from the liver. Commencing in the substance of the liver (see LIVER), they converge as they approach its posterior surface, and unite to form two or three large trunks, which open into the vena cava as it lies in the fossa venæ cavæ.

Some smaller vessels from the caudate lobe, and other parts of the liver in the neighborhood of the caval fossa, open directly into the vena cava. The hepatic veins contain no valves, but, in consequence of opening obliquely into the vena cava, a semilunar fold occurs at the lower margin of each orifice. The hepatic veins transmit the blood brought into the liver by both the hepatic artery and the portal vein.

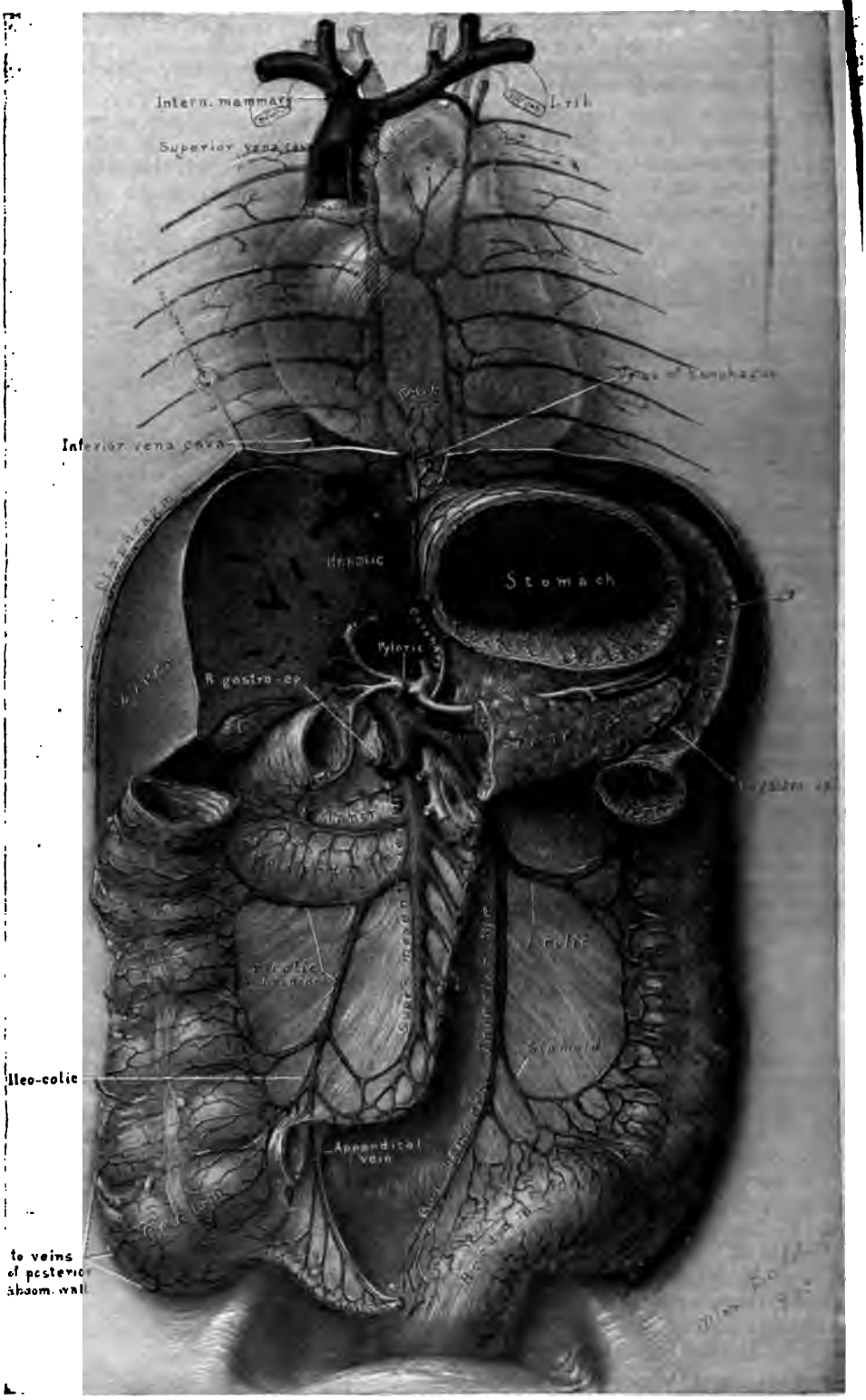
THE PORTAL VEIN

The veins corresponding to the inferior mesenteric, the superior mesenteric, and to some of the branches of the celiac artery, do not join the vena cava inferior directly, but unite to form a common trunk—the **portal vein.** This vein enters the liver, and breaks up in its substance into **sinusoids** from which the blood is again ultimately collected by the hepatic veins, and carried by them into the vena cava inferior. The portal vein and its tributaries have no valves.

The **portal** vein [v. portæ] (fig. 572), is a thick trunk 7 or 8 cm. (3 in.) in length. It is formed behind the neck of the pancreas, opposite the right side of the body of the second lumbar vertebra, by the union of the superior mesenteric with the splenic veins. It passes upward and to the right behind the superior part of the duodenum, and then between the layers of the lesser omentum. In the latter situation it passes in front of the foramen epiploicum and is accompanied by the hepatic artery and the bile-duct. Finally it enters the porta of the liver, and there divides into a right and a left branch.

In this course the hepatic artery and the common bile-duct are in front, the former to the left, the latter to the right. It is surrounded by branches of the hepatic plexus of the sympathetic nerve, and by numerous lymphatic vessels and some glands. The connective tissue sheath enclosing these structures is called the fibrous capsule of Glisson [capsula fibrosa, Glissoni]. Just before it divides it is somewhat dilated, the dilated portion being called the sinus of the portal vein. The division into right and left branches takes place toward the right end of the

FIG. 572.—THE PORTAL VEIN. (From Kelly, by Brödel.)



porta of the liver. The **right branch** is shorter and thicker than the left, and supplies the right **lobe** of the liver and a branch to the quadrate lobe. The **left branch** is longer and smaller than **the right**, and supplies the left lobe, and gives a branch to the caudate (Spigelian) and quadrate **lobes.** It is joined, as it crosses the left sagittal fossa, by a fibrous cord, known as the **ligamentum teres hepatis** (obliterated **vena umbilicalis**), and posteriorly by a second fibrous cord, the **ligamentum venosum** (obliterated **ductus venosus**). The position of the original course of the **umbilical** vein across the left portal is marked, in adult life, by a dilation of the latter vein, **called the umbilical recess** (fig. 573).

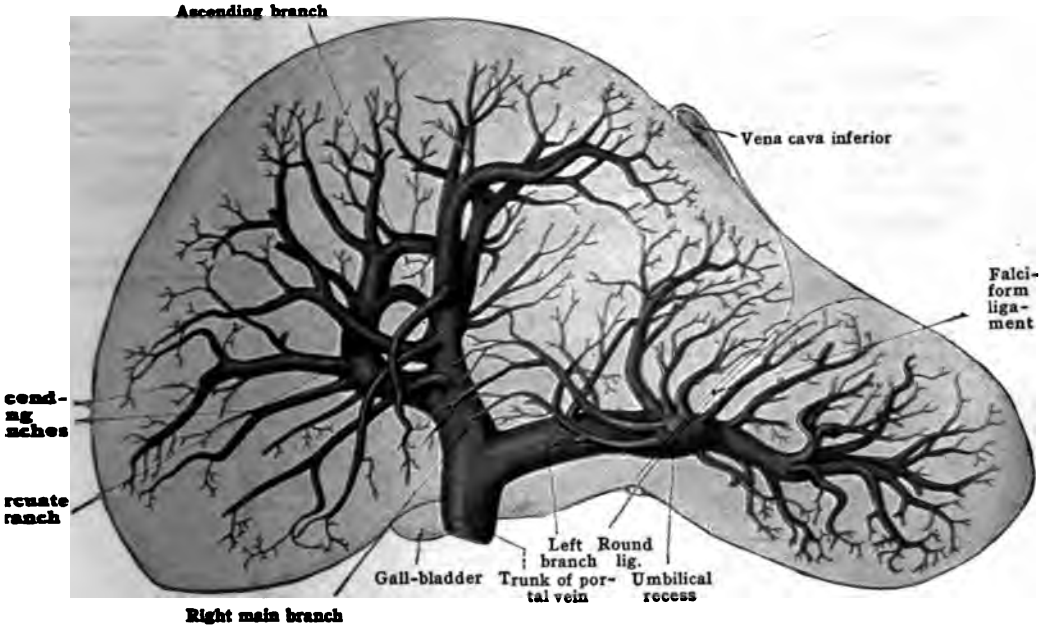
Tributaries.—The portal vein receives (1) the pyloric; (2) the coronary (**gastric**); (3) the cystic; (4) the superior mesenteric; and (5) the splenic veins.

1. **The pyloric** vein (figs. 572, 574) begins near the pylorus in the lesser curve of the stomach, **and,** running from left to right with the right gastric artery, opens directly into the lower part **of the portal** vein. It receives branches from the pancreas and duodenum.

2. **The coronary** vein [v. coronaria ventriculi] (figs. 572, 574) runs with the left gastric **artery,** first from right to left, along the lesser curvature of the stomach, toward the cardiac **end, and** then, turning to the right, passes across the spine from left to right to end in the **portal trunk** a little higher than the pyloric vein. At the cardiac end of the stomach it receives **small branches** from the esophagus.

3. **The cystic** vein [v. cystica] (fig. 574) returns the blood from the gall-bladder. It usually **opens into** the right branch of the portal vein.

FIG. 573.—THE PORTAL VEIN WITHIN THE LIVER. (After Rex.)



4. **The superior mesenteric** vein [v. mesenterica superior] (fig. 575) begins in **tributaries which correspond** to the branches of the superior mesenteric artery. **It courses upward a little** in front and to the right of the artery, passing with that **vessel from between** the layers of the mesentery. It passes in front of the **inferior portion of the duodenum,** and behind the pancreas, where it joins the **splenic vein to form** the portal trunk (fig. 572).

Tributaries.—In addition to the tributaries corresponding to the branches of **the superior mesenteric** artery—viz. the **ileocolic, right colic, middle colic** and **intestinal veins** (fig. 575)—it receives the **right gastroepiploic** and the **pancreatico-duodenal veins** just before its termination in the portal vein.

The **right gastroepiploic** vein [v. gastroepiploica dextra] (fig. 574) accompanies the artery of that name. It runs from left to right along the greater curvature of the stomach, receiving branches from the anterior and posterior surfaces of that viscus, and from the great omentum, and, passing behind the superior portion of the duodenum, ends in the superior mesenteric vein just before that vessel joins the portal trunk.

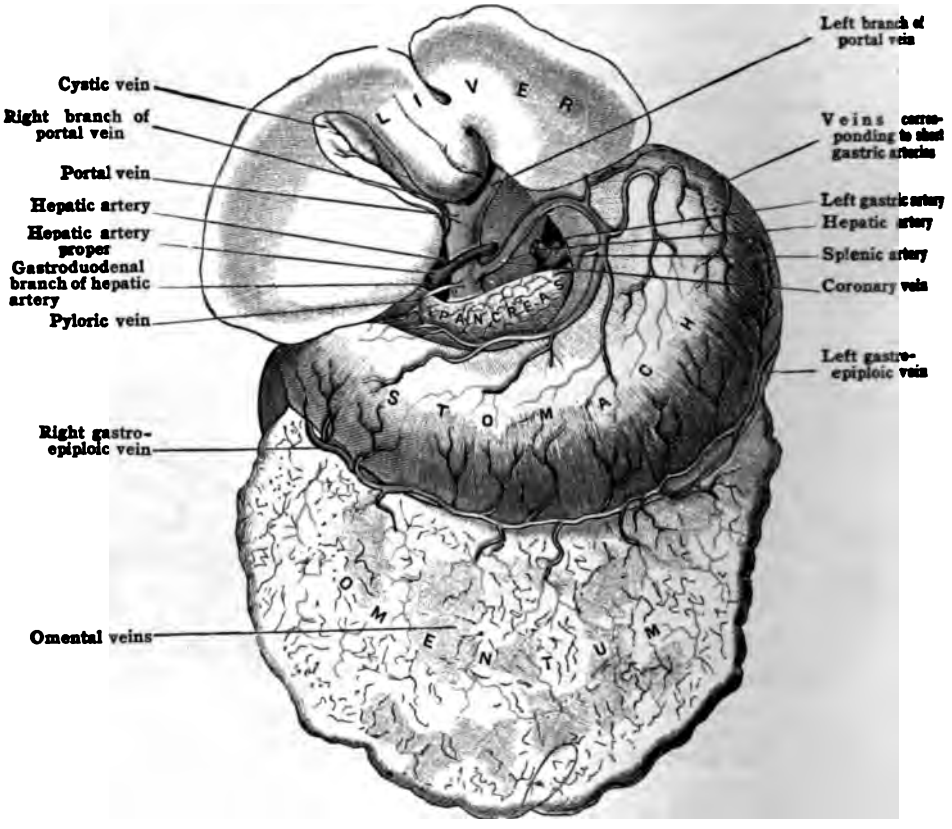
The **pancreatioduodenal** veins [vv. pancreaticoduodenales] (fig. 572) run with the superior and inferior pancreaticoduodenal arteries between the head of the pancreas and the second portion of the duodenum. They receive **pancreatic** and **duodenal** veins [vv. pancreaticæ et duodenales] and are collected into a single stem which follows the inferior pancreaticoduodenal artery and ends in the superior mesenteric vein a little below the right gastroepiploic vein.

5. The **splenic** vein [v. lienalis] (fig. 572) issues as several large branches from the hilus of the spleen. These soon unite to form a large trunk, which passes across the aorta and vertebral column in company with the splenic artery, below which it lies, to join the superior mesenteric vein at nearly a right angle. In this course it lies behind the pancreas; and at its union with the superior mesenteric to form the vena porta it is in front of the vena cava inferior.

Tributaries.—The splenic vein receives the **short gastric** veins [vv. gastricæ breves], from the fundus of the stomach, the **left gastroepiploic vein**, and the **inferior mesenteric** vein. As it lies in contact with the pancreas it receives also some small **pancreatic** veins [vv. pancreaticæ].

The **left gastroepiploic** vein [v. gastroepiploica sinistra] (fig. 574) accompanies the left gastroepiploic artery. It runs from right to left along the greater curvature of the stomach, receives branches from the stomach and omentum, and opens into the commencement of the splenic vein.

FIG. 574.—THE VEINS OF THE STOMACH AND THE PORTAL VEIN.
(From a dissection by W. J. Walsham.)

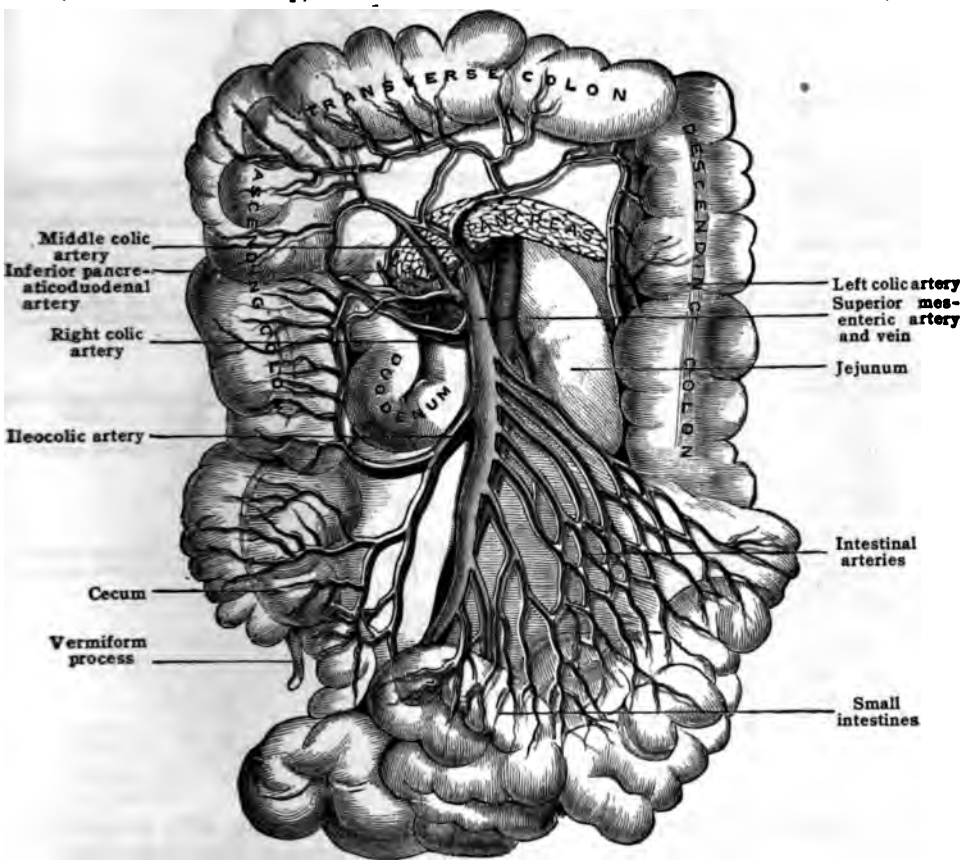


The **inferior mesenteric** vein [v. mesenterica inferior] (**fig. 572**) begins at the rectum as the superior hemorrhoidal vein. This emerges from the hemorrhoidal plexus in which it communicates freely with the middle and inferior hemorrhoidal veins. It passes out of the pelvis with the inferior mesenteric artery; but, after receiving the **sigmoid** and **left colic veins** [vv. sigmoideæ et v. colica sinistra] which accompany the arteries of the same names, it leaves the artery and runs upward on the psoas to the left of the aorta and behind the peritoneum. On approaching the pancreas it turns medially, and passes obliquely behind that gland to join the splenic vein just before the latter unites with the superior mesenteric to form the vena porta.

The adult portal vein and its tributaries contain no valves, a circumstance which adversely affects the circulation of blood within this system. The liability to excessive pressure in the most dependent part of the portal system is evidenced by the great frequency of the condition known as piles (hemorrhoids), due to dilation of the veins of the internal hemorrhoidal plexus. In early life valves are present in the veins of the stomach and of the intestinal wall but these undergo retrogression.

The accessory portal veins.—Since the blood returning from the abdominal portion of the digestive tract and spleen must pass through the hepatic capillaries before returning to the heart, extensive obliteration of these capillaries, such as occurs in certain diseases of the liver, would prevent the return of the portal blood to the heart were it not for anastomoses between tributaries of the portal vein and those of the caval systems, constituting what have been termed accessory portal veins. Some of the more important of these are—(1) between the branches of the coronary vein of the stomach and the esophageal veins which open into the vena azygos; (2) between the **parumbilical** veins [vv. parumbilicales], which communicate with the portal vein above and descend upon the ligamentum teres to the anterior abdominal wall to anastomose with the superior and inferior epigastric and superior vesical veins; (3) between the superior and middle hemorrhoidal veins, the latter opening into the hypogastric, and (4) between a wide-meshed retroperitoneal plexus of veins which communicates with the portal vessels over the posterior surface of the liver and the veins of the pancreas, duodenum and ascending and descending colon on the portal side, and with the phrenic and azygos veins on the systemic.

FIG. 575.—THE SUPERIOR MESENTERIC VEIN.
(The colon is turned up, and the small intestines are drawn over to the left side.)



THE COMMON ILIAC VEINS

The common iliac veins [vv. iliacæ communes], (fig. 577) are formed opposite the sacroiliac articulation by the confluence of the external iliac and hypogastric (internal iliac) veins. They converge as they ascend, and unite opposite the upper border of the fifth lumbar vertebra and a little to the right of the median line to form the vena cava inferior.

The right vein, shorter and more vertical in direction than the left, passes obliquely behind the right common iliac artery to its lateral side, where it is joined by the left common iliac vein.

The left vein lies to the medial side of the left common iliac artery, and, after crossing in front of the promontory of the sacrum and the fifth lumbar vertebra below the bifurcation of the aorta, passes beneath the right common iliac artery to join the right vein and form the vena cava inferior. The left vein may contain an imperfect valve.

Tributary.—The iliolumbar veins may enter the lower part of the common iliac, or open into the hypogastric vein. The left vein receives the middle sacral vein.

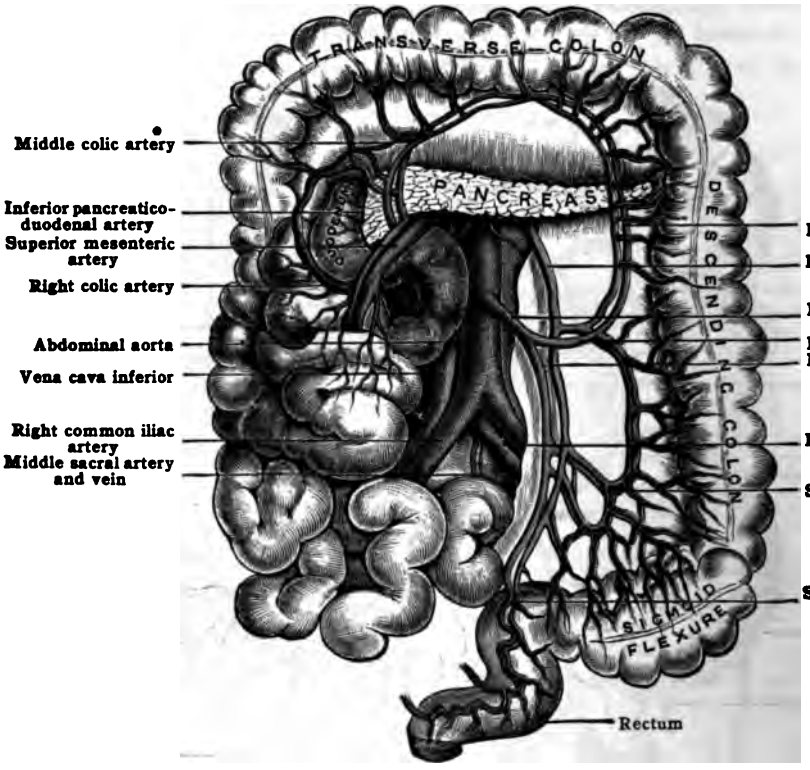
The middle sacral vein [v. sacralis media] opens usually as a single trunk into the left common iliac vein. The venæ comitantes which form it ascend on either side of the middle sacral

artery in front of the sacrum. They communicate with the lateral sacral veins, forming the anterior sacral plexus [plexus sacralis anterior] which receives the sacral intervertebral veins, and anastomoses freely with the neighboring lumbar and pelvic veins. Below, the middle sacral veins communicate with the hemorrhoidal veins.

THE VEINS OF THE PELVIS

The veins of the pelvis consist of the hypogastric vein, the spermatic or ovarian veins (according to sex) and the middle sacral vein. The spermatic and ovarian veins (p. 708) and the middle sacral vein have already been described.

FIG. 576.—THE INFERIOR MESENTERIC VEIN.
(The colon is turned up, and the small intestines are drawn to the right side.)



THE HYPOGASTRIC VEIN

The **hypogastric (internal iliac)** vein [v. hypogastrica] **(fig. 577)** is formed by the confluence of the veins (except the umbilical) corresponding to the branches of the hypogastric artery on each side. It varies considerably in length, but is usually quite a short trunk, extending from the upper part of the great sciatic foramen to the sacroiliac articulation, where it joins the external iliac to form the common iliac vein. It lies behind and a little medially to the hypogastric artery. It contains no valves.

Tributaries.—The hypogastric vein receives directly or indirectly the following vessels on each side:—the superior gluteal, iliolumbar, lateral sacral, obturator, inferior gluteal (sciatic), internal pudendal, and (in the female) the uterine veins; also branches from the pudendal, vesical, and hemorrhoidal plexuses. The single umbilical vein—corresponding to the right and left umbilical arteries—does not enter the pelvis, but, leaving the umbilical arteries at the navel, passes along the falciform ligament to the liver. After birth it is converted into the ligamentum teres hepatis. (See PORTAL VEIN, p. 711.)

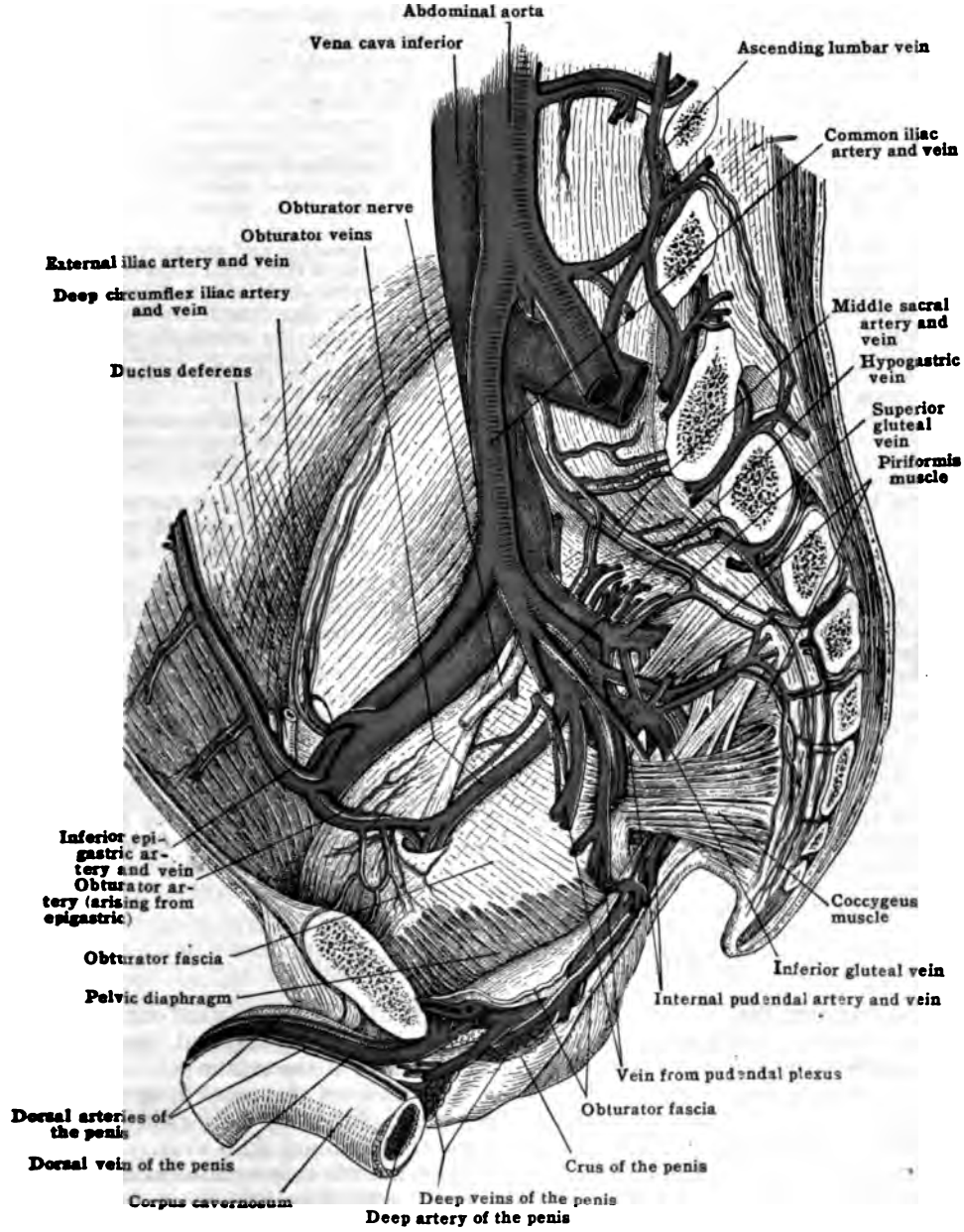
The superior gluteal veins [vv. glutææ superiores] (fig. 577) accompany the superior gluteal artery and, passing through the upper part of the great sciatic foramen, open into the hypogastric vein near its termination, either separately or as a single trunk.

The iliolumbar veins [vv. iliolumbales] open into the hypogastric a little higher than the superior gluteal. At times they join the common iliac vein.

The lateral sacral veins [vv. sacrales laterales] (fig. 577) join the superior gluteal or the hypogastric at or about the same situation as the gluteal. They form with the middle sacral veins a plexus in front of the sacrum, which receives tributaries from the sacral canal.

The obturator vein [v. obturatoria] (fig. 577), which lies below the obturator artery as it crosses the side of the pelvis, opens into the front of the hypogastric vein a little below the superior gluteal. Its branches correspond to those of the artery.

FIG. 577.—THE VEINS OF THE PELVIS, MALE. (After Toldt, 'Atlas of Human Anatomy, Rebman, London and New York.)



The inferior gluteal veins [vv. gluteæ inferiores] accompany the inferior gluteal (sciatic) artery, and, as a rule, unite to form a single trunk before joining the hypogastric a little below the obturator vein.

All the above veins so closely follow the ramifications of their respective arteries that no further special description is required. They all contain valves.

The **internal pudendal** vein [v. pudenda interna] (fig. 577) begins at the

termination of the deep veins of the penis [vv. profundæ penis] which issue from the corpus cavernosum penis with the artery of that body. These veins communicate with the dorsal vein at the root of the penis. In its course the internal pudendal vein runs with the internal pudendal artery, receiving tributaries corresponding to the branches of that vessel. It terminates in the lower part of the hypogastric vein.

The **dorsal vein of the penis** [v. dorsalis penis] (fig. 577) begins in a plexus around the corona glandis, then runs along the center of the dorsum of the penis between the two dorsal arteries. In this course it receives large tributaries from the interior of the organ, which, emerging for the most part between the corpus cavernosum urethra and corpus cavernosum penis, wind obliquely over the lateral surface of the latter structure to the dorsum of the penis to end in the dorsal vein. At the root of the penis the dorsal vein communicates with the subcutaneous veins of the dorsum of the penis and, leaving the arteries, passes straight backward between the two layers of the suspensory ligament. It then goes between the arcuate ligament and the transverse ligament of the pelvis, formed by the upper part of the fascia of the urogenital diaphragm. Here it bifurcates, each branch passing backward and downward to the pudendal plexus of veins. At times the dorsal vein begins as two branches, which run between the dorsal arteries and only unite to form a single trunk about 3.7 cm. ($1\frac{1}{2}$ in.) from the symphysis. After dividing into a right and a left branch within the pelvis, each vessel generally communicates with the obturator vein by a branch passing over the back of the pubis to the obturator foramen.

The **pudendal plexus** [plexus pudendalis] surrounds the prostate and the neck and fundus of the bladder. It receives in front the right and left divisions of the dorsal veins of the penis, and communicates with the posterior scrotal veins [vv. scrotales posteriores] and with the hemorrhoidal plexus. The prostatic veins and the vesical plexus open into it, and it also communicates with the internal pudendal vein. The veins forming the plexus are of large size, especially in old men, in whom they often become varicose, and contain phleboliths, or vein-stones. The plexus is surrounded by the *fascia prostata* (prostatic sheath); it terminates in a single stem on each side which opens into the hypogastric vein.

In the female the smaller pudendal plexus surrounds the urethra and receives the **dorsal and deep veins of the clitoris** [vv. dorsales et profundæ clitoridis], veins from the vestibule, and the **posterior labial** veins [vv. labiales posteriores]. It communicates freely with the uterovaginal plexus and is drained by the hypogastric veins.

The vesical plexus [plexus vesicalis] surrounds the apex, the sides, and the anterior and posterior surfaces of the bladder. It is situated between the muscular coat and the peritoneum, and where the bladder is uncovered by peritoneum external to the muscular coat in the pelvic cellular tissue. It opens into the pudendal plexus.

The **uterovaginal plexus** [plexus uterovaginalis] connects with the hemorrhoidal, vesical, and uterine plexuses. Its lower part drains through the internal pudendal veins and the pudendal plexus, and its upper portion largely through the ovarian veins, and partly through the **uterine veins** [vv. uterinæ] to the hypogastric (fig. 571).

The **hemorrhoidal plexus** [plexus hemorrhoidalis] surrounds the rectum, and is situated at the lower part of that tube. It consists of two portions, one of which, the internal hemorrhoidal plexus, is situated between the muscular and mucous coats, while the other, the external hemorrhoidal plexus, rests upon the outer surface of the muscular coat. The veins of this latter plexus terminate in the inferior, middle, and superior hemorrhoidal veins. The inferior [vv. hemorrhoidales inferiores] join the internal pudendal; the middle [v. hemorrhoidalis media] accompanies the middle hemorrhoidal artery and opens into the hypogastric and superior hemorrhoidal veins; the superior (p. 712) forms the commencement of the inferior mesenteric vein, and through this the blood gains the portal vein. None of these veins has any valves, hence the enlargement of the inferior hemorrhoidal veins, when the portal vein is obstructed, as in cirrhosis of the liver. Through the hemorrhoidal veins a free communication is established between the systemic and portal system of veins.

THE EXTERNAL ILIAC VEIN

The **external iliac** vein [v. iliaca externa] (fig. 577), is the upward continuation of the femoral. Beginning at the distal border of the inguinal ligament, it accompanies the external iliac artery along the brim of the minor pelvis, lying at first on the superior ramus of the pubis, and then on the psoas major muscle. It terminates by joining the hypogastric vein behind the hypogastric artery, opposite the sacroiliac articulation, to form the common iliac vein. It lies at first medially to the external iliac artery, and on the left side remains medial to the artery throughout its course. On the right side, however, as it ascends, it gradually gets behind the artery. It contains one or two valves.

In addition to the femoral, the external iliac receives the **inferior epigastric** veins [v. epigastrica inferior] (fig. 577) and the **deep circumflex iliac vein** [v. circumflexa ilium profunda] (fig. 582), which accompany the arteries of the same name. They anastomose with the superior epigastric, lumbar, iliolumbar, and superior gluteal veins, and with the superficial epigastric and superficial circumflex iliac veins.

THE VEINS OF THE LOWER EXTREMITY

The **veins of the lower extremity** are divided into (I) the superficial and (II) the deep. The **superficial** veins lie in the subcutaneous tissue superficial to the deep fascia, through which they receive numerous communicating branches from the deep veins. They are collected chiefly into two main trunks, which, beginning on the foot, extend upward, one, the great saphenous, lying anteromedially, and the other, the small saphenous, posterolaterally. The former finally joins the femoral vein by passing through the deep fascia at the groin; the latter reaches the popliteal by perforating the fascia at the ham. The **deep** veins, on the other hand, accompany their corresponding arteries. All the veins of the lower limb have valves which are more numerous than in the veins of the upper extremity and more numerous in the deep than in the superficial veins.

I. THE SUPERFICIAL VEINS OF THE LOWER EXTREMITY

The **superficial veins of the lower limb** begin in the plexuses of the foot. The **dorsal digital** veins [vv. digitales pedis dorsales] collect blood from the dorsal surfaces of the toes and unite in pairs, around each cleft, to form the **dorsal metatarsal** veins [vv. metatarseæ dorsales pedis]. The dorsal metatarsal veins, of which the first and fifth are larger than the others, join the **dorsal venous arch** [arcus venosus dorsalis pedis]. This arch is convex toward the toes and crosses near the bases of the metatarsal bones. From the medial and lateral ends of the arch the great and small saphenous veins, respectively, take origin. The area of the dorsum of the foot contained between the arch and the two saphenous veins is covered by the **dorsal venous rete** [rete venosum dorsale pedis] which extends as high as the ankle-joint (figs. 578, 580).

On the plantar surface the **plantar digital** veins [vv. digitales plantares] return the venous blood to the clefts of the toes and unite to form the **common digital** veins [vv. digitales communes pedis]. The common digital veins join freely with one another on the sole to form the **plantar venous rete** [rete venosum plantare]. There are numerous communications between the superficial veins of the dorsum and sole. These occur both in the clefts of the toes, by means of the **intercapitular** veins [vv. intercapitulares], and around the margins of the foot. Communications between the superficial and deep veins of the foot are very free (fig. 581).

The **great** (or internal) **saphenous** vein [v. saphena magna] (fig. 578) commences at the medial end of the dorsal venous arch, and, after receiving branches from the sole which join it by turning over the medial border of the foot, it turns proximally in front of the medial malleolus. It passes about a finger's breadth behind the medial border of the tibia in company with the saphenous nerve, which becomes superficial just below the knee. It then passes behind the medial epicondyle, and then runs up on the medial side of the front of the thigh to about 3.7 cm. (1¼ in.) below the inguinal ligament, where it dips through the fossa ovalis (saphenous opening) in the fascia lata, and ends in the femoral vein.

Tributaries.—In its course through the leg and thigh the great saphenous receives numerous unnamed cutaneous tributaries. In the thigh it often receives a large vein, the femoropopliteal which communicates with the small saphenous, and several of the cutaneous veins on the lateral part of the thigh, and a second vein, the **accessory saphenous** [v. saphena accessoria], formed by the union of the cutaneous veins from the medial and back part of the thigh (fig. 578). The great saphenous vein contains from ten to twenty valves.

Immediately before entering the fossa ovalis the great saphenous vein receives the superficial epigastric, superficial circumflex iliac, and external pudendal veins, though any of these veins—or all of them—may pierce the fascia separately and enter the femoral vein.

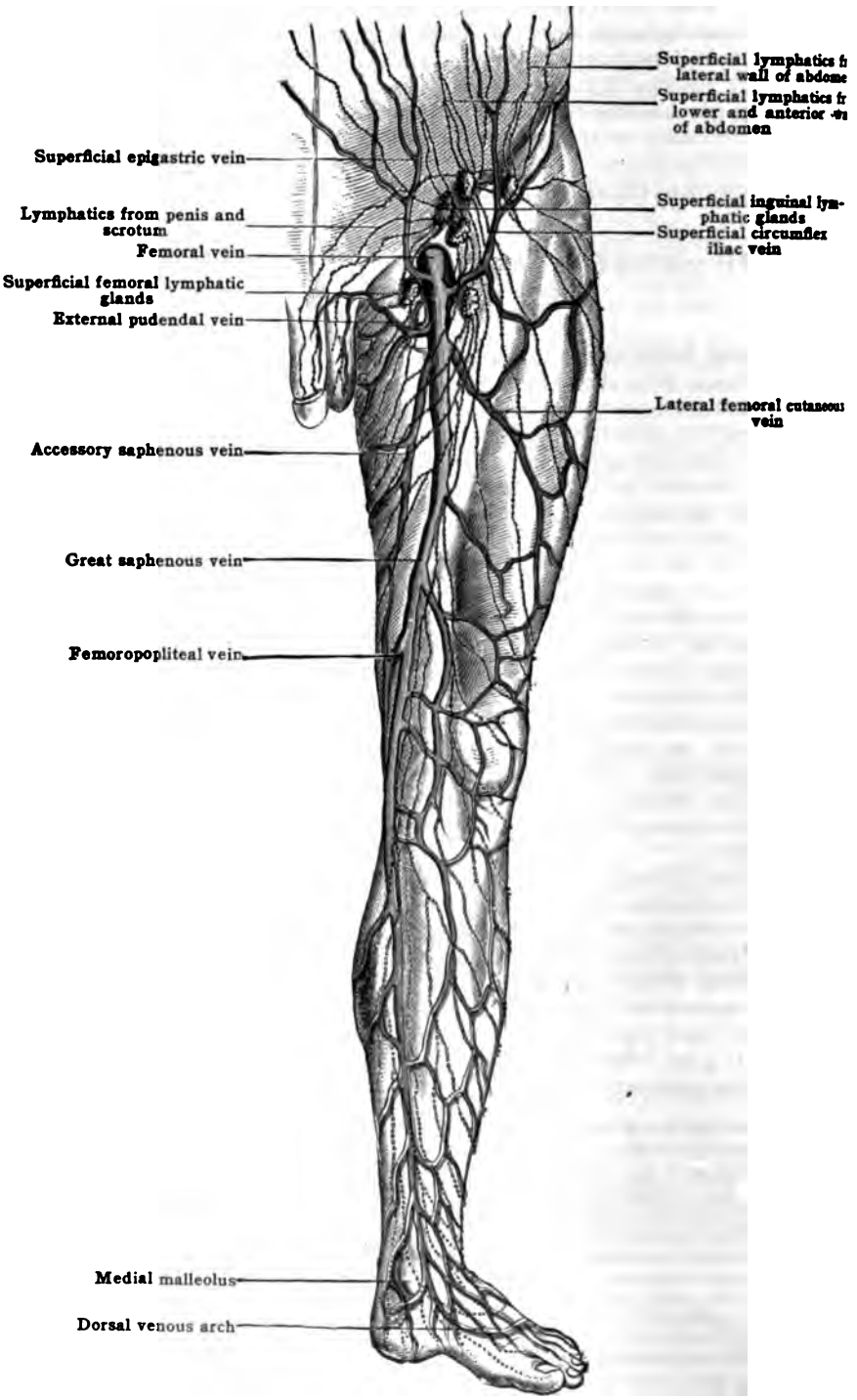
The **superficial epigastric** vein [v. epigastrica superficialis] anastomoses with the superficial abdominal, and parumbilical veins.

The **superficial circumflex iliac** vein [v. circumflex ilium superficialis] anastomoses with the thoraco-epigastric and the superficial circumflex iliac veins.

The **external pudendal** veins [vv. pudendæ externæ] collect venous blood from the **anterior scrotal or labial veins**, which anastomose with the posterior scrotal or labial veins, and from the **subcutaneous veins of the dorsum of the penis** [vv. dorsales penis subcutaneæ].

The **small saphenous** vein [v. saphena parva] (fig. 579) begins at the la end of the venous arch on the dorsum of the foot. After receiving branches the sole, which turn over the lateral border of the foot, it passes behind the la

FIG. 578.—THE SUPERFICIAL VEINS AND LYMPHATICS OF THE LEFT LOWER LIM (Walsham).

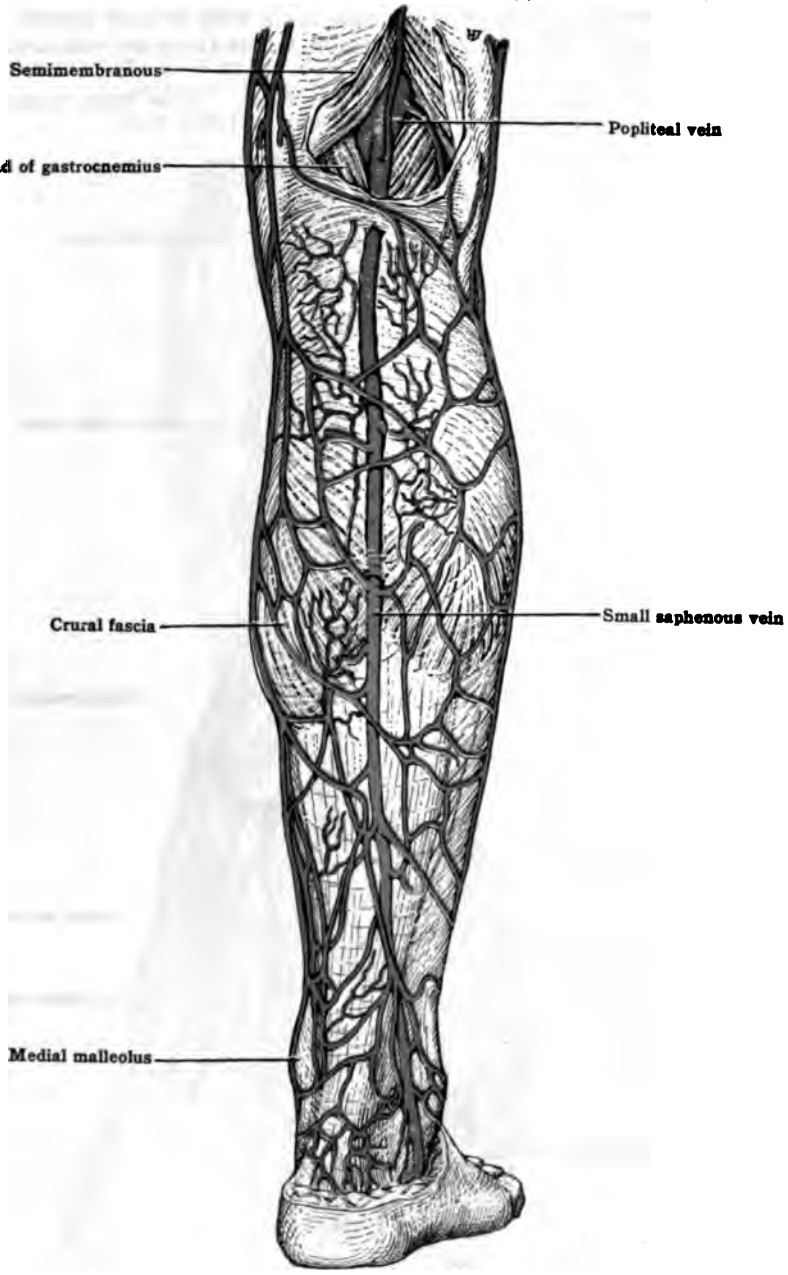


malleolus, and turns proximally, passing at first along **the lateral side of the calcaneus** (Achillis), afterward along the back of the **calf, in company wi ral** (short saphenous) nerve, to about the lower part of **the popliteal fossa,**

ates the deep fascia, and, sinking between the two heads of the gastrocne-
ens into the popliteal vein.

taries.—As it passes along the calf between the superficial and deep fascia, it receives
s cutaneous veins from the heel, and the lateral side and back part of the leg, and
icates at intervals, through transverse or intermuscular branches, with the deep veins

FIG. 579.—SMALL SAPHENOUS VEINS. (After Bonamy, Broca and Beau).

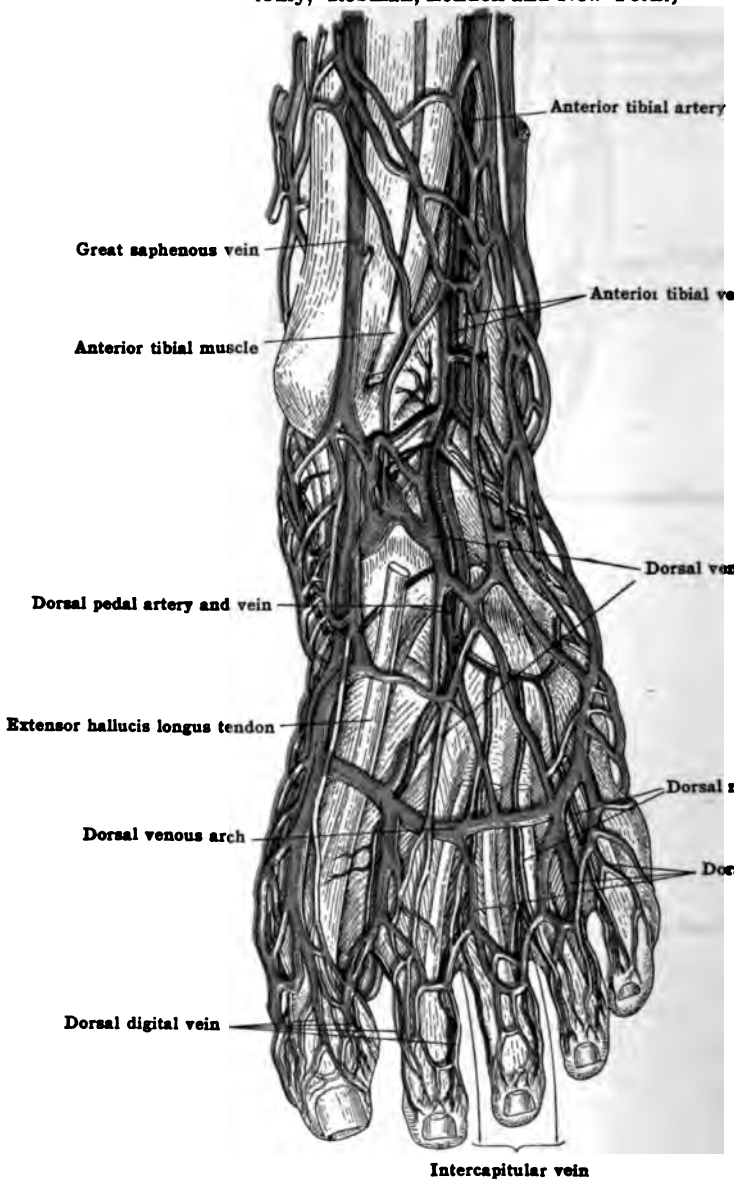


nying the peroneal artery. Just before perforating the deep fascia, it receives a large
ng branch, the **vena femoropoplitea** (fig. 578), from the lower and back part of the thigh.
mmunicates with a plexus of veins upon the posterior and lateral regions of the thigh and
great saphenous. In many cases the small saphenous vein is entirely drained, by means
moropopliteal, into the great saphenous. Under these circumstances the usual place
nation of the small saphenous is marked by a small vein opening into the popliteal. A
shoot from the inferior sural branch of the popliteal artery accompanies this vein for
listance along the back of the calf. The small saphenous vein contains from nine to
alves.

II. THE DEEP VEINS OF THE LOWER EXTREMITY

The **deep veins of the lower extremity** [venæ comitantes] accompany the arteries, and have received corresponding names. From the foot to the knee there are two veins to each artery. These veins run on either side of the corresponding artery, and communicate at frequent intervals with each other across it. From the knee upward there is a single main vein to each artery, except at the back of the thigh and in the gluteal region, where there are commonly two.

FIG. 580.—THE VEINS OF THE DORSUM OF THE FOOT. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



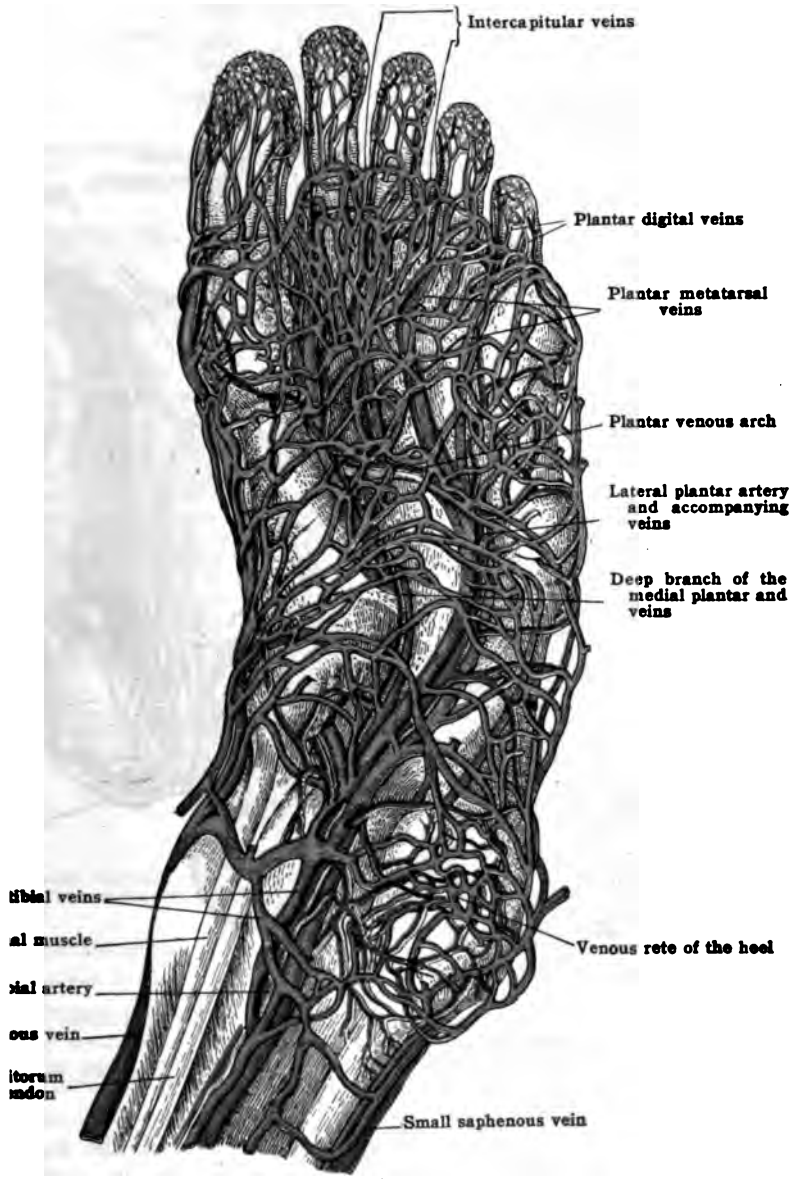
The veins of the foot and leg.—The deep veins of the foot become separated from the superficial where the plantar metatarsal veins [vv. metatarseæ plantares] leave the plantar digital and intercapitular veins to accompany the plantar metatarsal arteries. The plantar metatarsal veins empty into the plantar venous arch [arcus venosus plantaris] which accompanies the arterial plantar arch in the depth of the sole (fig. 581).

terior tibial veins [vv. tibiales posteriores] drain the plantar venous e superficial rete (fig. 583).

w the posterior tibial artery through the leg, receiving tributaries corresponding to the largest of which are the **peroneal veins** [vv. peroneæ]. They unite with the venæ comitantes at the lower border of the popliteus muscle.

rior tibial veins [vv. tibiales anteriores] begin in the dorsal venous rete any the anterior tibial artery through the leg receiving tributaries corto branches of the artery.

IE VEINS OF THE SOLE OF THE FOOT. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)


Intercapitular veins
Plantar digital veins
Plantar metatarsal veins
Plantar venous arch
Lateral plantar artery and accompanying veins
Deep branch of the medial plantar and veins
Venous rete of the heel
Small saphenous vein

backward between the interosseous membrane and the tibia and fibula to unite terior tibial veins. The posterior and anterior tibial veins unite at the distal popliteus muscle to form the popliteal vein.

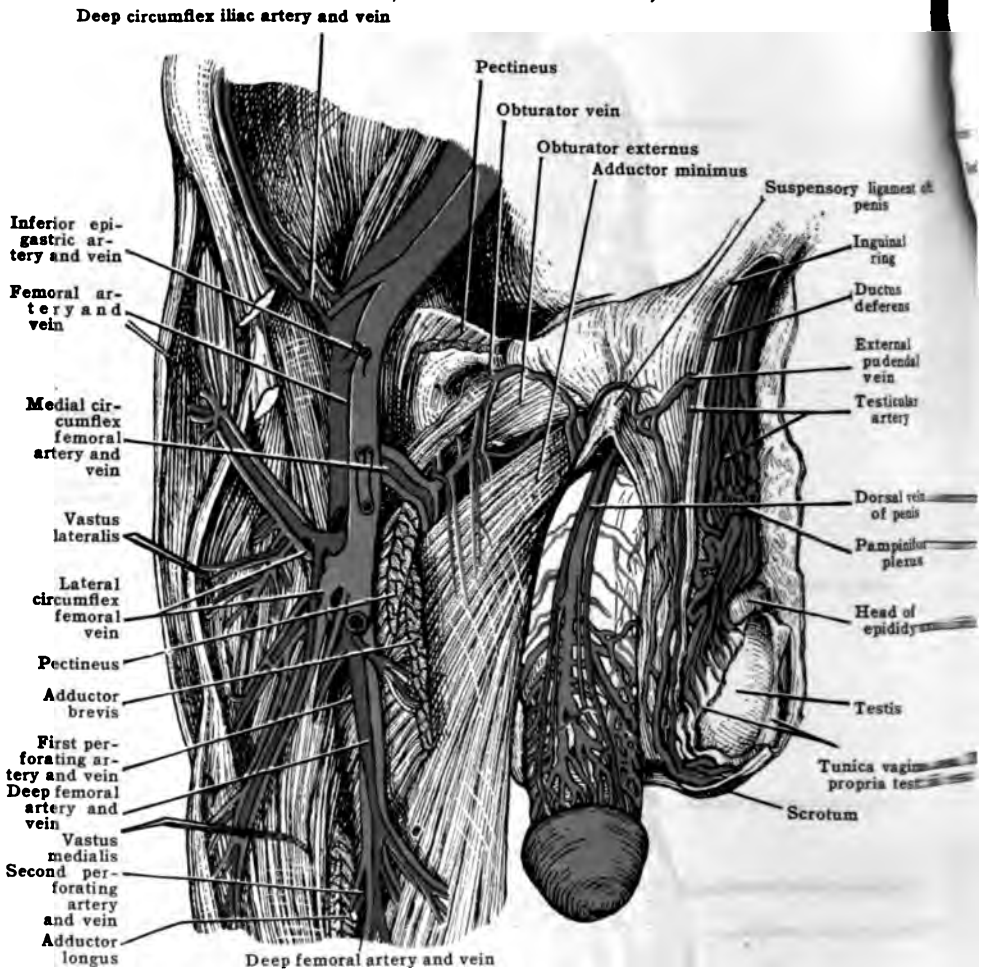
veins contain numerous valves, and communicate, by means of intermuscular h the superficial veins.

liteal vein [v. poplitea] (fig. 583), is formed by the confluence of the antes of the anterior and posterior tibial arteries at the distal border

of the popliteus, and extends proximally to the opening in the adductor magnus at the junction of the middle and distal third of the thigh, where it changes its name to femoral.

The popliteal vein accompanies the popliteal artery, lying superficial to it in the whole of its course, and tightly bound down to it by its fascial sheath. At the lower part of the fossa it is a little medial to the artery, but, crossing the vessel obliquely as it ascends, lies a little lateral to it at the proximal part of the fossa. The tibial (internal popliteal) nerve lies superficial to the vein, being lateral to it above, then posterior to it, and then a little to its medial side. The popliteal vein contains two or three valves.

FIG. 582.—VEINS OF THE THIGH, PENIS AND TESTIS. (After Toldt, 'Atlas of Human Anatomy', Rebman, London and New York.)



The popliteal receives the small saphenous vein. It is also joined on its lateral and medial sides by the *accessory popliteal* veins [vv. popliteæ accessoriæ] which form common trunks of termination of the sural and articular veins of the respective sides. The medial vein receives in addition, through a plexus extending as high as the opening in the adductor magnus, the veins accompanying the a. genu suprema.

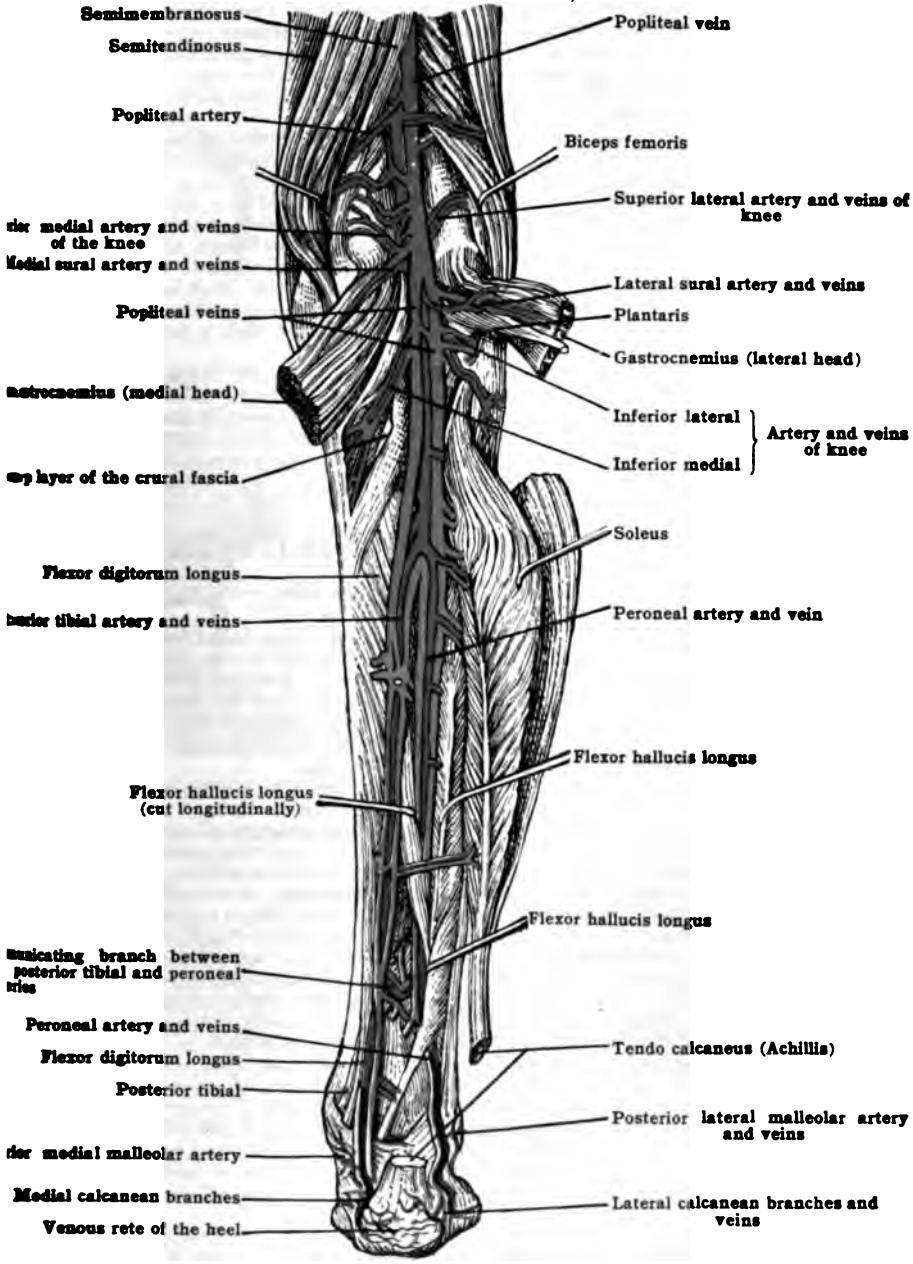
The **femoral** vein [v. femoralis], the continuation of the popliteal extends from the tendinous opening in the adductor magnus to the inguinal ligament. In this course its relations are similar to those of the femoral artery. As the vein passes through the adductor canal, it lies behind and a little lateral to the artery. At the apex of the femoral trigone (Scarpa's triangle) it is still posterior to the artery, but gradually passes to the medial side as it passes through the trigone (fig. 582).

In the neighborhood of the inguinal ligament the femoral vein lies on the same plane as the artery from which it is separated by a delicate prolongation of the fascia stretching between the front and back layers of the femoral sheath. On the medial side the vein is separated by a

r septum from the femoral canal. For relations of the femoral sheath and canal to femoral , see p. 1398. The femoral vein contains five pairs of valves.

ributaries.—The femoral vein receives (in addition to the great saphenous and, in some cases the superficial veins of the epigastrium and groin) the nda veins and a variable number of small femoral venæ comitantes.

83.—The Deep Veins of the Leg. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



e profunda femoris veins [vv. profundæ femoris] arise from the venæ comitantes correing to branches of the profunda femoris artery. The **medial and lateral circumflex** veins t blood from the muscles of the adductor and lateral rotator regions. The **perforating** anastomose with femoropopliteal and other veins of the posterior femoral region, and with rcumflex and accessory popliteal veins. They return blood from the femur and the tor, hamstring and vasti muscles.

addition to the main femoral vein, there are two very small **venæ comitantes,** which ipany the femoral artery on either side. They anastomose with one another, with the

femoral, and often with the popliteal vein. They terminate in the femoral a short distance above the profunda veins.

MORPHOGENESIS AND VARIATIONS OF THE VEINS

The developing heart, as soon as it has assumed the simple tubular form, is found to receive two pairs of veins, the vitelline and umbilical (fig. 34). The right and left vitelline veins return blood from the yolk-sac and reach the heart by traversing the splanchnic mesoderm. The single umbilical vein, which returns blood from the placental part of the chorion, reaches the embryo by way of the body-stalk. Before entering the body-wall it divides into two branches, each of which traverses the somatopleure of its own side to unite with the corresponding vitelline vein near the venous end of the heart. The heart thus receives two short common vitelloumbilical trunks which join the parts of the sinus venosus known as the right and left sinus-horns.

During the further course of development two pairs of veins appear which are entirely intraembryonic; they are the right and left precardinals and postcardinals. The precardinal veins drain the head and neck, while the postcardinals drain the trunk and developing extremities. Each precardinal vein joins the postcardinal vein of its own side to form a medially directed vessel called the common cardinal. Each common cardinal unites with the common vitelloumbilical stem of its own side. The two common cardinal veins, although they undergo a considerable amount of shifting, are recognizable until a relatively late stage of development, while the proximal parts of the vitelline and umbilical veins, on the other hand, are partially destroyed. The *duct of Cuvier*, the venous trunk which leads into either horn of the sinus venosus, probably includes the entire common cardinal vein together with a portion of the original vitelloumbilical trunk.

Little is known regarding the development of the PULMONARY VEINS. The efferent components of the embryonic capillary plexus from which the pulmonary arteries arise are probably connected with the left atrium. That these components occasionally form abnormal connections with systemic veins is indicated by some of the anomalies which may occur. One or other of the pulmonary veins has been found to open into the vena cava superior, into the left innominate, or into the vena azygos.

THE VENA CAVA SUPERIOR AND ITS TRIBUTARIES

1. MORPHOGENESIS

(*a*) **Vena cava superior.**—The *precardinal veins* at first return blood from the head and neck only (fig. 34). As the heart gradually migrates toward the thorax, however, relative positions become altered and the precardinal veins soon receive, through the subclavian veins, the blood returning from the upper extremities also. By the time the venous end of the heart has entered the thoracic region the Cuverian ducts no longer preserve their original transversely dorsoventral position. They begin to assume a longitudinal direction and become the proximal portions of the symmetrically placed venæ cavæ superiores.

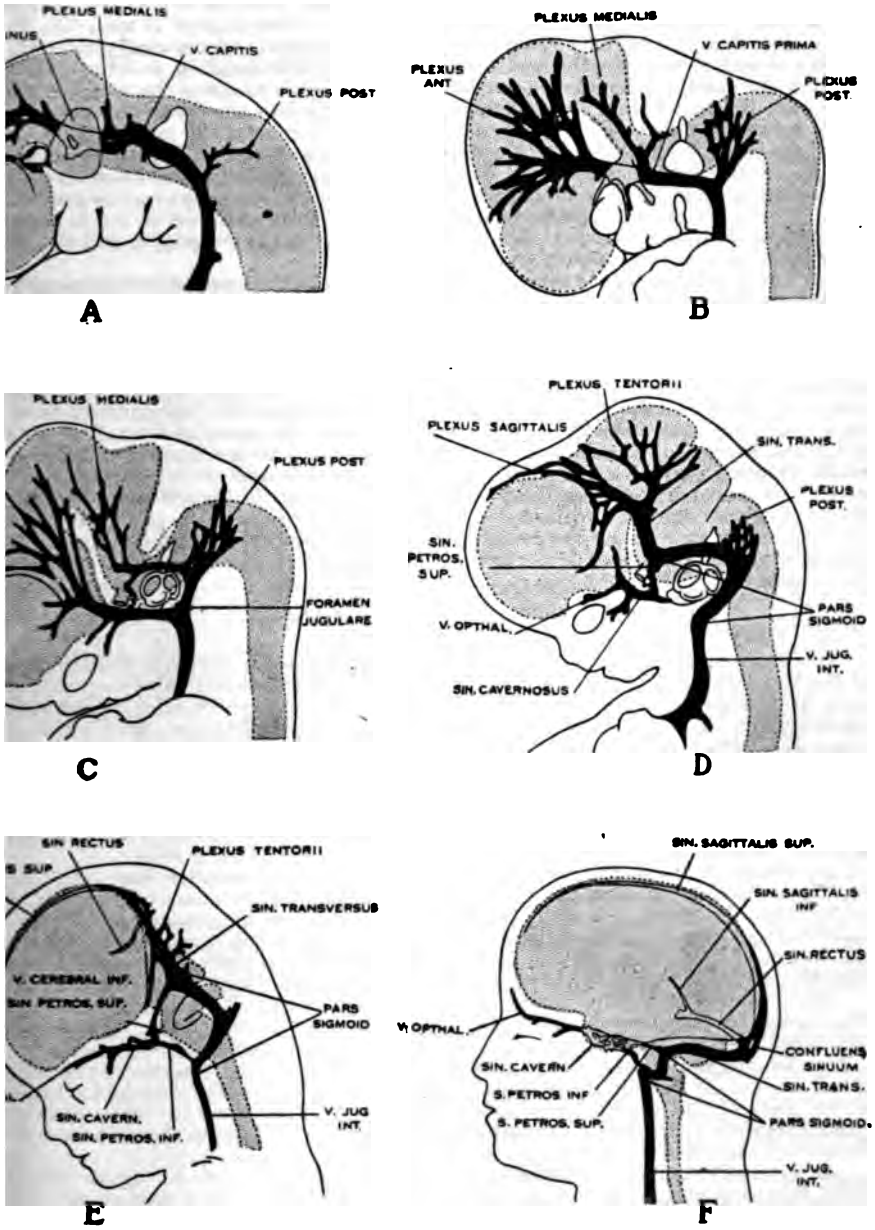
At a stage of about 16 mm. the thymicothyroid veins, which open into the right and left precardinals, become connected and form a transverse venous channel between the two precardinal veins. This soon becomes a large vessel, and its presence allows of a revision of the nomenclature of the neighboring venous channels. The cross-branch itself becomes the major part of the *left innominate vein*. The part of the right precardinal which extends from the right extremity of the cross-branch to the proximal end of the right subclavian vein, becomes the *right innominate vein*, while the part extending from the cross-branch to the right duct of Cuvier becomes the distal portion of the right *superior cava*. On the left side the parts immediately above and below the cross-branch, become the left end of the left innominate and the distal portion of the left superior cava respectively. The left innominate vein rapidly increases in size and the right superior cava gradually usurps the function of the corresponding vessel of the left side. The left vena cava superior eventually disappears but evidences of its former presence are recognizable in the adult as the *oblique vein of Marshall* (p. 564).

(*b*) **The veins of the neck and upper extremity.**—The portion of the precardinal vein extending from the innominate vein to the base of the skull on either side appears to become divided longitudinally to produce the *internal jugular* and *vertebral* veins (Thyng). The former drains the dural sinuses, while the latter receives the segmental veins which drain the vertebral plexuses. The embryonic *linguofacial vein* drains the submental and anterior and posterior facial regions into the internal jugular veins (F. T. Lewis), and becomes the *common facial vein*. The *external and anterior jugular veins*, which appear relatively late in development, may take over parts of the original linguofacial area of drainage.

The veins of the *upper extremity* at first form part of the general superficial venous plexus of the neck and thorax, which is drained by the umbilical vein and by the cardinals. A marginal vein soon becomes apparent upon the free border of the developing limb, the preaxial and postaxial limbs of which are known as the radial and ulnar vein respectively. The drainage of the upper extremity and the chest is now taken over by a large channel which connects the ulnar vein with the precardinal. The ulnar vein receives the largest vein of the chest, the thoracoepigastric, while the radial vein becomes reduced to a plexus. The ulnar vein becomes the *basilic* and the *axillary vein*, the thoracoepigastric becomes the *lateral thoracic*. The *subclavian* vein replaces the original channel of connection between the ulnar vein and the precardinal. The *venæ comitantes* of the deep arteries of the limb, and the *cephalic vein* appear later in development; the latter at first opens into the external jugular.

ıe **venous sinuses of the dura mater** (fig. 584).—The forebrain and midbrain are **vested, at an early stage of development, by a plexus of capillaries which eventually** ›nverted into the circulus arteriosus and the cerebral and choroidal arteries and veins. **us is drained on either side by a vein which courses along the ventrolateral aspect of** ›rain and is connected by an occipital intersegmental vein with the corresponding **al.** The longitudinal vein which forms the first part of the drainage line of the fore-

—DEVELOPMENT OF THE DURAL VENOUS SINSUES. (Streeter, Carnegie Contributions to Embryology, 1918.)



l **midbrain has long been known as the** *v. capitis medialis*, for it lies upon the medial **e cranial ganglia.** It was formerly thought to pass, by a form of anastomotic migra- **he lateral side of the ganglia, and thus become converted into the** *v. capitis lateralis*. **wever, finds that these vessels are formed independently and substitutes for them the** ***a primitiva rhombencephali*** **and** *vena capitis prima*, respectively.
lexus formed from the vasa primitiva rhombencephali is fed by arterial offshoots of ı **arch system.** It is subsequently converted into the arteries and veins of the hind- **n addition to receiving the venous stem of the forebrain and midbrain plexus, the** **tis prima receives two other branches from the plexuses of the anterior and posterior** **he hindbrain, respectively.** By the time the three main tributaries of the *v. capitis*

prima are fully formed, the forebrain and midbrain plexus consists of a superficial part, which drains the dura, and of the original deeper part in which cerebral arteries and veins are undergoing differentiation. The blood entering the three tributaries is derived very largely from the dural layer of the head. On this account the terms *anterior*, *middle*, and *posterior dural plexus* have been substituted by Streeter for the terms anterior, middle and posterior cerebral veins (of Mall).

The main dural venous channels present in embryos of the stage of 4 mm., and the alterations in their arrangements which lead to the production of the adult arrangement, are indicated in fig. 584. It will be seen that at the stage of 18 mm. (C), a new connection has arisen between the middle and posterior plexuses; this, together with the stem of the posterior plexus, will become the sigmoid part of the *sinus transversus*. At the stage of 21 mm. (D), the anterior and middle dural plexus have coalesced to form the sagittal and tentorial plexuses. The part of the *v. capitis prima* upon the medial side of the trigeminal ganglion, now the *sinus cavernosus*, receives the *ophthalmic* and *middle cerebral* veins. The remainder of the v. capitis prima having been lost, the blood from the cavernous sinus drains into the transverse sinus through the *sinus petrosus superior*, originally the lower part of the stem of the middle plexus. The drainage of the entire venous system of the dura mater is now effected through the sinus transversus. During the succeeding stages of development (E and F) the *inferior petrosal sinus* appears and the sagittal plexus becomes differentiated into the *sagittal sinuses* and *sinus rectus*. The tentorial plexus becomes the *confluens sinuum* and the horizontal part of the s. transversus, its connections with the posterior dural plexus form the *sinus occipitalis*, and the plexus itself persists, in part, as the *marginal sinuses*.

(*d*) **The azygos system of veins.**—The azygos, hemiazygos, accessory hemiazygos and superior intercostal veins are the adult representatives of the thoracic portion of a pair of embryonic veins to which Huntington and McClure have applied the term *supracardinal*. The supracardinal veins pursue a longitudinal course through the abdomen and thorax lying dorsolaterally to the aorta. They take over the drainage of the lumbar and intercostal veins from the postcardinals which eventually disappear almost entirely. The right and left supracardinal veins intercommunicate in several places, the persistence of one or two communications, at about the level of the eighth thoracic segment, usually determines the eventual drainage of the larger part of the left supracardinal vein into the right. The latter vein is connected superiorly, through a small persisting portion of the postcardinal, with the right duct of Cuvier (vena cava superior); its intrathoracic part becomes the vena azygos. The part of the left supracardinal above the fourth thoracic segment becomes the *left superior intercostal* vein. The part of the supracardinal which now drains downward, and across into the azygos becomes the *accessory hemiazygos*, while the remainder of the intrathoracic portion of the left supracardinal becomes the *hemiazygos* vein.

2. VARIATIONS

(*a*) **Vena cava superior.** The connection between the embryonic thymicothyroid veins of the two sides may fail to persist. In this case both embryonic venæ cavæ will persist and each receive the subclavian and internal jugular vein of its own side, the innominate veins being absent. The left vena cava superior may coexist with the right even when the embryonic connection between them has appeared in the usual way. The innominate veins are present in such cases, but the left is commonly small. A left vena cava superior may altogether replace the right of the adult in association with *situs inversus* or as an independent variation. The left superior cava is formed from the left duct of Cuvier and the adjacent part of the left precardinal vein and joins the coronary sinus. The abnormal termination of the vena cava inferior into the vena cava superior is mentioned below under the azygos system.

(*b*) **Veins of the neck and upper extremity.** The comparative size of the two internal jugular veins depends upon the manner of drainage of the dural sinuses. Either *the anterior* or *the external* jugular vein may be absent. In such cases the *common facial* vein resembles more closely than usual the embryonic linguofacial from which it is derived. The external or the anterior jugular vein may, on the other hand, almost entirely replace the common facial; variations in the relative extent of the areas drained by these three veins are extremely common.

The *cephalic* vein may be absent, or it may cross the clavicle to enter the external jugular. The *lateral thoracic* (embryonic thoracoepigastric) may be very large. The *subclavian* vein occasionally passes between the subclavius muscle and the clavicle.

(*c*) **Venous sinuses of the dura mater.** The *superior sagittal sinus* may be partially reduplicated, or it may bifurcate at the lambda and follow the limbs of the lambdoid suture to join the lateral ends of the ss. transversi (Malcarne). It may be small, or altogether absent. In either case the s. rectus and s. sagittalis inferior are large and receive the superior cerebral veins through dilated channels in the falx.

An accessory sinus or series of sinuses in the falx may drain both the s. sagittalis inferior and the v. magna cerebri in cases in which the *s. rectus* is absent. The s. rectus may drain only the v. magna cerebri in cases in which the *s. sagittalis inferior* is absent, or, being present, is drained into the superior sagittal sinus by large veins of the falx.

The *transverse sinuses* may be equal in size when the confluens sinuum is large, or the horizontal part may be absent from one side. Both ss. transversi may be small in cases in which the *s. occipitalis* is large enough to carry most of the blood from the confluens to the *marginal sinuses* and so to the jugular veins. The occipital and marginal sinuses may be absent.

The variations mentioned above seem to afford instances of lack of uniformity in the selection of channels from amongst the many alternative routes afforded by a plexiform system. The appearance of the *s. petrosquamosus* depends, in all probability, upon the occasional persistence of an anterior tributary to the stem of the middle dural plexus.

(*d*) **The azygos system of veins.** Variations in the details of the drainage of the intercostal veins are very common. They are referable either to an increase in the number of transverse

[redacted]ections between the two embryonic supracardinal veins or to their entire absence. In [redacted]me cases, all of the left intercostal veins may terminate in the v. azygos, the hemiazygos [redacted] and accessory hemiazygos being entirely absent. In such cases the single azygos vein [redacted]lly opens into the vena cava superior; it may, however, open through a persistent left duct [redacted]Cuvier into the coronary sinus (Gruber). In the absence of the part of the vena cava in[redacted]ior normally derived from the right subcardinal connecting with the hepatic vein, the lower [redacted]rt of the vena cava may be continued into the azygos (Winslow, etc.), or into the hemiazygos [redacted]d so into the azygos (Quain), or into a left-sided azygos vein which opens into the coronary [redacted]us.

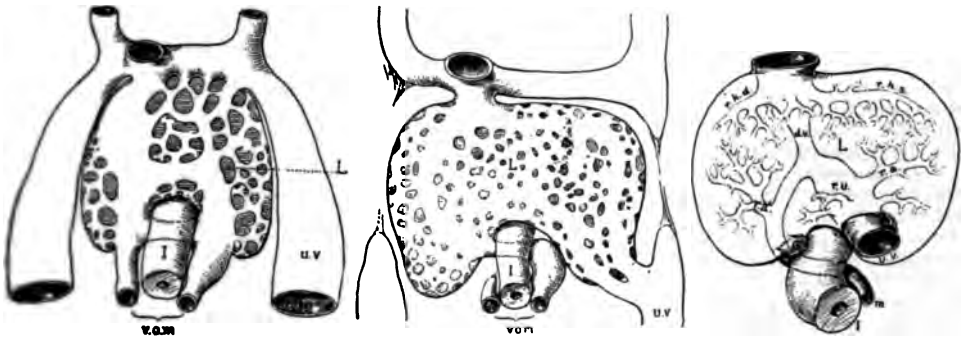
B. THE VENA CAVA INFERIOR AND ITS TRIBUTARIES

1. MORPHOGENESIS

The vena cava inferior is a vessel of a composite origin. The upper part of it receives the [redacted]patic veins, which contain the venous blood returning from the alimentary viscera; its devel[redacted]pment is described in connection with that of the portal system of veins. The lower part of [redacted]e vena cava inferior receives venous blood from the remainder of the abdominal viscera, and [redacted]rom the abdominal walls and lower extremities; its development is described with that of its [redacted]ributaries.

(a) The portal system of veins arises by means of a series of transformations which take place [redacted]in the vitelline and umbilical veins of the embryo. The proximal ends of the vitelline veins, [redacted]where they lie between the umbilicals, are early enveloped in, and invaded by, the growing

FIG. 585.—SEMIDIAGRAMMATIC RECONSTRUCTIONS OF THE VEINS OF THE LIVER, VENTRAL ASPECT (MALL). A, EMBRYO OF 4.5 MM. LONG; B, 4 MM. (MORE ADVANCED THAN A); C, 7 MM. d.v., ductus venosus; I., intestine; L., liver; m., superior mesenteric (continued as portal) vein; r.a., ramus angularis; r.a'., right branch of portal vein; r.h.d., right hepatic vein; r.h.s., left hepatic vein; r.u., recessus umbilicalis; u.v., left umbilical vein (the right umbilical vein is not labelled); v.o.m., vitelline veins.



A B C

liver. The columns of liver cells, while not penetrating the endothelium, subject the vitelline veins to a process of fenestration by which the original channels are subdivided into innumerable smaller vessels or sinusoids. The *sinusoids* arising from the two vitelline veins intercommunicate to form a continuous network within the liver in which the vessels are larger in the afferent (portal) and efferent (hepatic) areas than in the intermediate zone.

The two umbilical veins now form communications with the portal area of the sinusoidal network and eventually lose their original connection with the sinus venosus (fig. 585). The fate of the umbilical veins differs on the two sides; the right degenerates, from the sinus venosus to the common umbilical vein, while the left persists to receive all the blood flowing from the placenta. The left umbilical vein, having lost its connection with the sinus venosus, discharges its blood partly into the portal sinusoidal zone, and partly, by means of a direct channel of new formation, the *ductus venosus*, into the right vitelline (fig. 585).

The hepatic portion of the left vitelline vein eventually loses its connection with the sinus venosus and becomes reduced to sinusoidal channels, while that of the right increases very considerably in caliber. The hepatic portion of the right vitelline now forms the only means of transit between the hepatic sinusoids and the sinus venosus of the heart, and is called the *common hepatic* vein. The main venous channels of the lower abdomen, having undergone a series of changes meanwhile, acquire a connection with the common hepatic vein, which thus becomes the upper part of the *vena cava inferior*.

The single vitelline vein of the yolk-stalk separates into right and left veins before entering the liver. In a position intermediate between the proximal and distal anastomoses between the right and left vitelline veins, which occur (ventrally to the intestine) within the liver and upon the yolk-stalk, respectively, a third connection appears on the dorsal aspect of the duodenum. The formation of the *portal vein* is effected by the disappearance of the portion of the right vitelline vein on the distal side of the dorsal connection and of the portion of the left vitelline upon the proximal side. The portal vein is joined by the *superior mesenteric* vein upon the left

side of the duodenum and by the *splenic vein* behind it; the portion of the common vitelline vein beyond the junction of the superior mesenteric with the left vitelline subsequently disappears.

(*b*) **The lower part of the vena cava inferior.** At an early stage of development the postcardinal veins are invaded by the growing Wolffian bodies and here become transformed into an intercommunicating system of sinusoids, which is drained by three longitudinal venous channels. One of these traverses the dorsal region of the organ, and retains the name postcardinal; one traverses the medial region and is called the *subcardinal* vein (F. T. Lewis). The third vein traverses the ventral region and does not share in the development of the vena cava inferior or its tributaries. The subcardinals are united across the median line, on a level subsequently occupied by the kidneys, by what is commonly known as the *renal anastomosis*, and each subcardinal receives a vein from the suprarenal gland and from the gonad of its own side. The postcardinal veins for a long time remain the chief drainage channels for the Wolffian bodies and for the iliac veins; they later, however, relinquish the drainage of the veins of the body-wall to a pair of veins of later formation, the *supracardinals* (Huntington and McClure, Am. Jour. Anat., vol. 6, 1907).

Each supracardinal vein pursues a longitudinal course near the dorso-lateral aspect of the aorta; it is connected with the postcardinal near the place of entry of the iliac veins, and extends to the anterior end of the postcardinal vein of its own side, into which it opens a short distance below the duct of Cuvier. The supracardinal veins intercommunicate at frequent intervals and eventually replace the thoracic portion of the postcardinal veins. A large communication between the supracardinal and the subcardinal vein occurs, at the level of the renal anastomosis, so that the aorta is surrounded by a venous ring, the renal collar.

The drainage of the left common iliac vein is now transferred by means of a cross anastomosis, to the right supracardinal, which becomes the part of the vena cava inferior below the renal anastomosis. The remainder of the vena cava inferior is formed from the right half of the renal collar, part of the right subcardinal vein above the renal anastomosis and a venous communication between this and the common hepatic vein. The embryonic components of the vena cava inferior become enormously enlarged and the left supracardinal vein diminishes in size.

As soon as the kidneys have attained their permanent position, the ureter is found to pass between the supracardinal vein and the postcardinal; the dorsal loop of the periureteral ring described by Hochstetter in 1893 is, therefore, a part of the supracardinal vein. Two veins (dorsal and ventral) leave each kidney to open into the corresponding side of the renal collar. The left ventral kidney-vein retains its connection with the renal anastomosis, forming the left renal vein of the adult. The ventral kidney-vein of the right side persists as the right renal vein of the adult, which opens into the vena cava inferior. The portion of the left subcardinal vein above the renal anastomosis becomes the left suprarenal vein. The corresponding portion of the right subcardinal vein forms a part of the vena cava inferior and the entire right suprarenal vein. The part of the postcardinal vein contained within the Wolffian body diminishes in size and forms a connection between the gonadic vein of each side and the corresponding subcardinal. Some part of the postcardinal vein persists, therefore, as the spermatic (or ovarian), the right opening into the vena cava inferior and the left into the left renal vein.

(*c*) **The veins of the lower extremity.** The superficial plexus of the developing limb is at first drained by the postcardinal and umbilical veins. It soon becomes condensed into a marginal vein, the fibular limb of which enters the pelvis as the hypogastric vein and continuing as the common iliac vein, joins the postcardinal. The external iliac vein grows from the common iliac, and forms a connection with the plexiform tibial limb of the marginal vein. This connecting branch receives the venous drainage of the thigh and lower abdomen and subsequently forms the proximal part of the femoral and great saphenous veins. The deep veins of the limb appear somewhat later. The popliteal takes over the distal part of the fibular marginal vein, which then becomes the small saphenous. The proximal part of the fibular vein is transformed into a plexus upon the back of the thigh, which is drained by the great saphenous vein and the hypogastric veins. The drainage of the common iliac veins is later transferred from the postcardinal to the supracardinal veins, and the upper part of the left common iliac vein is formed by an inter-supracardinal anastomosis.

2. VARIATIONS

(*a*) **The portal system of veins.** Major variations of the *portal system* of veins are practically unknown. In cases in which the lower part of the vena cava inferior is continued into the vena azygos, or into the v. hemiazygos in postnatal life, the common hepatic vein is smaller than usual and transmits blood from the portal system only.

(*b*) **The lower part of the vena cava inferior.** The left renal vein not uncommonly passes on the dorsal (instead of the ventral) side of the aorta. This condition is due to the persistence of the dorsal, and not the ventral, of the two embryonic kidney-veins which open into the left side of the 'renal collar.' The left suprarenal, and the left spermatic vein open, in such cases, into the vena cava inferior and not into the left renal vein.

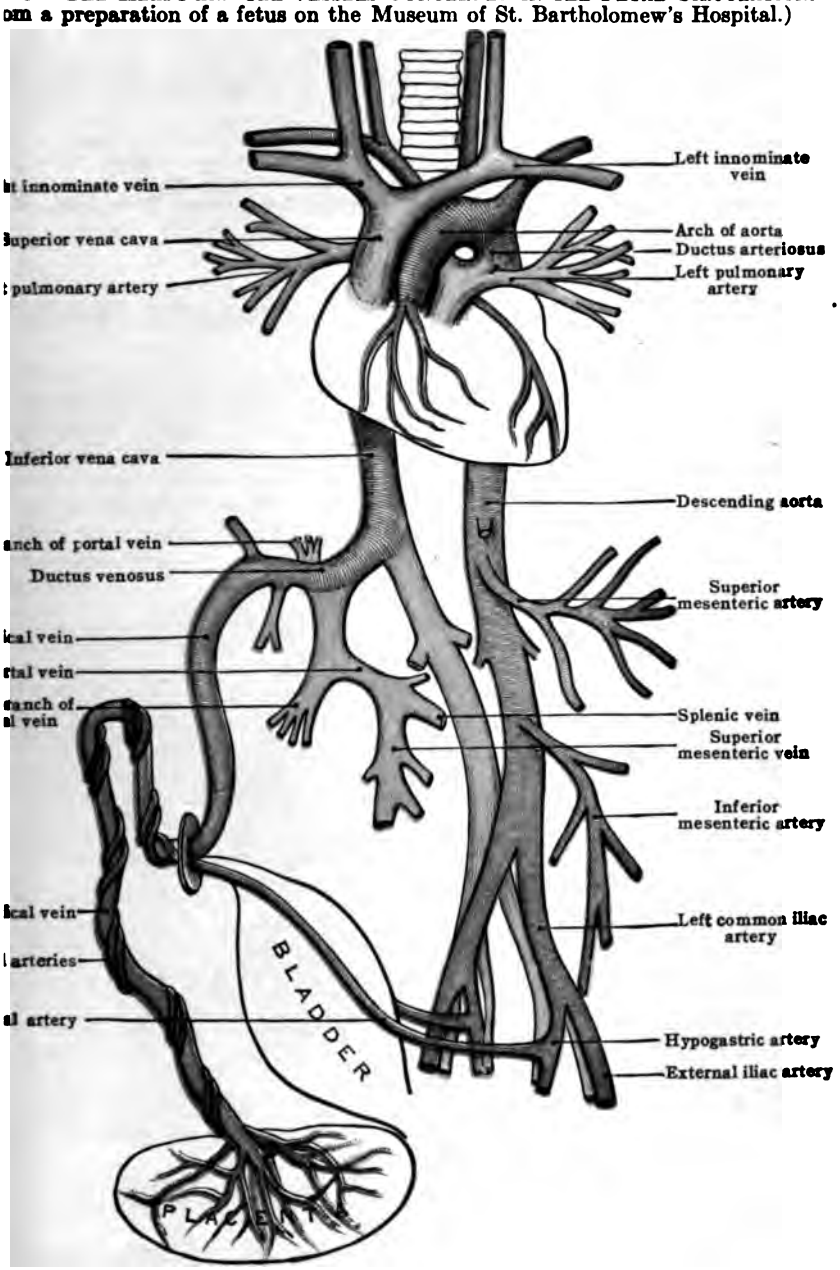
The *vena cava inferior* lies upon the left side of the aorta in cases of *situs inversus*, and in some cases without situs inversus. In the latter case the left supracardinal vein, instead of the right, has persisted below the level of the renal veins; the left inferior vena cava is continued across the front of the aorta and, receiving the left spermatic and the left suprarenal vein, passes to the right atrium in the usual way. There are occasionally two venæ cavæ, one on each side of the aorta; the two persisting supracardinal veins are united, in such cases, by the embryonic renal anastomosis. In all cases in which the left vena cava is present, with or without a right, the part which crosses the aorta is derived from the embryonic renal anastomosis and, therefore, corresponds in origin to the proximal part of the left renal vein.

Cases of dissociation of the embryonic antecedents of the vena cava inferior have already been mentioned (see azygos system). The venous blood from the lower part of the vena cava

such cases finds an outlet through the thoracic portion of one of the supracardinal

al vein of either side may open into the common iliac, particularly in cases in which is lower than usual. The vein of a pelvic kidney may open into the middle sacral ny interesting anomalies of a less striking character may occur.

586.—THE HEART AND THE VESSELS CONCERNED IN THE FETAL CIRCULATION. om a preparation of a fetus on the Museum of St. Bartholomew's Hospital.)



e veins of the lower extremity. Major variations of the veins of the lower extremity nmon. The small saphenous vein is frequently continued upon the back of the thigh, thout communication with the popliteal. It is drained in such cases into the great , either by means of a plexus or through a definite femoropopliteal vein.

FETAL CIRCULATION

principal vessels of the fetal circulatory systems are shown in fig. 586. cussion of the fetal circulation and of the postnatal changes, see Section , 35.

References for blood-vascular system.—A. **Heart**:—Adult anatomy and development treated fully by Tandler in Bardeleben's Handbuch der Anatomie des Menschen, **Bd. 3**, Abt. 1, and in Keibel and Mall, Manual of Human Embryology. See also Bayne-Jones (vessels of heart valves) Am. Jour. Anat. 21: 449; Bardeen (estimation of size and weight) Am. Jour. Anat., 23: 423; Morrill (atrial septa) Am. Jour. Anat., 20: 351; Waterston (general development) Trans. R. Soc. Edinb., 52: 275.

B. **Blood vessels**; *Development:* Evans in Keibel and Mall, Manual of Human Embryology; Bremer (early development) Am. Jour. Anat., 16: 447; Huntington (pulmonary arteries) Anat. Rec., 17: 165; Huntington and McClure (vena cava inferior and azygos veins) Anat. Rec., 20: 1; Sabin (early development) Carnegie Contrib. Embryol., 6: 61, and 9: 213, (vena azygos) 3: 5; Senior (lower extremity arteries) Am. Jour. Anat., 25: 55, and Streeter (dural sinuses) Contrib. Embryol. 8: 7. *Anomalies.* Barkow, Comp. Morph. d, Mensch. T. 6, 1868, and Ang. Samm. Breslau 1869; Dubrueil, Des anom. arter., 1847; Gruber (upper extremity), Abhandl. a.d. Mensch. u. vergl. Anat., 1852; Hyrtl, Schlag. d. Unterschenk., K. Akad. d. Wissensch. Wien, 1864; Quain, Arteries of Human Body, 1844; Ryan, Dissert. Edinb., 1809; Tiedemann, Tabualæ arteriar., 1822; Supplement 1846; and Zoja, Gabinet. d. Anat., Pavia, Angiol., 1877; Krause in Henle's Handb. d. syst. Anat., Bd. 3; Senior (leg arteries) Jour. Anat., 53; 130.

SECTION VII

THE LYMPHATIC SYSTEM

REVISED FOR THE SIXTH EDITION

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I. GENERAL ANATOMY OF THE LYMPHATIC SYSTEM

THE blood-vascular system has, as a part of its function, the collection of substances from the various tissues of the body which are to be conducted to the other tissues. In carrying on this function it is assisted by a second system of collecting vessels, the lymphatics. The lymphatic system consists of a set of closed vessels which start as closed capillaries in the various organs and tissues, continue as closed vessels, pass through lymph-nodes in which the vessels break up into capillaries and spaces separated from the outside fluid by endothelium, and again collect into closed vessels, which eventually terminate in the veins of the neck.

This second system resembles the blood-vascular system in many ways, but differs markedly in others. Like the blood-vascular system, it is made up of minute endothelial-lined capillaries, where the absorption of substances occurs, and of larger conducting vessels. It differs from the blood-vascular system in two important particulars. While the blood-vascular system is provided with a pumping mechanism by which its fluid content is driven through a complete circuit from the heart, through artery, capillary, vein and back to the heart, the lymphatics merely conduct fluid *from* the capillaries to the larger vessels, which eventually empty their contents into the large veins of the neck. The second important difference between the two systems is found in the presence, along the course of the lymphatic vessels, of glands or nodes (fig. 590) [lymphoglandulæ] in which the vessels branch out into lymph-capillaries. These are lined, as are the absorbing capillaries, with a single layer of endothelial cells, thus permitting an interchange of substances between the contents of the lymph-capillaries and the lymphoid tissue around them.

Our present knowledge does not permit an exact statement of the complete extent of the lymphatic system. While, in a general way, the lymphatics may be said to be present wherever blood-capillaries occur, there are certain tissues where lymphatics have not been definitely demonstrated. The *tissue-spaces* outside the lymphatic endothelium, which are filled with a fluid or semifluid material, which has often been termed 'lymph' but which would better be termed 'tissue-fluid, are not part of the lymphatic system. Similarly, the various serous cavities —pleural, percardial, synovial, cerebrospinal, etc.—while they may serve, as in the case of the cerebrospinal spaces and the intraocular spaces, a somewhat similar function, are not considered as parts of the lymphatic system.

The general constitution of the lymphatic system will be considered under three heads—(1) the capillaries, (2) the collecting vessels and (3) the lymphoid organs.

1. *THE LYMPHATIC CAPILLARIES*

The lymphatic capillary, like the blood-capillary, is the portion of the lymphatic system which is chiefly concerned in the specific function of this system. In the blood-capillaries, where the blood is separated from the outside tissues by a single layer of flat endothelial cells, there occurs the interchange of fluid substances and of cells, while the heart, arteries and veins serve to transport the blood, modified in the capillaries, to other parts of the body. Similarly in the lymphatic system, it is in the capillaries, both those most peripheral and those in the lymph nodes, where the absorption and interchange of fluid substances and of cells takes place. Consequently it becomes of prime importance to obtain a clear understanding of the structure of the lymphatic capillaries, their relation to the other

tissues, and their mode of functioning. At the outset, however, it must be admitted that our knowledge on this subject is far from complete.

Historical.—Previous to the development of microscopic anatomy, in the middle third of the 19th century, there was no accurate knowledge of such small structures as the lymphatic capillary. In order to explain the absorption of substances by the lymphatics, as well as the passage of substances from the blood-vessels through the tissues, various theories were invented. Prominent among such theories was that of the 'vasa serosa,' of H. Boerhaave and other 18th century anatomists and physiologists, which was perhaps most elaborately developed by Bichat, 1801-03. According to this theory there are two sets of minute vessels. The one set leads from the blood-capillaries onto the various surfaces and into the loose spaces in the tissues—the 'exhalants.' The other set leads from the body surfaces (including the serous cavities) and the loose spaces in the tissues to the lymphatics—the inhalants or 'absorbants.' This theory was somewhat shaken by the criticism of early 19th century anatomists who developed the technic of injection of lymphatics to a high point.

Our present conception of the lymphatic capillaries may be said to have started with Kölliker who, in 1846, saw, with the aid of the microscope, the lymphatic capillaries in the transparent tails of living frog larvæ. Like Schwann who, in 1837, had studied the blood-capillaries in the tail of the frog larva, he erroneously supposed that the fine processes of the lymphatic capillaries were continuous with similar processes of the surrounding connective tissue cells. Since, according to the conception current at the time, cells were thought to be hollow structures, it was concluded that the mode of transmission of fluid from blood to lymphatic capillary took place through canaliculi inside these cells. This conception was elaborated by Virchow, in his Cellular-Pathologie.

In 1862 von Recklinghausen by means of the silver nitrate staining method discovered that the lymphatic vessels are lined with an endothelium made up of flattened cells whose outlines show as fine dark lines after this treatment. Von Recklinghausen, however, held that unstained parts outside the lymph-vessels represent a system of irregularly shaped lymph-canaliculi ('Saftkanälchen') which are in open communication on one the hand with the blood-capillaries, and on the other with the lymphatics. This conclusion has since been disproved by numerous investigators.

Von Recklinghausen also described open communications ('stomata') between the lymphatics and the peritoneal cavity. Cohnheim described similar though smaller openings in blood-capillaries, and His described them in other lymphatic capillaries. Arnold termed the openings in the vessels 'stigmata,' as distinguished from the openings into the peritoneal cavity, or 'stomata.' More recent investigators (Kolossow, A. W. Meyer, W. G. MacCallum) have failed to find these 'stomata.' Careful studies of the lymphatic capillaries in the transparent tails of living frog larvæ, which may be clearly seen with the higher magnifications of the microscope, show that the endothelial lining of these capillaries is complete, with no trace of an opening into the spaces in the tissue outside (E. R. Clark).

With the advent into microscopical technic of the various dyes for staining cell-nuclei and protoplasm, and the more precise methods for making histological studies, the endothelial wall of the lymphatic capillary has been definitely established, although much remains to be learned concerning the differences between the lymphatics of the various tissues.

Form.—The shape of the lymphatic capillaries has been found to vary enormously in the different parts of the body where they have been studied. In general they form richly anastomosing plexuses, from which may extend cul-de-sacs, which end blindly. Such cul-de-sacs are especially noticeable in the dermal papillæ, in the filiform papillæ of the tongue, and in the intestinal villi. The plexuses are often present in two layers—a superficial and a deep. The vessels of the superficial plexus are of smaller caliber than those of the deep. These two sets of plexuses are particularly well seen in the skin and the gastrointestinal tract. In relation to the blood-capillaries, the lymphatic capillaries are generally the more deeply placed. In caliber, unlike the comparatively uniform diameter of blood-capillaries, the lymphatics vary enormously. In the same capillary a very narrow part may be succeeded by a very wide one (figs. 587, 588). Teichmann found lymphatic capillaries varying in diameter from a few micra to one millimeter or more. The capillaries are without valves.

Activity.—That the lymphatic endothelium is not exclusively a passive membrane has been shown by Clark in studies on the lymphatics in the transparent tails of living frog larvæ. The lymphatics here are seen to send out protoplasmic processes which, somewhat like an ameba, actively take into the interior of the lymphatic red blood-cells accidentally forced from the blood-capillaries into the tissue-spaces. The mode of passage of leucocytes into or out of the lymphatics offers no such difficulties as that of the fluids, for they are able, by ameboid movement, to pass independently through the endothelium—a process first directly observed by Cohnheim.

1. The Extent and Character of Lymphatic Capillaries

The *skin* over the entire surface of the body is richly provided with lymphatic capillaries. They form two sets of plexuses in the dermis, a superficial and a deep. The superficial set sends out blind cul-de-sacs into the dermal papillæ. The richest skin plexuses are found in the scrotum, the palms of the hand and palmer side of the fingers and in the soles of the feet and plantar side of the toes. In the loose *subcutaneous* fascia, according to Teichmann, there are present only the larger collecting vessels, with no lymphatic capillaries. Lymphatic capillaries of the *scrotum* are shown in fig. 587.

The *conjunctiva*, both the sclerotic and corneal, is supplied with a rich plexus of capillaries, which are narrower in the corneal than in the sclerotic portion. At the corneal border the capillaries form a fairly regular ring which has been called by Teichmann a circulus lymphaticus.

.t the various *orifices* of the body, the skin plexuses go over into the mucous plexuses, ing anastomoses with them. Throughout the entire *alimentary tract*, including the nasal .ies, the lymphatic capillaries form extensive plexuses which are in many places divided a superficial plexus in the mucosa and a deeper plexus in the submucosa. In portions pro- d with a peritoneal covering, there is a third rich subserous plexus. In the tongue and the l intestine the plexus in the mucosa sends out blind cul-de-sacs; in the tongue into the rm papillæ; in the small intestine into the villi. Where muscle is present along the ali- tary tract, the lymphatics pass between the muscle bundles, but form no plexuses around a.

The lining of the *tracheal* and *bronchial passages* is supplied with a double plexus of lym- ic capillaries, a mucous and a submucous set, which vary in richness according to the loose- of the tissue. In the smaller bronchi but a single layer of capillaries is present, and, ac- ing to Miller, no capillaries are present around the air cells. Plexuses surround the pul- ary arteries and veins. Under the *pleura* lie rich plexuses which connect with deeper phatics around the veins only in places where the veins reach the surface of the lung. Concerning the arrangement of the lymphatic capillaries in the *glands* derived from the entary tract much remains to be learned. The *salivary glands* have been studied by aard, who has found lymphatic capillaries accompanying the blood-vessels into the interior he lobules, and forming here irregular plexuses.

The *thyroid gland* contains lymphatic plexuses which lie in relation to the colloid-con- ing alveoli. Direct connection between the lymphatics and the alveoli has been described Matsunaga, but this observation needs verification. The lymphatics are apparently erned in the absorption of the colloidal secretion, for traces of it have been found in the phatics draining the gland.

587.—The Lymphatics of the Scrotum. (After Teichmann.) Showing the transition of the capillaries to the vessels with valves (*a*, *a*, *a*).

Concerning the lymphatics of the *parathyroids* nothing is known.

The course of the lymphatics draining the *thymus* has been recently described, but the re of the capillaries in this gland is unknown.

The lymphatic capillaries of the *liver* are of great importance, for the lymph which flows this organ forms a very considerable part of the total lymph which is collected into the atic duct. And yet very little is definitely known about the nature and distribution of the phatic capillaries in the interior of the organ. In the capsule there is a rich plexus, lying er the peritoneum, in which very large widenings have been described (called by Teichmann aphbehälter'). In the interior rich plexuses surround the branches of the hepatic artery portal vein (fig. 589), and plexuses have been described accompanying the branches of the al vein into the lobules. The path from blood-capillary to lymphatic in the perilobular es is more open than has been found in other organs, for Mall has found that if very finely ular masses are used, and are injected through portal vein or hepatic artery under mild sure, the granules pass over into the lymphatics. Moreover, the lymph from the liver is er in proteins—more like the blood serum—than is the lymph from other organs.

The linings of the large *bile-ducts* and the *gall-bladder* are provided with a submucous network mphatics (Sudler and Clermont). The gall-bladder has also a rich subserous plexus.

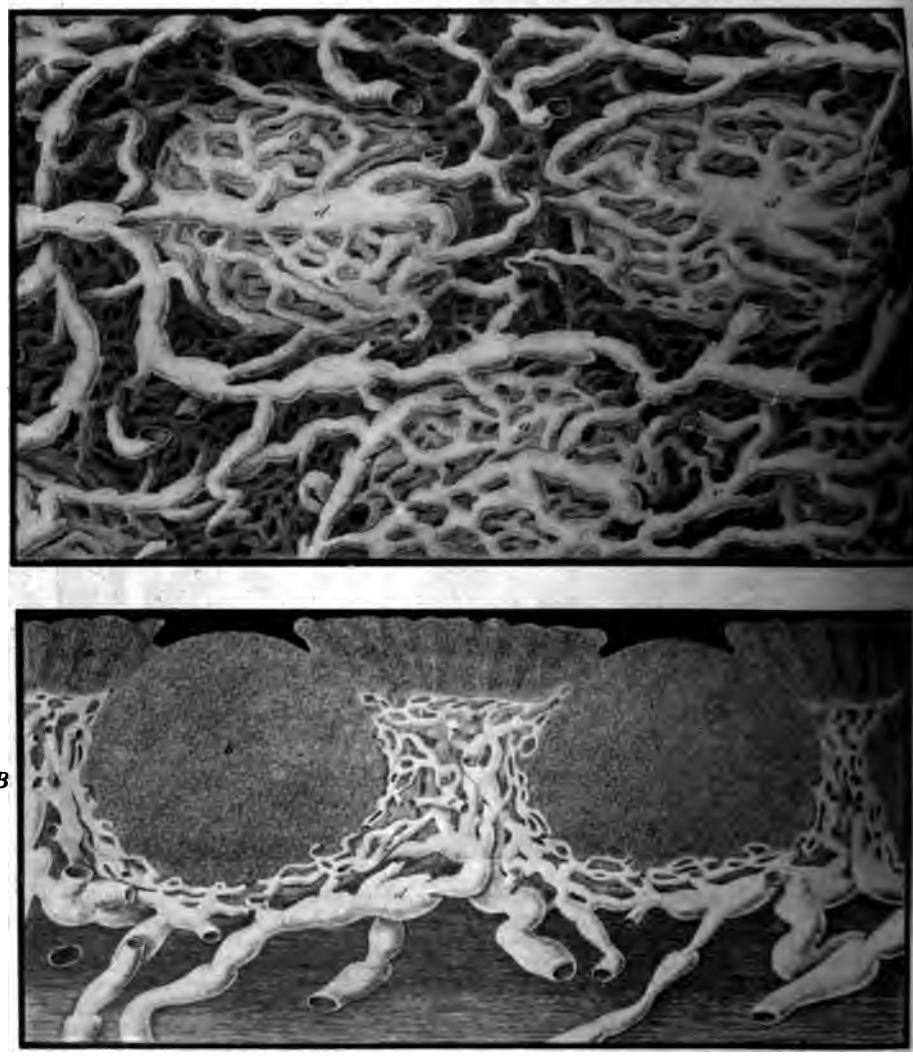
Concerning the lymphatic capillaries of the *pancreas* Bartels notes briefly that they form y branched plexuses in the interlobular connective tissues, which surround larger or smaller s of whole lobules, not the single gland elements.

The mucous lining of the *genitourinary tract*, wherever it has been carefully studied, has found provided with plexuses of lymphatics. In the *bladder* they form a rich plexus of

irregular capillaries which lie immediately under the almost intraepithelial blood-capillaries. They connect, through the muscular layer, with a subserous plexus. The lymphatic plexus of the *urethra* anastomoses with the capillaries of the base of the bladder, and in the male with those of the glans penis. In the *prostate* (Camineti) the lymphatics form rich plexuses surrounding the glands, which connect with a very wide meshed subcapsular plexus, surrounding the entire gland.

In the *testis* there is a rich superficial plexus, lying directly beneath the tunica albuginea. Concerning the deep lymphatics of the testis there has been much dispute. Ludwig and Thomsa found the lymphatic capillaries going over into lacunæ, without endothelium. This has been disputed by Tommasi and Gerster, who find, in the septa, capillaries with endothelial wall, which they consider the beginnings of the lymphatics.

FIG. 588.—SURFACE VIEW AND SECTION OF LYMPH-NODES OF THE INTESTINE. A. Solitary follicle. B. Peyer's patch. (After Teichmann.)



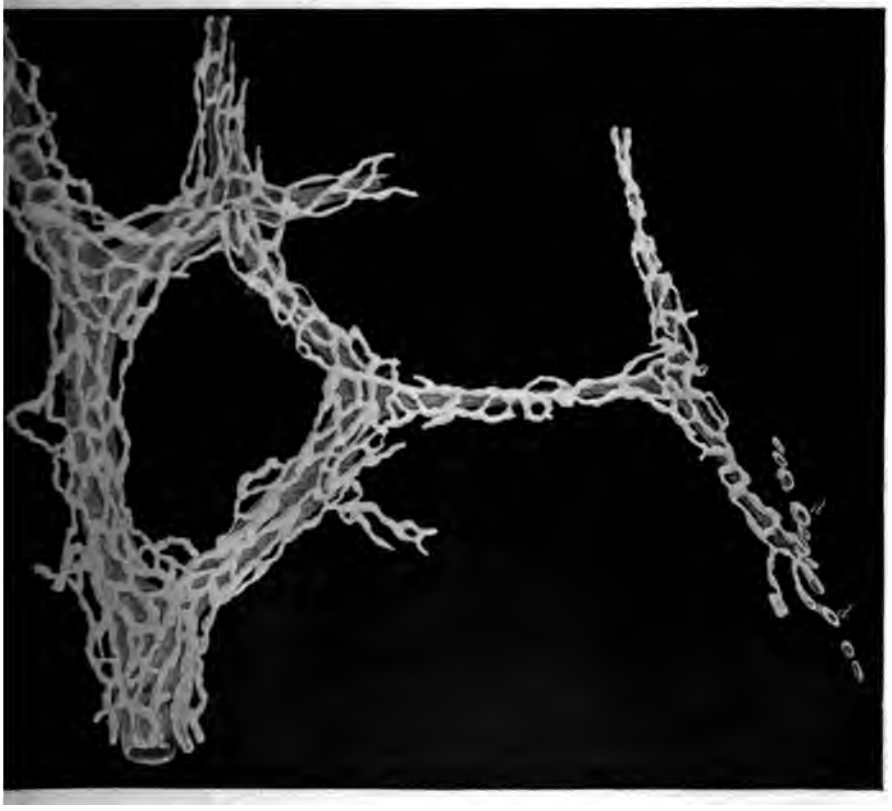
In the female, lymphatic plexuses have been found in the mucosa of *vagina* and *hymen*, anastomosing with those of the vulva. In the *uterus*, capillaries in the mucosa are very difficult to demonstrate. Definite lymphatics, however, have been found passing through the muscularis, and under the peritoneum a rich subserous plexus of capillaries is present. In the pregnant uterus these subserous capillaries are much distended (Schick). The *Fallopian tubes* are provided with lymphatics, but they have not been carefully described.

The *ovary* has a rich superficial lymphatic plexus. In the interior of the gland, according to His, the capillaries form networks in the connective tissue framework. In the tunica externa of the follicles there is a rich plexus.

The *kidney* has two sets of lymphatics, a superficial, capsular set, and a deep set. The capsular set is divided into two layers, one lying directly beneath the peritoneum made up of a wide meshed plexus, and the other in the fibrous capsule of the kidney, with finer capillaries and narrower meshes, which anastomose with the deeper capillaries. The lymphatic capillaries of

ey parenchyma have been described by Kumita. He found rich plexuses in both
ıd medulla, surrounding the straight and convoluted tubules, the loops of Henle and
cting tubules. He also found a plexus surrounding and accompanying the blood-
ıto the interior of the glomeruli.
lymphatic capillaries of the *suprarenal* have also been described by Kumita. His
gree with those of Stilling, who studied the lymphatics of the suprarenal of horse, cow
Like the kidney, the suprarenal possesses a superficial and a deep set. The superficial
two layers, as in the kidney, the outer lying in the looser tissue around the suprarenal
nner lying within and just under the capsule. The latter is made up of a rich lymphatic
which anastomoses with the capillaries of the parenchyma. The parenchymatous
ics are present in the form of plexuses which surround the groups of cells.
ite of numerous investigations, endothelial-lined lymphatics have not been definitely
the central nervous system, or in the peripheral nerves. The subarachnoid and similar
ncluding the perineural spaces, do not form parts of the lymphatic system.
plexuses of lymphatic capillaries are present in the *tendons* of *muscles* (Schweigger-
ıd Ludwig). In muscles, themselves, the question of the presence of lymphatics has
a disputed, sometimes answered in the affirmative, more often in the negative. A re-

.—Lymphatic Plexus around the Portal Vein in an Adult Man. (After Teichmann.) Showing the supporting relation of the vein.



y by Aagaard, however, would seem to place beyond doubt the presence of lymphatic
s in *striated muscles*. By long continued injection, he was able to find lymphatics in
muscular portions of the tendons, which extended out among the muscle-fibers them-
He also found capillaries in the tongue musculature.
heart is provided with a subpericardial plexus of lymphatic capillaries. A subendo-
lexus has also been described (Sappey, Rainer). Bock has found an extremely rich
ic network throughout the substance of the heart. According to his description, the
ic capillaries are more numerous than the blood-capillaries.
periosteum of bones is provided with a rich plexus of lymphatic capillaries. They are
n several layers, of which the outermost form the richest plexus. Lymphatic capillaries
o been described accompanying the blood-vessels in the Haversian canals in bones
, Schwalbe, Budge). Nothing is known concerning the lymphatics of the bone-mar-
artilage lacks both blood- and lymphatic capillaries.
capsular membranes of *joints* are richly provided with lymphatic capillaries (Tillmanns).
e arranged in two layers—an inner layer made up of a rich plexus of wide capillaries,
st outside the subendothelial blood-capillaries, and an outer layer, consisting of a rich
n the subsynovial tissue. The lymphatic capillaries have no open connection with the
vity.
membranes surrounding the *pleural*, *pericardial* and *peritoneal cavities* are richly sup-

plied with lymphatic capillaries, which form here thick plexuses under the mesothelium. These plexuses are usually described with the underlying organ, as the subserous lymphatic capillaries of the intestine, etc. In the central tendon of the diaphragm the subperitoneal lymphatics are extremely rich. They widen out here to form very large endothelial-lined cavities which, in the spaces between the connective tissue bundles, lie directly in contact with the peritoneal epithelium. The existence of open connections between these capillaries and the peritoneal and pleural surfaces (the 'stomata' of von Recklinghausen) has been disproven. The capillaries on the two surfaces of the central tendon communicate freely with one another.

2. *THE LYMPHATIC VESSELS*

The lymph which enters the lymphatic capillaries passes over into collecting vessels, which carry it through the lymph-glands (nodes) to the large veins at the base of the neck. The general course of the lymphatic drainage from any given region is usually very similar to that of the corresponding venous drainage. The lymph-vessels course in the loose subcutaneous tissues, in the connective tissues between muscles and organs, often accompanying the arteries and veins, sometimes forming networks around them. An idea of their arrangement can be best obtained by glancing at the illustrations of the lymphatics of special regions. In general they are made up of numerous long, narrow vessels, rarely more than half or three-fourths of a millimeter in diameter, which occasionally communicate with one another, and which converge toward groups of lymph-glands placed in certain definite regions. In the lymph-glands (fig. 590) the afferent lymph-vessels break up into capillaries, which again collect into efferent vessels. Several of these efferents from each lymph-gland may pass to a second lymph-gland, where they undergo a second widening into capillaries. In this way the lymph, passing through one, two, three or more lymph-nodes in succession, eventually reaches the thoracic duct, or one of the short ducts, all of which empty into the large veins at the base of the neck. The thoracic duct which receives, at its lower end, the lymph from the lower half of the body, is the only lymphatic vessel which attains any considerable size (four to six mm. in diameter) and is usually the only one large enough to be seen readily without injection.

In *structure* the lymphatic vessels much resemble the veins. They possess an intima, a media and an adventitia, although the line of demarcation between the different layers is not sharp. In the thoracic duct, the endothelium of the intima is succeeded by a delicate layer of fibers, mainly elastic; outside of this is the media, made up mainly of circular smooth muscle-cells, interspersed with elastic and connective tissue fibers; then follows a layer of coarse elastic and connective tissue fibers, which is succeeded by the adventitia, containing longitudinal and transverse bundles of smooth muscle-cells, as well as blood-vessels and nerves. The other lymphatic vessels possess the three layers, which, however, toward the capillaries, grow thinner, and eventually reach a stage in which, outside the endothelium, there are found only single muscle-cells, or muscle-cells in groups of two or three.

The lymphatic vessels are characterized by their great richness in valves, which are present throughout their entire course, from their beginnings in the capillary region to their openings into the veins of the neck. The valves are bi- or tri-cuspid, and are always arranged so as to prevent the flow of lymph back to the capillaries. They thus aid indirectly in the *movement of the lymph*, in that any external pressure on the vessels must always force the lymph onward. The pressure of the surrounding organs and skeletal muscles, and the contraction of the smooth muscle in the walls of the lymph vessels, form important secondary factors in the movement of the lymph. The primary force, however, doubtless comes from the secretory or filtration phenomena of the lymphatic capillary walls.

Nerves of lymphatic vessels.—That the thoracic duct and the smaller lymphatic vessels are provided with nerves has been shown by several observers. According to Kytmanoff (in dogs) the nerves to the lymphatics are mainly non-medullated, and are both motor and sensory. They form four sets of plexuses—adventitial, supramuscular, intermuscular, and subendothelial. Sensory nerve-endings are found in adventitia and media, in the form of free-ending threads and bush-like endings. Motor endings are present in connection with the smooth muscle cells of the media. In the intima there is a plexus of extremely fine varicose threads. The physiological action of the nerves supplying the cisterna chyli has been tested by Camus and Gley who found in dogs a dilatation of the cisterna as the result of electrical stimulation of the splanchnic nerve.

3. *THE LYMPHOID ORGANS*

Closely associated with the lymphatic capillaries and vessels is a group of glandular structures known as lymphoid organs. They consist, essentially, of groups of round lymphoid cells, lying in a meshwork of reticulum fibers, and having often a definite relationship to the blood- or lymph-vessels. The group of lymphoid organs includes, in addition to the lymph-glands [lymphoglandulæ] or lymph-nodes, which are particularly related to the lymphatic vessels, the

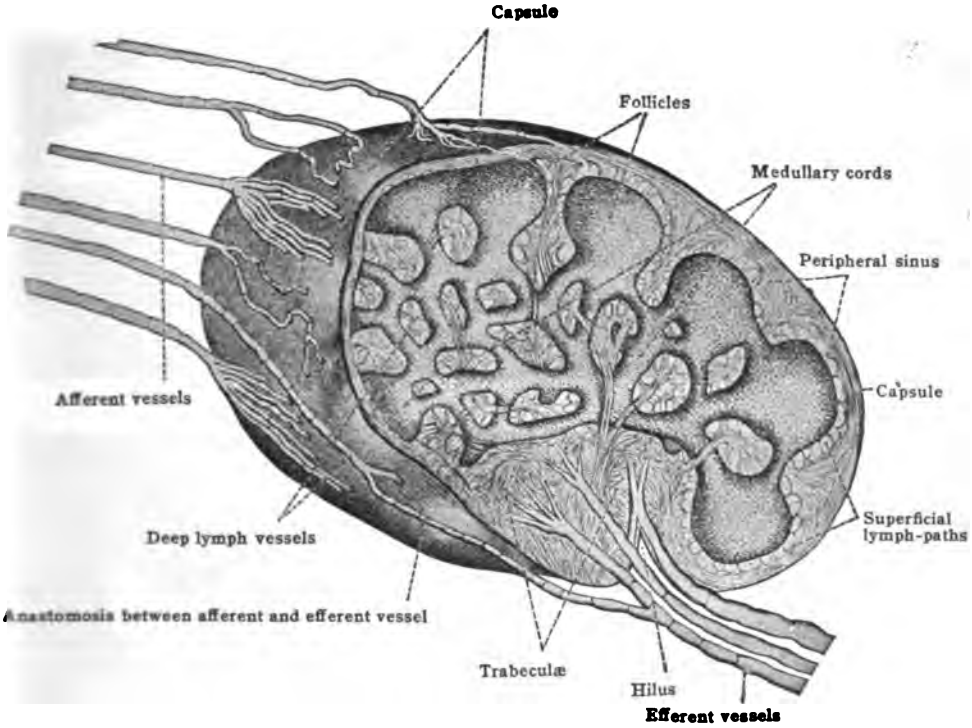
spleen, thymus and (in part) bone-marrow, which are also largely made up of lymphoid tissue. The thymus, however, is considered separately with the GLANDS OF INTERNAL SECRETION.

In their most simple form, the lymphoid organs form mere irregular accumulations or patches of lymphoid cells, which have been termed lymphoid infiltrations. Such patches are frequent in mucous membranes especially along the intestinal tract and the air-passages in the lungs.

Larger accumulations of lymphoid cells produce definite round nodules, which may occur singly, as *solitary follicles* or in groups, as *aggregated follicles* (Peyer's patches) (fig. 588). In the solitary follicle the lymphoid cells are arranged concentrically, with a region in the center where the cells are less closely packed together. This is called the germinal center, and contains numerous cells undergoing mitotic division. The solitary follicle contains blood-capillaries. Lymph-capillaries, however, do not enter the follicle but form a rich plexus about it.

The **lymph-glands** or nodes (fig. 590) are larger lymphoid structures, which are developed along the course of the lymph-vessels. They vary much in size, shape, and color, and may occur singly or in small or large groups. The *size* varies from the size of a pin-head to that of an olive, or larger. In *shape* they may be spherical, oval, or flattened on one or more sides, according to their relations to other organs. Each gland has an indentation or hilus, where the arteries

FIG. 590.—DIAGRAM OF A LYMPH-NODE. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



enter, and where the veins and efferent ducts emerge. Their *color* depends upon position and state of function. The glands along the respiratory tract are black, due to the presence of carbon granules. The mesenteric glands are milk-white during digestion, and other nodes are pale and translucent when their sinuses are filled with fluid, and pink or even red when red-blood cells are present in the sinuses. The lymph-gland is made up of four distinct elements: lymphoid elements, lymphatic capillaries, supporting structures, and blood-vessels.

The *lymphoid elements* (fig. 590) are arranged as follicles and as cell-strings. The follicles lie around the circumference of the gland, and form the cortex [substantia corticalis]. The cell-string or medullary cords are irregular cords of cells which extend from the follicles through the central or medullary portion [substantia medullaris] of the gland. The follicles and medullary cords are made up, as are the solitary follicles, of round lymphoid cells.

The *lymphatic vessels* (figs. 590, 591) enter the lymph-gland as several vasa afferentia, and leave it, at the hilus, as the vasa efferentia. The vasa afferentia spread out in the cortical portion of the gland into an extremely rich plexus of wide capillaries which surround the follicles, forming the peripheral sinus. The capillaries do not enter the follicle. This plexus continues, around the follicles, into the medullary portion where it forms again a rich plexus, the medullary sinus, in the spaces around the medullary cords. The medullary sinuses are broken up by naked reticulum fibers and cells, which are thus exposed directly to the lymph passing through the gland. At the hilus medullary capillaries collect into larger vessels and emerge as the vasa efferentia.

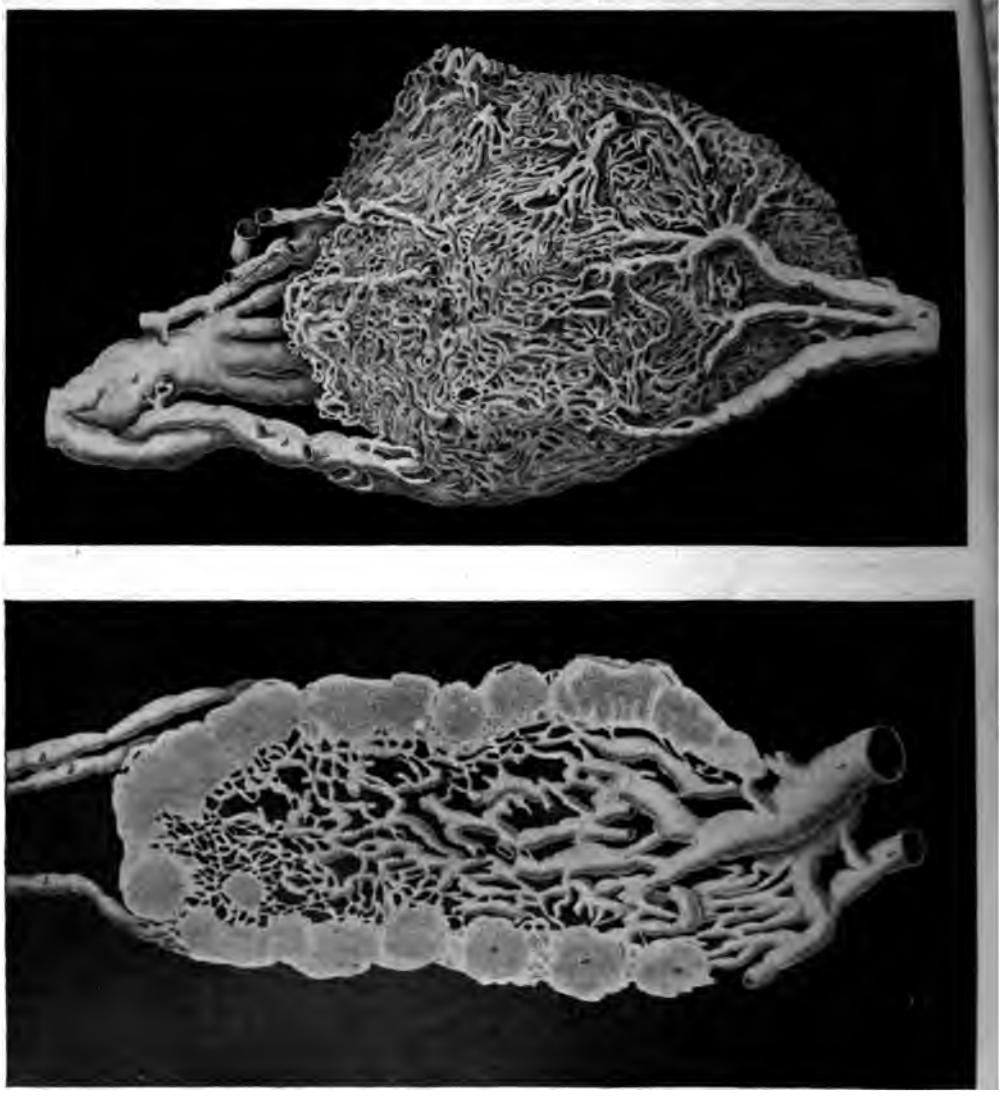
The *supporting structures* consist of a fibrous capsule surrounding the gland, from which

trabeculæ or septa pass in, around and between the follicles and cords. From the septa, a fine reticulum passes into the follicles and cords, where it forms a rich dense meshwork, in the interstices of which lie the lymphoid cells. The capsule and trabeculæ are made up of white fibers, elastic fibers and smooth muscle-fibers.

The *blood-vessels*, which enter and leave at the hilus, send branches into the follicles and into the medullary cords.

The enormous widening of the lymph-stream in the lymph-node from the vasa afferentia to the capillaries—like a brook widening out into a pond—causes a very great diminution in the rate of flow of the lymph. Thus there is present in the gland a very slowly moving stream of lymph, which is separated from the lymphoid tissue outside by a single layer of flattened

FIG. 591.—SURFACE VIEW AND SECTION OF A LYMPH-NODE SHOWING THE PERIPHERAL AND CENTRAL SINUSES. (After Teichmann.)



endothelial cells. There is thus possible an easy interchange of substances, and an opportunity or the passage, through the endothelium, of wandering cells. While the entire mode of functioning of the lymph-gland is not clear, it is known that lymphocytes, formed here, enter the lymph-stream, and that substances such as, for instance, carbon granules, or leucocytes laden with bacteria, are checked in their course by the lymph-gland. It is also known that lymph-glands become swollen as a result of the presence, in the lymph reaching them, of the poisonous products of bacterial action.

Lymphoid tissue is markedly reduced in amount during starvation (Jolly) and increased by rich feeding (Settles). The number of lymphocytes in the blood stream is increased during digestion.

Variations in lymphoid tissue according to age.—Lymphoid tissue—including lymph-glands, palatine and pharyngeal tonsils, aggregated and solitary follicles, the lymphoid portion

spleen and thymus—is much larger in amount in the child than in the adult (cf. p. 36). fact, after an early period of relatively rapid growth there is a steady reduction in size, or ophy, of lymphoid tissue both relative and absolute, which commences before adult life is ched. Miller believes that an exception is furnished by the lymphoid tissue in the lungs, due the continuous irritation produced by carbon particles inhaled, which are taken up mainly lymphoid cells, and deposited largely around lymphoid accumulations.

Arrangement.—The lymph-glands are so arranged throughout the body that all the lymph which enters the lymphatic capillaries must pass through one or more lymph-glands on its way to the veins.

It is possible that this rule may have exceptions, although none have yet been definitely proved. Thus, some of the small lymphatics which join the thoracic duct may enter it without having passed through a gland. Moreover, there is often found (fig. 590) a direct anastomosis between an afferent and an efferent lymphatic vessel.

Most of the glands are collected in certain regions, where they form centers toward which the lymphatic vessels radiate. Such groups are termed regional glands. The glands forming such a group are connected with one another by numerous anastomoses, which are termed lymphatic plexuses. In addition to the regional glands there are many isolated glands which lie along the course of the lymph-vessels, and through which pass the vessels draining a much more limited capillary area. Such glands are termed *intercalated* glands.

4. THE DEVELOPMENT OF THE LYMPHATIC SYSTEM

Our knowledge of the lymphatic system has been very greatly increased during the past twenty years by studies on its mode of development. Previous to 1902 nothing definite was known about the primary development or the mode of growth of the lymphatic system. It was concluded by some (Budge, Gulland and Saxer) that the lymphatics arise from undifferentiated mesenchyme cells; Ranvier believed that they arise from veins by budding of the endothelium; while Sala described them as arising partly from the mesenchyme and partly from venous endothelium. Regarding the mode of growth and spreading of the lymphatics, various theories were likewise held. Kölliker, His, Goethe and, later, Sala held that growth takes place by the successive addition of mesenchyme cells; Langer, Rouget, and Ranvier maintained that growth takes place by sprouting of the endothelium. S. Mayer thought that new lymphatics are derived from transformed blood-capillaries.

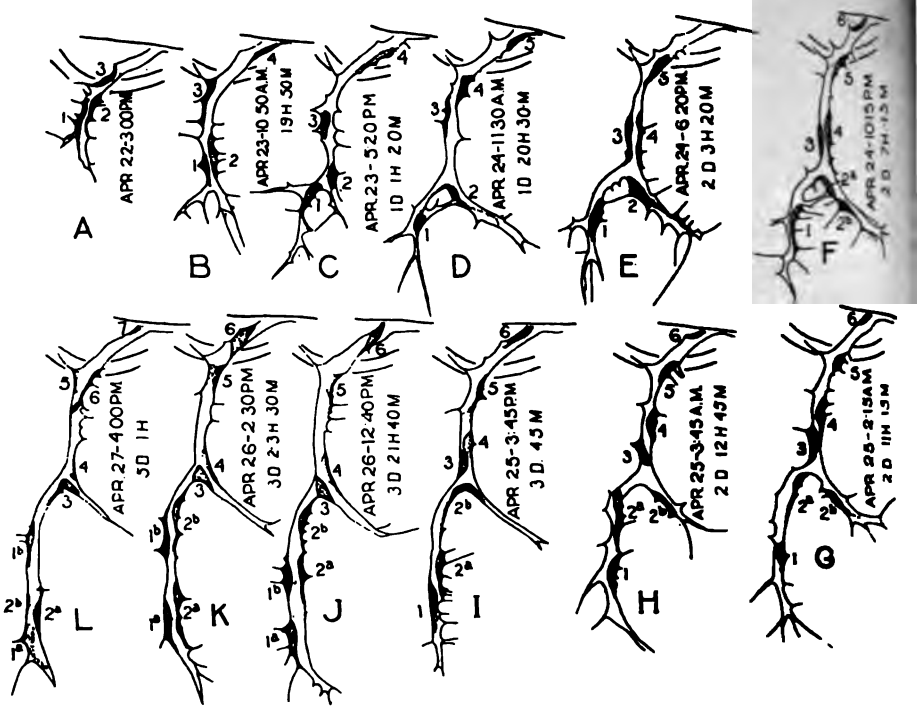
Miss Sabin, in 1902, gave the first clear picture of the mode of origin and growth of the lymphatic system, and our present knowledge has grown largely out of her discoveries. She showed, by injections of pig-embryos, that the lymphatics of the skin appear first in four regions of the body—two on each side at the base of the neck, and two in the inguinal region—in the form of sacs which are connected with the veins and spread out step by step over the skin of the entire body in the form of a richly anastomosing capillary plexus. Numerous studies have since been made on the mode of development of lymphatics, in many different animals, including man. The results of these studies leave many points still matters of controversy, and several divergent views have been developed, particularly as to the primary source of lymphatic endothelium. Miss Sabin first made the obvious conclusion that it is derived from venous endothelium by a process of sprouting, a view maintained by Hoyer and his pupils and by Kampmeier. F. T. Lewis described the first lymphatics as forming by the actual transformation of veins into lymphatics—a view which Miss Sabin later concurred in. Huntington and McClure at first also agreed with this view, but later gave it up in favor of the view that all lymphatic endothelium is derived from mesenchyme cells. This view has been supported chiefly by their pupils—Stromsten, Miller and West. E. R. and E. L. Clark failed to find any evidence for the transformation of blood-capillaries into lymphatics. There is pretty general agreement that the earliest lymphatic endothelium differentiates in certain definite regions, in the neighborhood of the veins. A recent study of the early lymphatics in chick-embryos, however, casts doubt upon the validity of this view. It was found that, in chick-embryos, if regions such as the posterior body-wall and the base of the posterior limb-bud are experimentally isolated from their supposed source of lymphatic supply, lymphatics develop *in loco*—but whether from blood-vessels or mesenchyme cells the authors were unable to determine. However, it has been found by all investigators that lymphatics have numerous connections with the veins, at early stages, particularly in certain regions, and that the number of connections is rapidly reduced, as the separated lymphatics grow together and anastomose, until, in most higher vertebrates, the only connections which persist are those at the right and left jugulosubclavian angles. The exact mode of origin is still in dispute and uncertain, largely on account of difficulties in technique.

The method by which lymphatics extend after their primary differentiation is also a matter of dispute. According to Huntington and McClure, lymphatic endothelium spreads chiefly by the continued differentiation of the indifferent mesenchyme cell into lymphatic endothelium. S. Mayer thought that spreading occurred by the continuous transformation of blood-vessels into lymphatics, although E. R. Clark, working on the same material, showed conclusively that he was in error. A similar view has been tentatively proposed by F. T. Lewis. Another group including Ranvier, MacCallum, Sabin, Hoyer, Clark, etc., hold that the spreading takes place by sprouting—that after the primary differentiation new lymphatic endothelium is derived exclusively from old. This has been observed in the transparent tails of living frog-

larvæ (fig. 592). Studies of very early lymphatics in pig- and chick-embryos indicate clearly growth by sprouting (fig. 593). There is therefore solid basis for the view that lymphatic endothelium, after its primary differentiation (the exact extent of which in time and place has not yet been entirely cleared up), becomes a specific, independent tissue, from which all lymphatic endothelium is derived.

The *lymphatic nodes* do not make their appearance until the system of vessels is well established. They are at first represented by masses of lymphoid tissue in the meshes of a lymphatic network. Later the lymphoid mass breaks up into smaller portions, into which the blood-vessels and branches from the surrounding network penetrate; and each mass, together with the portions of the network surrounding it, becomes enclosed in a connective tissue capsule. The original lymphoid tissue becomes transformed into the medullary cords and cortical nodules of the node, while the enclosing lymphatic capillaries form its peripheral lymph-sinus.

FIG. 592.—THE GROWTH OF A LYMPHATIC CAPILLARY, AS SEEN IN THE TRANSPARENT TAIL OF A LIVING FROG-LARVA. Nuclear areas are dotted, and corresponding areas are numbered. (After E. R. Clark.)



The earliest nodes appear in the places occupied by the primary lymphatic plexuses and sacs (Miss Sabin, F. T. Lewis, Jolly), and have been termed the 'primary nodes' (Miss Sabin). Secondary and tertiary sets of nodes develop later at places of confluence of many lymphatics (cf. A. H. Clark.)

Regeneration and new growth of lymphatic vessels and glands.—While blood-vessels are known to possess throughout life the capacity for regeneration and new growth, this process in lymph-vessels has been very little studied. Yet enough has been learned from the work of Coffin and Evans to justify the statement that lymphatic vessels also possess the capacity for new growth.

The question as to whether lymph-glands may form anew is not yet entirely settled. The study of the problem is extremely difficult, because very small lymph-nodes may be normally present in a certain region, yet they may escape observation until they become hypertrophied under certain conditions. A. W. Meyer in a careful experimental study found no evidence for new-formation of lymph glands. On the other hand, there is considerable evidence for the new formation of lymph-glands under pathological conditions.

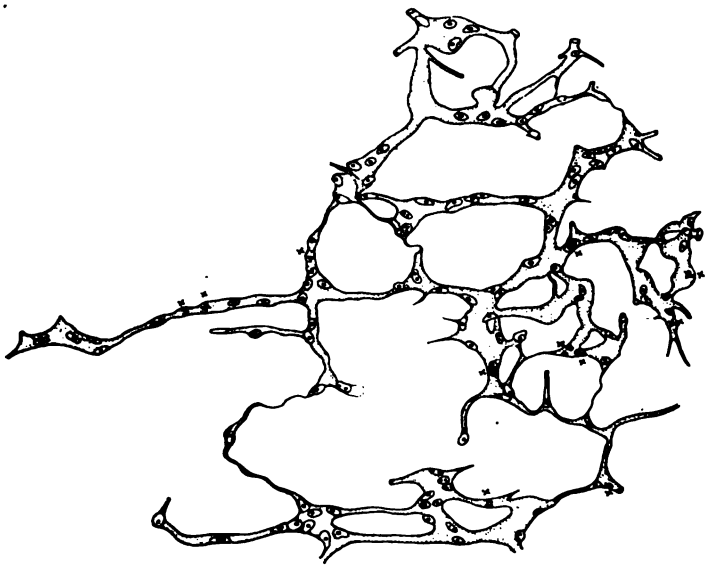
The Hemal nodes.—In addition to the lymph-nodes, there are present in certain animals (bovines, sheep and goats), and probably in man, a set of nodes somewhat similar to lymph-nodes in size, but related to the blood-vascular system, and without any connections with lymphatic vessels—the *hemal nodes*. Their structure resembles that of lymph-nodes, in that there are accumulations of lymphoid tissue, with peripheral and central sinuses, but the sinuses are filled with blood instead of lymph, thus giving them a red color. There is considerable resemblance, histologically, between hemal nodes and accessory spleens, and without doubt the two have frequently been confused. There is still some question as to the precise relationship between the sinuses and the arteries and veins. Some observers hold that arteries supply and veins drain the sinuses, others that the vascular connections of the sinuses are purely venous. Their function is unknown.

Their distribution is variable. In sheep (A. W. Meyer) they may be found anywhere near the viscera, from the base of the skull to the rectum, with a tendency to the following groupings: pararectal, lumbar or prevertebral, mediastinal, and cervical. The total number in sheep averages between thirty and forty. In bovines there is a variable number (2–36) of subcutaneous hemal glands, located mainly over the back in neck, shoulder and hip-regions. There are probably no hemal glands in cat, dog, pig, guinea-pig, rat and rabbit.

A much disputed point has been the question as to whether there is a type of gland, intermediate between the hemal gland and the lymph-gland. Several observers have described such glands. However, A. W. Meyer, who has made the most thorough studies of hemal glands, is very strongly of the opinion that there is no intermediary type—that the hemal glands are definite and distinct structures, and that the term 'hemolymph' gland should be discarded.

Comparative.—Lymphatics are present in all vertebrates, excepting possibly the lower fishes. In amphibia, there are several longitudinal vessels, two of which connect with a variable number of segmental veins. There is also an important connection at the junction of the anterior and posterior cardinal veins. At the points of connection of the

FIG. 593.—PORTION OF EARLY SUBCUTANEOUS LYMPHATIC PLEXUS. From the hip region of a chick embryo of 5 days, 7½ hrs. incubation, showing the character of the primitive plexus and the frequency of mitoses (marked X.) (After E. R. and E. L. Clark.)



lymph-vessels with the veins, lymph-hearts (in variable number, over 100 in Gymnophonia) are found, which pump the lymph into the veins. In reptiles, there is but a single pair of lymph-hearts (posterior). In certain birds, chiefly aquatic, a pair of posterior lymph-hearts persists throughout life, while in others, such as the chick, a pair is present and active until the time of hatching, after which it atrophies and disappears. No lymph-hearts are present in mammals. In the frog there are found large subcutaneous lymph-sacs, which are drained by lymphatic vessels.

The thoracic duct is double in lower vertebrates, and in early embryonic stages of mammals. In adult mammals it is normally single. The number of persistent connections of the lymph-vessels with the veins shows a reduction from lower to higher vertebrates. In reptiles, there are two pairs, in birds, one or two pairs, in mammals (typically) one pair.

No lymph-glands have been found in fishes, amphibia or reptiles. In birds (Jolly) lymph-glands are present in some of the lamellirosters—swan, duck and goose—but are absent in hen and pigeon. In mammals, all of which have more extensive sets of lymph-glands, the first to develop arise out of the primary lymph-sacs and correspond in location to the lymph-glands found in birds.

II. SPECIAL ANATOMY OF THE LYMPHATIC SYSTEM

The lymphatic system will be considered by regions as follows: A, head and neck; B, upper extremity; C, thorax; D, abdomen and pelvis; E, lower extremity.

A. THE LYMPHATICS OF THE HEAD AND NECK

The lymphatics of the head and neck may be divided into two sets. One set is superficial, draining the entire skin-surface, and has its nodes, for the most part, in the neck, the principal group lying along the external jugular vein. The other

set is deeper and drains the mucous membrane of the upper part of the digestive and respiratory tracts, together with the deep organs, such as the thyroid gland, and the tendons of the muscles. The nodes of this set are deeply placed being situated along the carotid arteries, with outlying retropharyngeal nodes.

1. THE SUPERFICIAL NODES OF THE HEAD AND NECK

Lymph-nodes appear first in the neck in the process of development. In the pig the first node to appear develops from the lymph-sac, which is in the supraclavicular triangle behind the sternocleidomastoid muscle. From here vessels grow across the muscle and give rise to a chain of nodes along the external jugular vein. This chain is to be considered as the main chain of superficial nodes in the neck. From it lymphatic vessels grow over the back of the head, the side of the head, the face, and the front of the neck, and in their course groups of secondary nodes develop. The nodes of the main chain are known as the superficial cervical nodes, and are from four to six in number. The secondary groups are—(1) the occipital; (2) the posterior auricular; (3) the anterior auricular; (4) the parotid; (5) the submaxillary, with the facial as a tertiary set, and (6) the submental.

1. **The occipital nodes** [lymphoglandulæ occipitales].—The lymphatics of the scalp of the back of the head collect into a few trunks that either empty into from one to three small nodes near the occipital insertion of the semispinalis capitis muscle, or pass by the secondary group and empty directly into the upper nodes of the main superficial cervical chain (figs. 594, 596).

2. The **posterior auricular nodes.**—A portion of the temporal part of the scalp, together with the posterior surface of the auricle, except the lobule, and the posterior surface of the external auditory meatus, drain into two small nodes on the insertion of the sternocleidomastoid muscle. The efferent vessels of these nodes pass to the upper part of the superficial cervical chain (fig. 594).

3. The **anterior auricular nodes** are few in number—from one to three—and are situated immediately in front of the tragus. They receive vessels from the anterior surface of the auricle and the external auditory meatus, from the integument of the temporal region and the lateral portion of the eyelids. Their efferents pass to the parotid and superior deep cervical nodes (fig. 596).

4. **The parotid nodes.**—The parotid group of nodes (figs. 595, 596, 600) is considerably larger than the two preceding, containing from ten to sixteen nodes, and the group drains a more complex area. It receives vessels from the adjacent surface of the external ear, the external auditory meatus, the skin of the temporal and frontal regions, and the eyelids and nose. The deeper nodes of this set receive vessels from the parotid gland.

In the embryo these nodes lie in the pathway of the lymph-vessels that grow to the scalp; many of these vessels, however, pass the parotid group and empty into the superficial cervical chain. The nodes of the parotid group lie embedded in the substance of the parotid gland, and their efferents pass to the submaxillary and the superior superficial and deep cervical nodes.

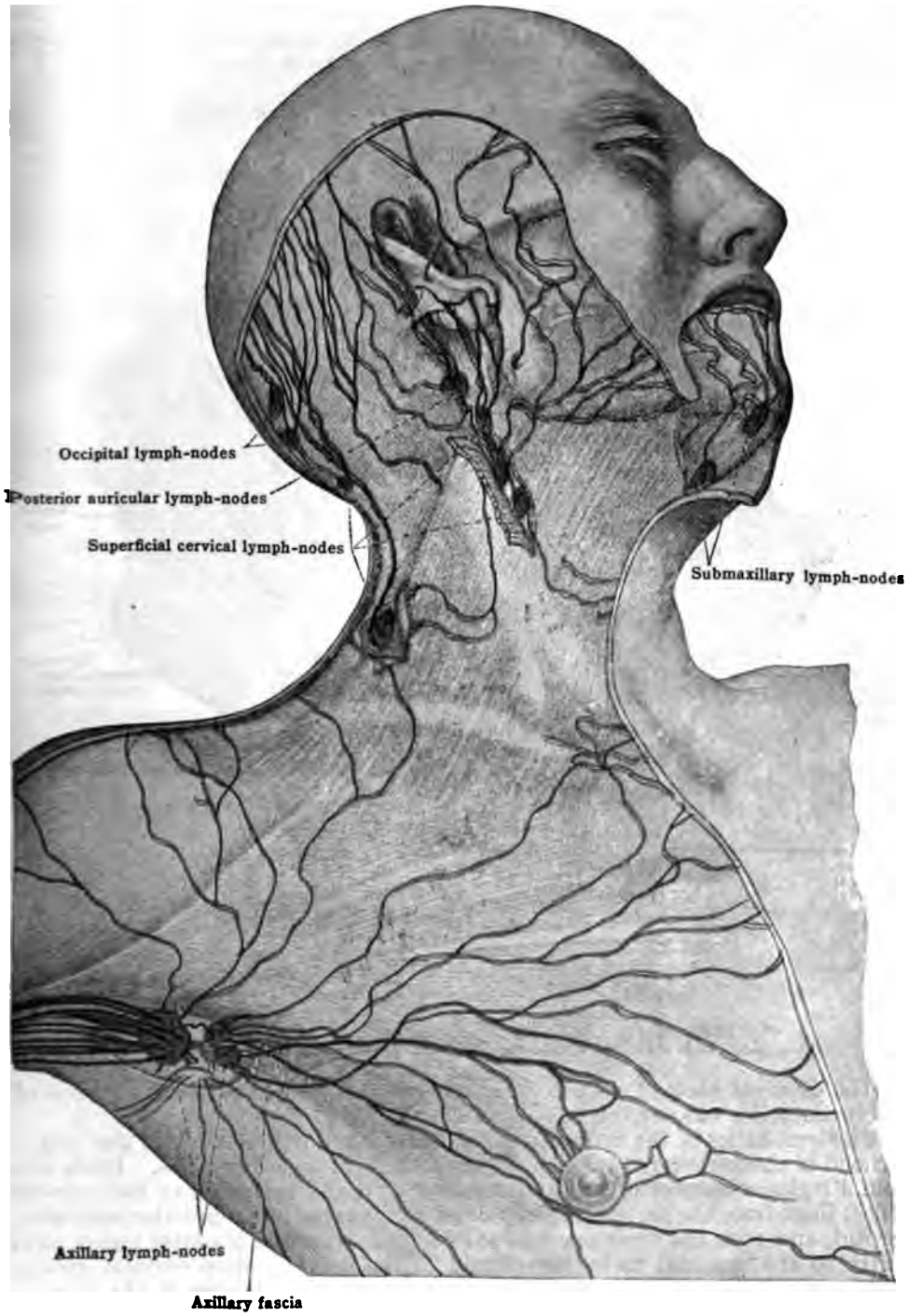
As 'inferior auricular nodes' (fig. 596), Bartels designates one or two small glands of the parotid group which lie below the ear, and receive afferent vessels from its lower part.

5. **The submaxillary and facial** [lgl. faciales profundæ] **nodes.—The submaxillary** (or 'mandibular') group (figs. 595, 596, 600) consists of a chain of from three to six nodes, resting on the submaxillary (salivary) gland, along the inferior border of the mandible. They lie usually on the submaxillary gland, but may extend from the insertion of the anterior belly of the digastric to the angle of the jaw. They are about 5 mm. in diameter, and the largest is near the point where the external maxillary (facial) artery crosses the mandible. The submaxillary nodes, together with the next group, the facial, drain a complex area, including not only skin, but mucous membrane. They receive lymph-vessels from the nose, cheek, upper lip, the lateral part of the lower lip, together with almost all those from the gums and teeth and from the anterior third of the lateral portions of the tongue. In agreement with the fact that these nodes, though lying superficially and draining the skin, drain also the mucous membrane, their vessels empty not only into the superficial cervical chain, but also into the deep cervical chain.

The facial nodes (figs. 595, 597) are evidently outlying nodes of the submaxillary group. They are in two main sets—(1) the **supramaxillary set,** which consists of from one to thirteen nodes, resting on the mandible near the point

where it is crossed by the external maxillary (facial) artery; (2) the **buccinator set,** lying on the line connecting the lower margin of the ear and the angle of the jaw.

FIG. 594.—THE LYMPHATICS OF THE HEAD AND NECK. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)

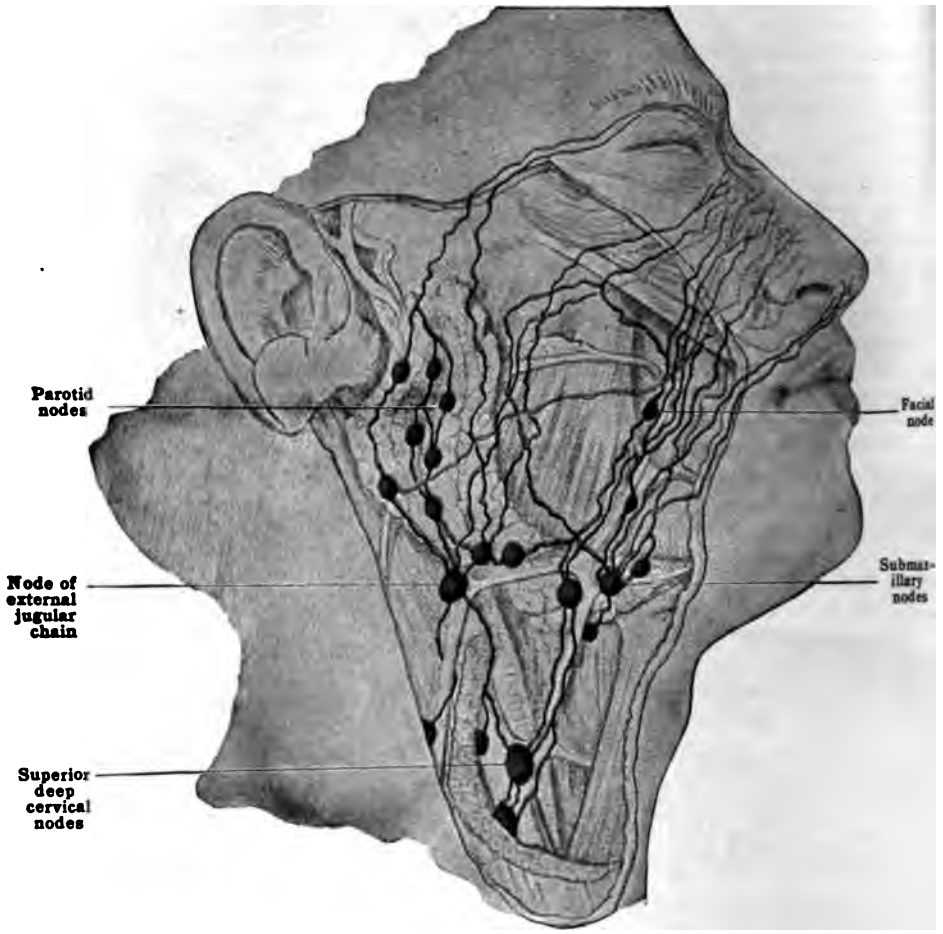


Of these latter nodes, some lie near the point where the parotid duct perforates the buccinator muscle; the others are further forward, between the external maxillary artery and the **anterior facial** vein. Additional nodes belonging to the group may occur near the nose and in the **suborbital region.** These facial nodes receive afferents from the outer surface of the nose,

the lips, eyelids, cheek, temporal part of the face, the mucosa of the mouth, the teeth of the upper jaw, the gums, the tonsils, and the parotid gland. Their efferents pass to the submaxillary and parotid nodes.

6. The **submental nodes,** usually two in number, lie in the triangle bounded by the anterior bellies of the two digastric muscles and the hyoid bone (figs. 594, 598, 602). They are usually near the median line, and drain the skin of the chin, the skin and corresponding mucous membrane of the central part of the lower lip and jaw, the floor of the mouth, and the tip of the tongue. The efferent vessels pass either to the submaxillary nodes or to the deep cervical chain.

FIG. 595.—LYMPHATICS OF THE FACE. (After Küttner.)



2. THE LYMPHATIC VESSELS OF THE FACE

The different parts of the face and their lymphatic relation to these groups of superficial nodes will now be considered.

The **lymphatics of the scalp** (figs. 594, 600) form a rich network in the neighborhood of the vertex, from which vessels pass in various directions. From the frontal region a number of vessels pass downward and backward to the parotid nodes; those from the parietal and temporal regions pass to the anterior auricular, parotid, and posterior auricular nodes; and those from the occipital region pass partly to the occipital nodes and partly to the superior deep cervical group, while a single large vessel descends along the posterior border of the sternomastoid muscle to terminate in one of the inferior deep cervical nodes.

The lymphatics of the eyelids and conjunctiva.—The capillary plexus of the eyelids and the conjunctiva is an abundant one, and at the free border of the eyelids becomes extremely close. The lymphatics from the lateral three-fourths

e lids pass to the anterior auricular and parotid groups of nodes, while those the medial one-fourth pass obliquely across the cheek with the facial vein to inate in the facial and submaxillary nodes (figs. 595, 596, 600).

. 596.—Lymphatic Nodes and Vessels of the Ear, Eyelids, Nose and Lips. New-hild. P, parotid. M, submaxillary gland. B, buccal fat ('sucking pad'). The dorsal ervical lymph nodes are not labelled. (After Bartels.)

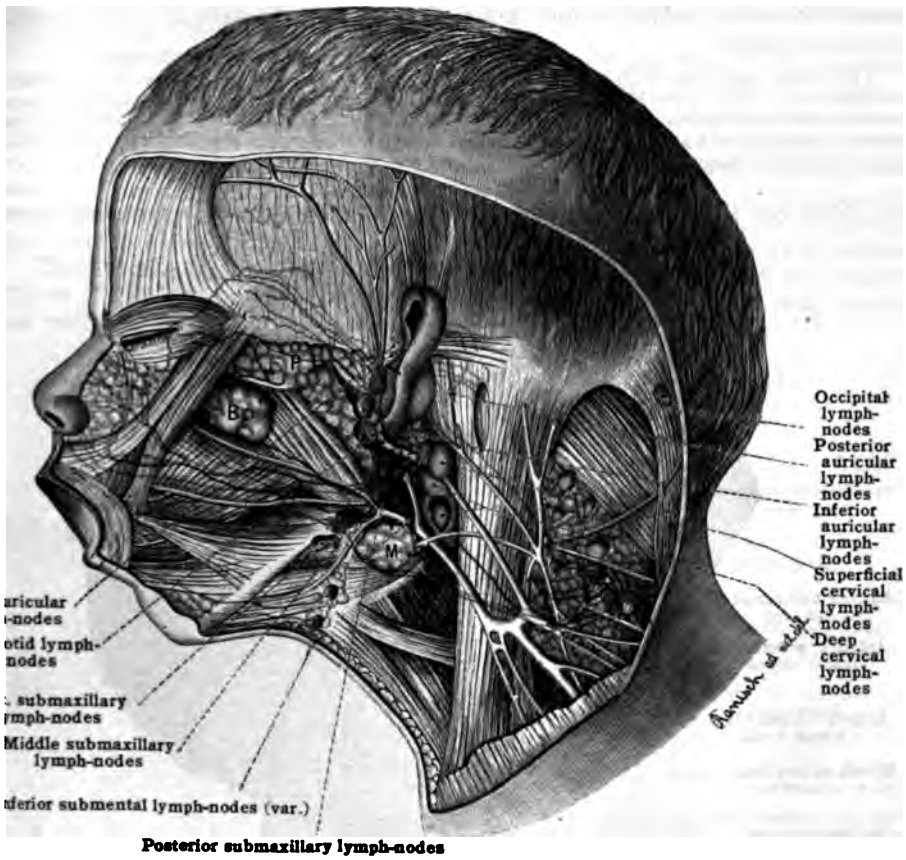
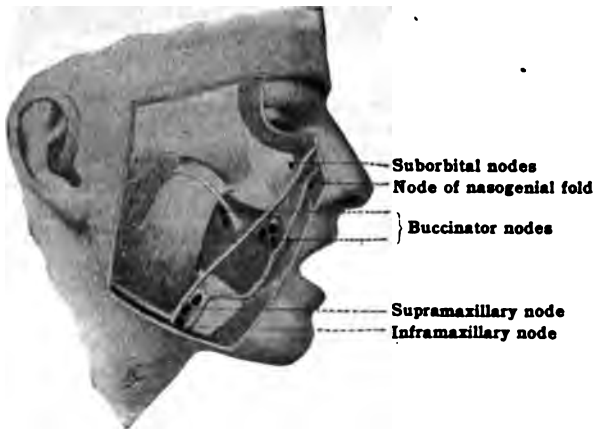


Fig. 597.—The Facial Nodes. (After Buchbinder.)



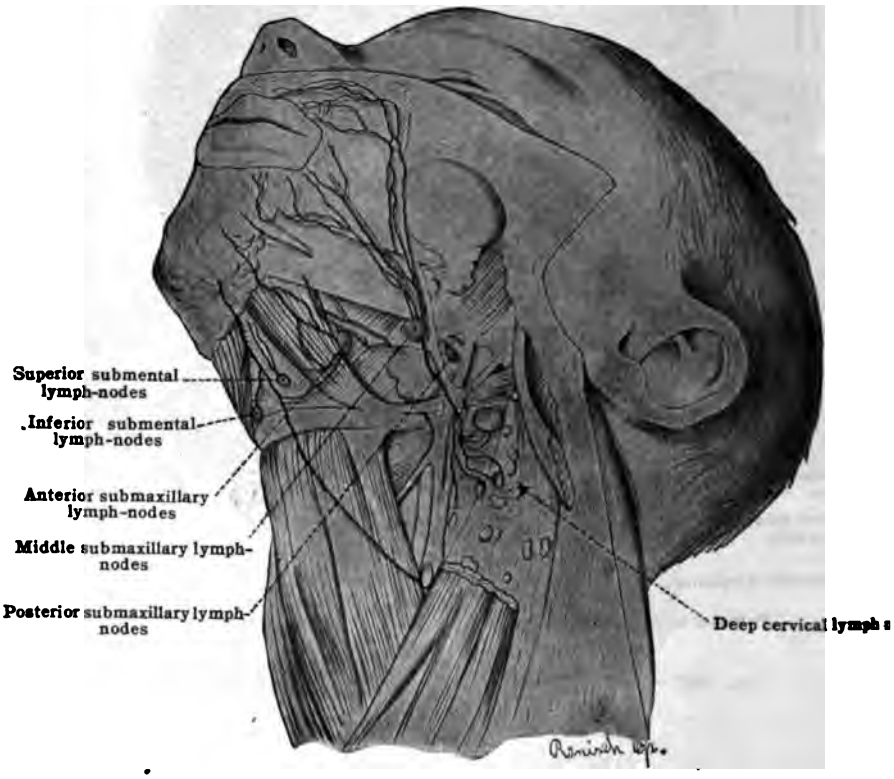
he lymphatics of the nose.—The lymphatics of the nose (figs. 595, 596) form a **ork** which is coarse at the root of the organ, but dense over the alar region. **vessels** run in three sets—(1) one set passing over the eye to the parotid nodes; **set passing** under the eye to the same nodes; and (3) the most important

group, consisting of from six to ten trunks, passing to the facial and submaxil nodes. There are some anastomoses between the capillaries of the skin and t of the mucous membrane of the nose.

The lymphatics of the lips (figs. 598, 600).—The capillary plexuses of the and mucous membrane are continuous at the free border of the lips. The ve of the upper lip, of which there are about four on each side, pass to the maxillary nodes. From the lower lip the trunks from near the angle of the m pass to the submaxillary nodes, while those from the center of the lip pass to submental nodes.

There are from two to four subcutaneous vessels and from two to three submucous v on either side. The collecting trunks passing to the submaxillary nodes do not anastomos the same is true of the submucous vessels of the lower lip. On the other hand, the subcuta vessels passing to the submental nodes anastomose freely, an important fact in connection the extension of cancer of the lower lip.

FIG. 598.—THE LYMPHATICS OF THE LIPS. Newborn child. (From Bartels after Dore



The lymphatics of the auricle and external auditory meatus.—The lym plexus in the auricle, external auditory meatus, and the outer side of the ty membrane is an abundant one. An anastomosis has been described bet scanty plexus on the inner side of the tympanic membrane and the plexus outside. The collecting vessels pass to three sets of nodes:—(1) those fr external and internal surface of the auricle and the posterior part of the e auditory meatus pass to the posterior auricular nodes; (2) those from the the helix, a part of the concha and the outer portion of the external auditor tus pass to the inferior auricular and superficial cervical chain; some of the from the first and second areas also run to the deep cervical group; (3) an a group from the tragus and part of the external auditory meatus consisting o four to six trunks, pass to the anterior auricular nodes, which are connecte the parotid nodes.

3. THE DEEP LYMPHATIC NODES OF THE HEAD AND NE

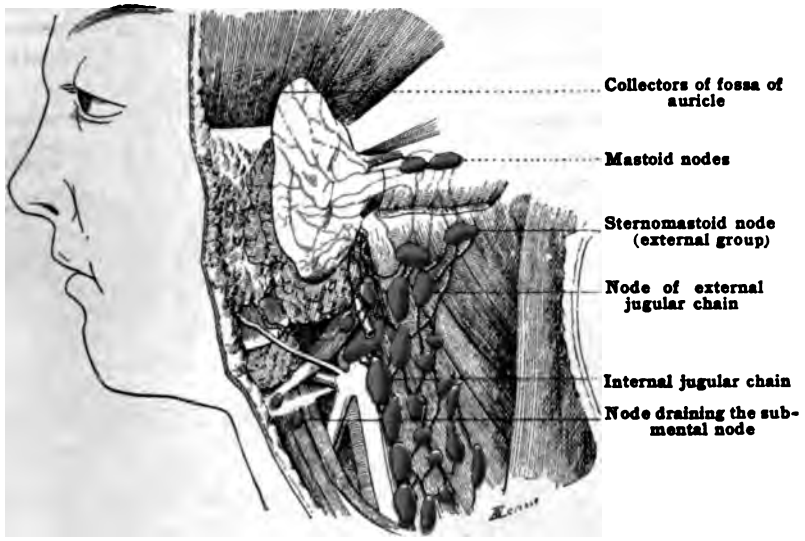
The **deep cervical chain** (figs. 595, 596, 598–600) is the largest mass of in the neck. It consists of from fifteen to thirty nodes, which lie along the

course of the carotid artery and internal jugular vein. This chain receives vessels from all the superficial nodes, also directly from the skin, as well as from the entire mucous membrane of the respiratory and alimentary tracts in the head and neck. Thus it drains both the superficial and the deep structures.

For convenience of description this long chain, though usually continuous, is divided into two groups—(1) a superior group, lying above the level at which the omohyoid muscle crosses the carotid artery, and (2) an inferior or supraclavicular group, lying below that level.

(1) **The superior deep cervical nodes** extend from the tip of the mastoid process to the level at which the omohyoid muscle crosses the common carotid artery. The **dorsal** and smaller nodes of the chain lie on the splenius, levator scapulæ, and scalene muscles (fig. 596). They drain the skin of the back part of the head, both indirectly and directly, and receive (1) efferents from the occipital and posterior auricular nodes, (2) a large vessel from the skin of the occipital part of the scalp, (3) some trunks from the auricle, and (4) cutaneous and muscular vessels from the neck. The **ventral nodes** of the chain lie on the internal jugular vein. They drain the face both directly and indirectly, as well as the deeper structures of the head and neck. They show especially well in fig. 602 in connection with the tongue.

FIG. 599.—THE DEEP CERVICAL CHAIN. (After Poirier.)

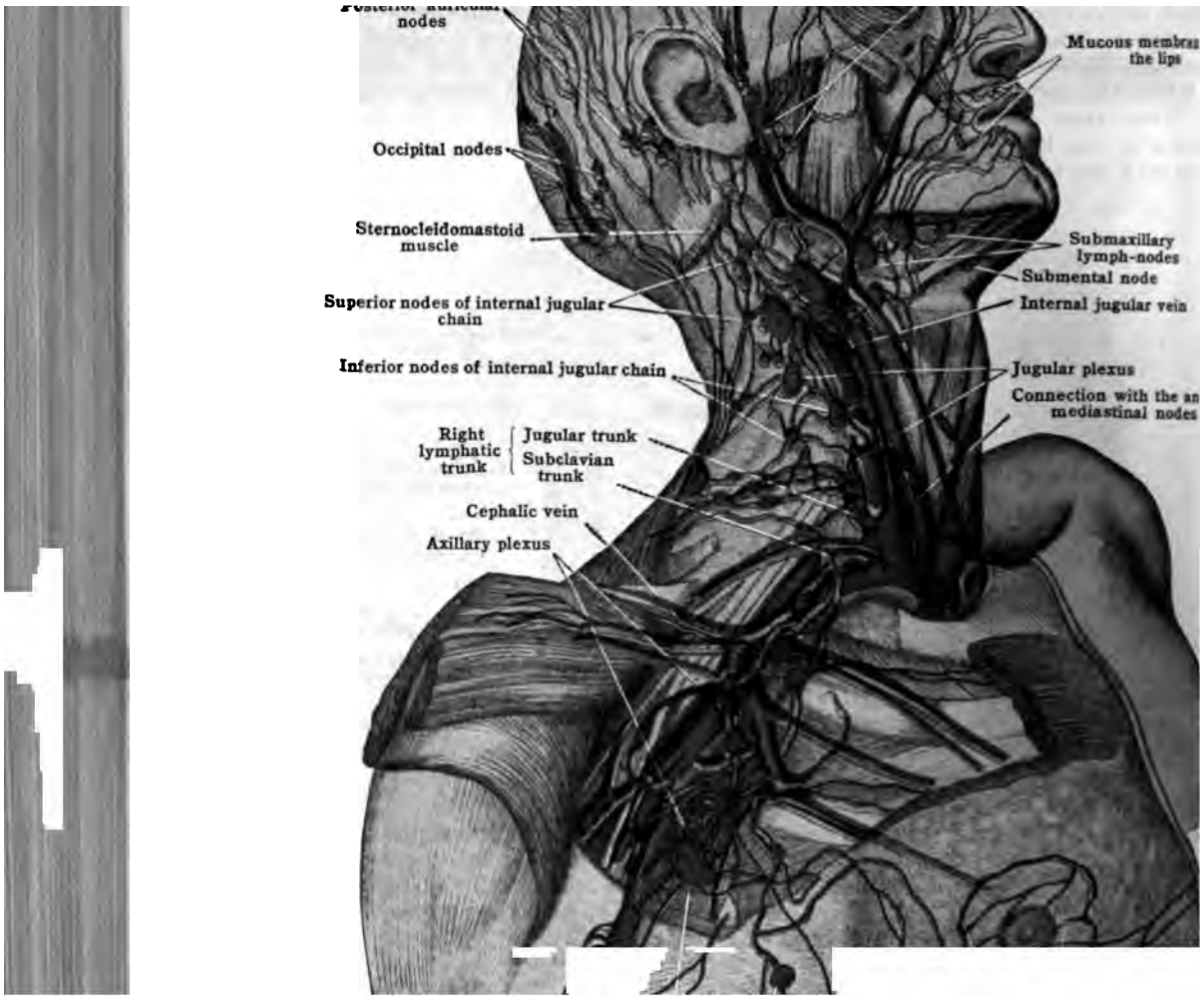

Collectors of fossa of auricle
Mastoid nodes
Sternomastoid node (external group)
Node of external jugular chain
Internal jugular chain
Node draining the submental node

(2) The **inferior deep cervical** or supraclavicular nodes lie in the supraclavicular triangle (fig. 600). In the upper part of the triangle the nodes rest on the splenius, the levator scapulæ, and the scalene muscles, while at the base of the triangle they are related to the subclavian artery and the nerves of the brachial plexus. They drain a wide area, receiving vessels from the head, neck, arm, and thoracic wall. They are connected with the superior deep cervical chain, and receive afferents from the axillary nodes, and, in addition, they receive vessels directly from the back of the scalp, from the skin of the arm, and from the pectoral region. Thus it will be seen that a large part of the lymph of the head and neck, as well as some from the arm and thorax, passes through these nodes. Their efferents unite to form the jugular trunk, which ends at the junction of the internal jugular and subclavian veins.

In the descriptions of the deep lymphatic vessels certain additional groups of nodes will be considered, which may be regarded as outlying groups from the deep cervical chain.

4. THE DEEP LYMPHATIC VESSELS OF THE HEAD AND NECK

The lymphatics of the brain.—It is now recognized that there are no lymphatics in the brain and cord, so that the function of absorption must be accom-

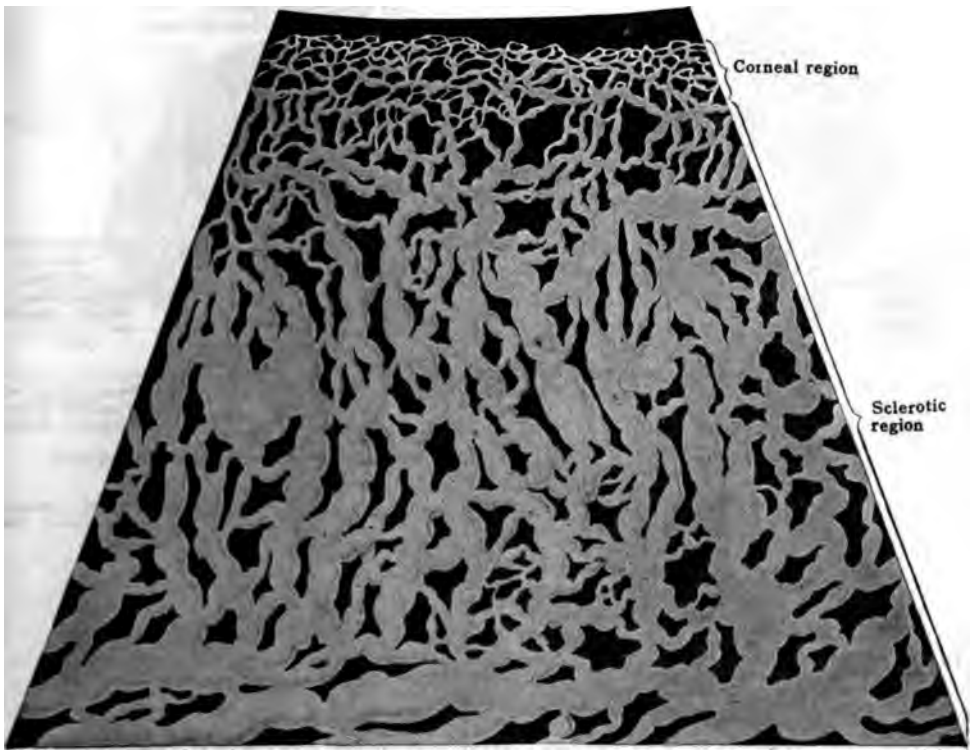

nodes
Mucous membra
the lips
Occipital nodes
Sternocleidomastoid
muscle
Submaxillary
lymph-nodes
Submental node
Superior nodes of internal jugular
chain
Internal jugular vein
Inferior nodes of internal jugular chain
Jugular plexus
Connection with the an
mediastinal nodes
Right
lymphatic
trunk
Jugular trunk
Subclavian
trunk
Cephalic vein
Axillary plexus

There is a continuous renewal of the fluid in the cerebral ventricle, chiefly derived from the choroid plexus. It passes into the subarachnoid spaces through the three foramina in the roof and at the sides of the fourth ventricle. Fluid is removed from the subarachnoid spaces chiefly by passing through the arachnoidal villi into the venous sinuses of the cranium.

The lymphatics of the eye.—No lymphatic vessels have as yet been discovered either in the eyeball or in the orbit. In both, however, there are abundant tissue-spaces, the most noteworthy of the orbit being the **interfascial space (space of Tenon)**, which communicates by a space between the optic nerve and its sheath with the subarachnoid spaces of the cranial cavity.

In the eyeball the tissue-spaces are abundant, aside from the vitreous and aqueous chambers. Numerous spaces exist in the choroid coat, especially in the lamina suprachoroidea, and in the sclerotic, both sets communicating by perivascular spaces surrounding the venæ vorticosæ with the interfascial space. In the cornea there are abundant lacunæ, united by their anastomosing canaliculi, to form a network of lymph-spaces which come into close relation with the conjunctival lymphatics at the corneal margin.

FIG. 601.—THE LYMPHATICS OF THE CONJUNCTIVA, SURFACE VIEW. (After Teichmann.)



The conjunctiva, however, being a portion of the integument, does possess **lymphatic vessels** (fig. 601), arranged in a double network whose collecting vessels **accompany those of the eyelids**, and terminate with them in the submaxillary, **anterior auricular**, and parotid nodes.

THE LYMPHATICS OF THE DIGESTIVE TRACT IN THE HEAD AND NECK

The lymphatics of the gums.—The lymphatics from the mucous membrane **of the gums pass to the** submaxillary nodes. The capillary plexus is abundant; **the collecting vessels arise** from it on the inner surface of the gum, and pass **between the teeth to reach** a common semicircular collecting vessel on the outer **surface.** Lymphatics **have** been demonstrated in the pulp of the tooth (Schweitzer).

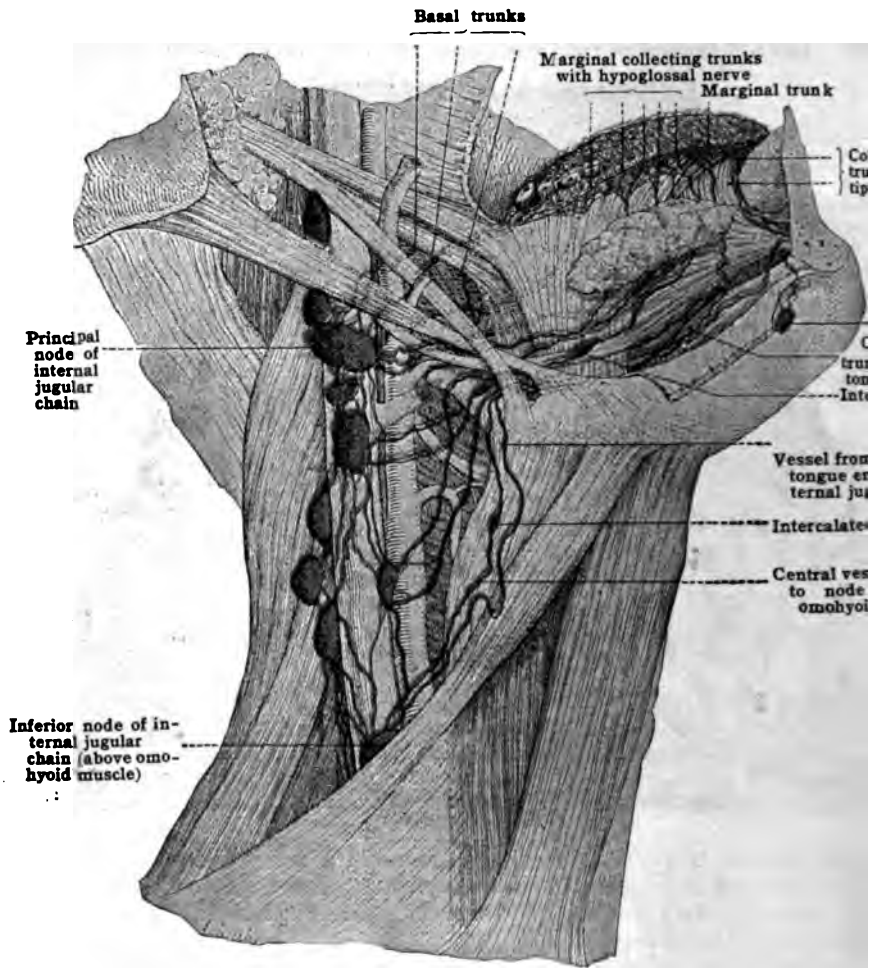
The lymphatics of the tongue (fig. 602).—There is a rich lymphatic plexus **throughout the entire** extent of the submucosa of the tongue, but **that portion lying in the basal part** of the tongue seems to be more or less independent of the **rest. According to Aagaard** the tongue muscles are provided with lymphatics

which are drained by the vessels from the submucosal plexuses. There a groups of collecting vessels—(1) apical, (2) marginal, (3) basal, and (4) cen

(1) The *apical vessels* are usually four in number, two on each side. One pair pe the mylohyoid muscle and ends in a suprahyoid median node, while the other pair pa deep cervical chain. The latter are long, slender vessels, which run along the frenu tongue to the surface of the mylohyoid muscle, cross the hyoid bone just behind th of the digastric and then run downward in the neck to a node of the deep cervical ch above the omohyoid. It will be noted in fig. 602 that the most anterior vessels en lowest nodes, while those from the back of the tongue end in higher nodes.

(2) The *marginal vessels* are from eight to twelve in number. They all pass to the deep cervical nodes, a part of them passing external to the sublingual gland, while t number pass internal to it. There is one large and constant node at the point where the muscle crosses the jugular vein, to which a large number of the vessels converge.

FIG. 602.—THE LYMPHATICS OF THE TONGUE. (Poirier and Charpy.)


Basal trunks
Marginal collecting trunks with hypoglossal nerve
Marginal trunk
Principal node of internal jugular chain
Vessel from tongue ex ternal ju
Intercalate
Central ves to node omohyoi
Inferior node of internal jugular chain (above omohyoid muscle)

(3) The *basal vessels* are seven or eight in number, and drain the basal portion of t Some end in the large node just mentioned, while others run backward close to t line, where they anastomose, as far as the glossoepiglottidean fold, when they sep join the tonsillar vessels to pass outward to the superior deep cervical nodes.

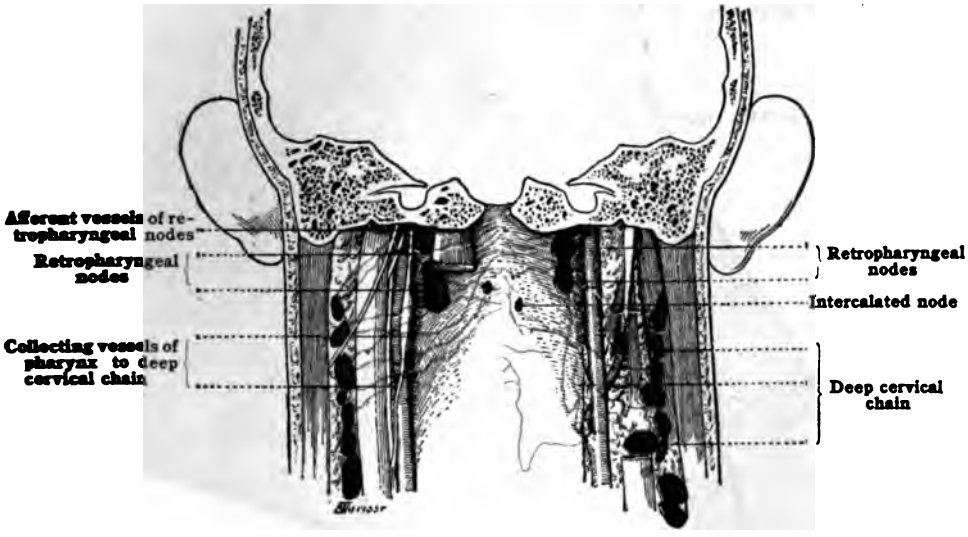
(4) The *central vessels*, arising from the central portion of the tongue, pass ba the median line on the ventral surface of the tongue. They lie upon the mylohoyo cross the hyoid bone, and end in the superior deep cervical chain.

The lymphatics of the palate.—The lymphatics from the palate pa deep cervical chain. The trunks from the hard palate run in the submuc as the last molar tooth, where they pass in front of the anterior palatine arc and end in the superior deep cervical nodes beneath the digastric mu the soft palate the capillary plexus is very rich, reaching a maximum in t

From the inferior surface of the soft palate and the palatine arches vessels pass directly to the superior deep cervical chain, but some of the vessels from the upper surface of the soft palate run forward with the pharyngeal vessels and end in the *retropharyngeal nodes*. It will be seen from fig. 603 that the retropharyngeal nodes are simply outlying nodes from the deep cervical chain.

The lymphatics of the pharynx.—As has just been stated, there are certain outlying nodes of the deep cervical chain which lie behind the pharynx. They receive some of the vessels from the submucosa of the roof of the pharynx, but many of the pharyngeal vessels pass by these nodes and end directly in the superior deep chain. The tonsil is especially rich in lymphatics, and its efferents, together with those from the middle and inferior portions of the pharynx, end in the superior deep cervical chain. The lymphatics of the Eustachian tube run to the lateral retropharyngeal lymph-nodes or, passing these, to the deep cervical nodes.

FIG. 603.—THE LYMPHATICS OF THE PHARYNX. (After Poirier and Cunéo.)



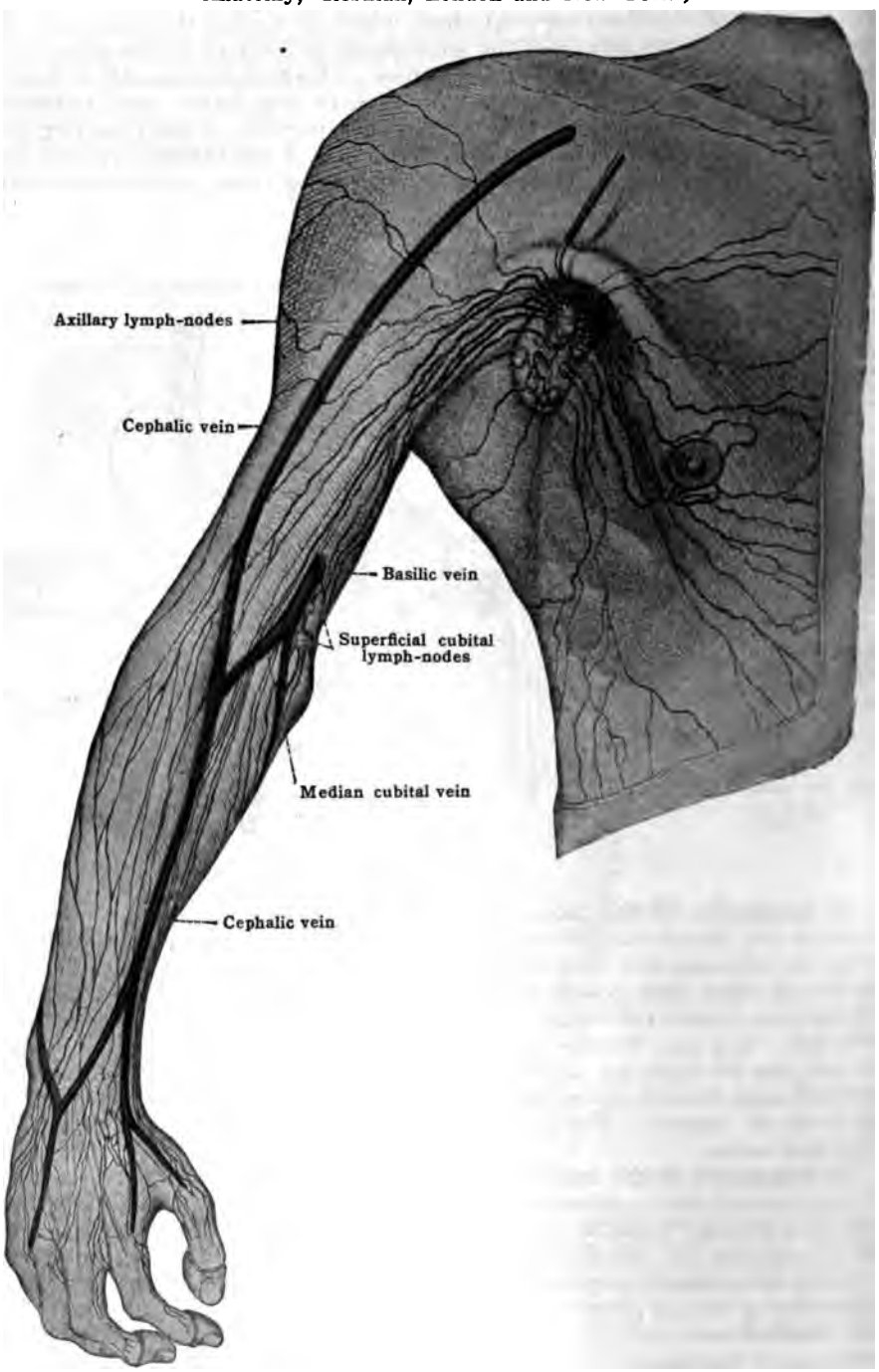
The lymphatics of the nasal cavities.—The mucous membrane of the nose contains a rich lymphatic plexus whose main trunks pass to the retropharyngeal nodes. An anterior set, however, anastomoses with the subcutaneous vessels, and through these their lymph is conveyed to the facial and submaxillary nodes. The posterior vessels run either to the deep cervical chain or to the retropharyngeal nodes. Key and Retzius have shown that an injection of the lymphatics of the nose may be made by injecting the subarachnoid spaces at the base of the brain, although there is presumably no direct connection between the spaces and the lymphatic vessels. The lymphatics of the nasal sinuses end in the retropharyngeal nodes.

The lymphatics of the larynx.—The larynx is, for the most part, drained by the deep cervical nodes, although its lymph may also pass through certain outlying nodes situated upon its ventral surface. The mucous membrane is divided into two zones by the ventricular folds, the mucous membrane of these structures possessing but a scanty lymphatic plexus. The vessels from the upper part of the larynx, four or five in number, pass to the nodes of the superior deep cervical chain, situated near the digastric muscle; those from the lower part pass to the lower nodes of the same chain, some even descending as far as the supraclavicular nodes. The lymphatics of the trachea pass, on each side, to the paratracheal and inferior deep cervical nodes.

The lymphatics of the thyroid gland.—The lymphatics of the thyroid gland pass either to the small nodes situated in front of the larynx and trachea, or to nodes of the deep cervical chain, a part of them ascending and a part descending.

It will thus have been seen that the lymphatics of the mucous membrane of the head and neck all end in the deep cervical chain of nodes or in its outlying nodes. Some of the vessels pass by the outlying nodes, but since the nodes

FIG. 604.—THE LYMPHATICS OF THE UPPER EXTREMITY. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



of the chain are so closely connected, the lymph must pass through several nodes before entering the veins. The palatine tonsils, the numerous lingual and pharyngeal tonsils, together with small lymph-follicles in the submucosa of the respiratory tract, represent lymph-nodes in the capillary zone.

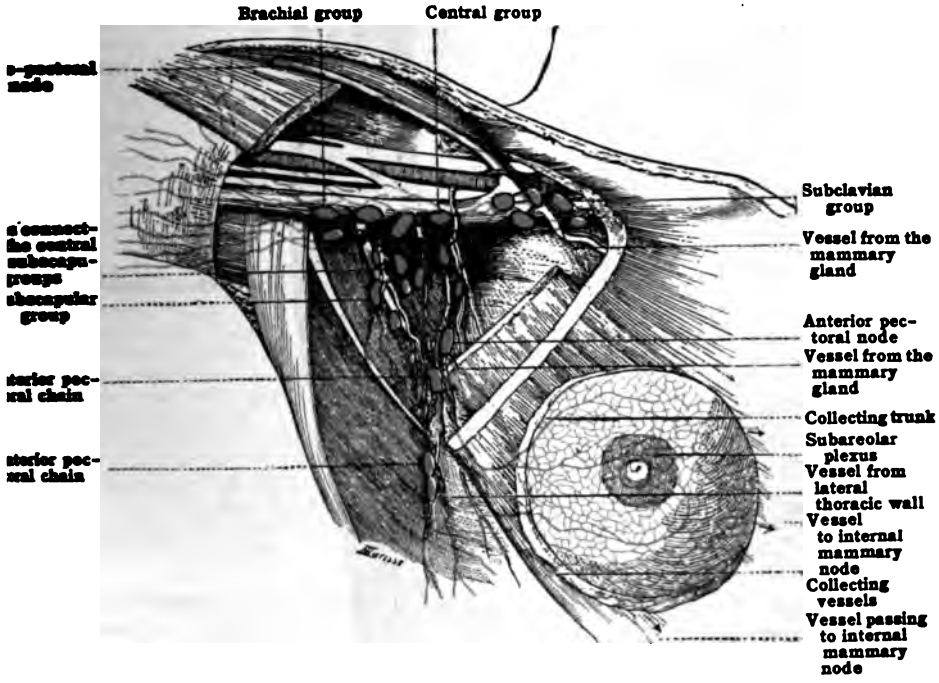
B. THE LYMPHATICS OF THE UPPER EXTREMITY

1. THE LYMPHATIC NODES OF THE UPPER EXTREMITY

The lymph-nodes of the arm lie, for the most part, in the axilla, where there is rge group of nodes which receive almost the entire drainage of the arm and thoracic wall. In addition, there is in the arm a set of outlying superficial es, the superficial cubital (supratrochlear), while small isolated nodes are often rcalated along the course of the deep lymphatic vessels which accompany the ial, ulnar, anterior interosseus and brachial arteries, the cephalic vein, and the p cubital vessels.

(1) **The antibrachial nodes** are very small nodes (size of pin-head) intercalated ng the deep lymphatics which accompany the radial, ulnar, anterior and pos- ior interosseus arteries.

FIG. 605.—THE AXILLARY LYMPH-NODES. (After Poirier and Cunéo.)



(2) The **deep cubital nodes** are also very small nodes, one or two in number, ercalated along the lymphatic vessels, near the deep vessels at the bend of the ow.

(3) The **superficial cubital** (or supratrochlear) **node** is situated three or four - above the medial epicondyle of the humerus. It lies in the superficial fascia the medial side of the basilic vein near the place where it passes through the p fascia. It is usually single, but may be absent or represented by a chain of n two to five nodes. Its efferents follow the basilic vein.

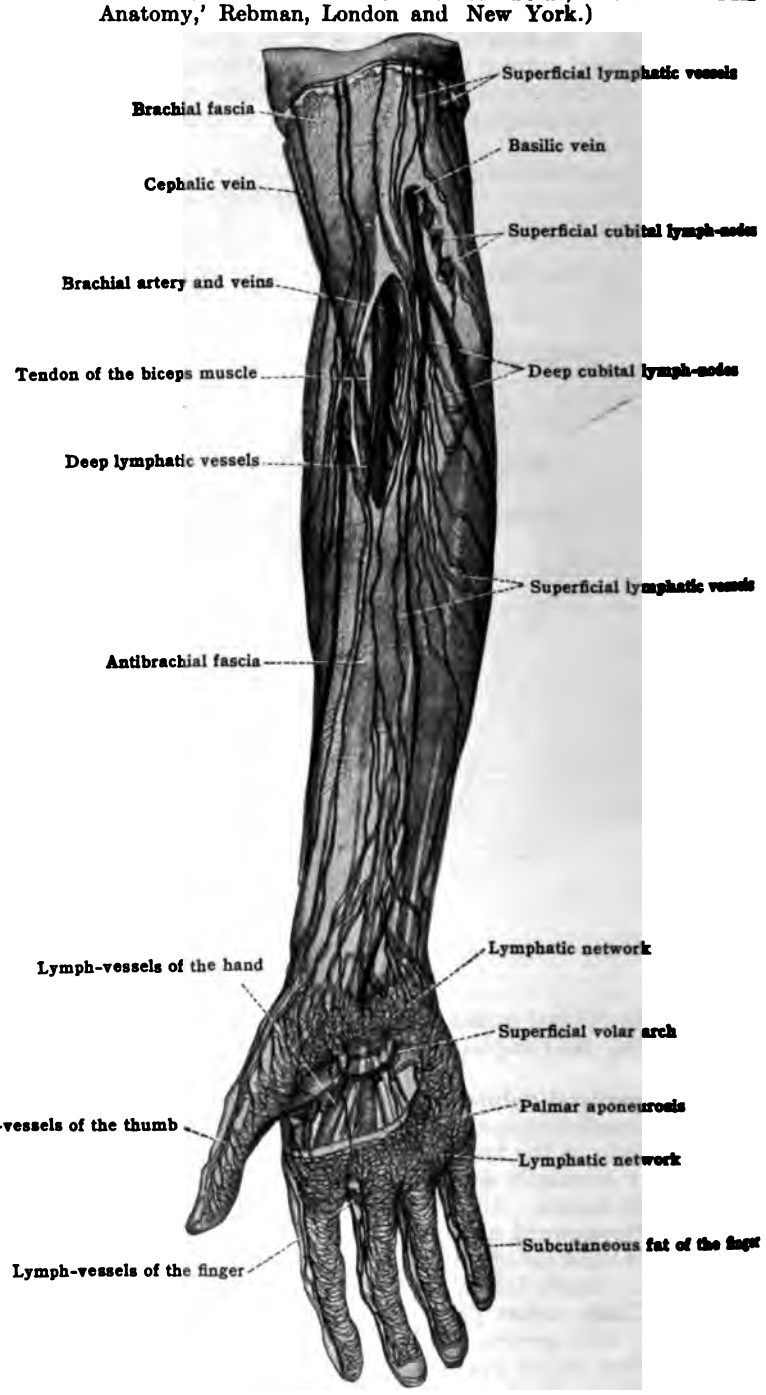
(4) The **deltopectoral nodes** are very small intercalated nodes, from one to e in number, and are situated in the groove between the deltoid and pectoral scles. Their vessels follow the cephalic vein.

(5) The **axillary nodes** [lgl. axillares], from twelve to thirty-six in number, y be divided into groups according to the areas which they drain (figs. 604,). In addition to the upper extremity, they receive lymphatic drainage from thoracic walls, including dorsal, lateral and ventral (mammary) regions.

(a) The *subclavian group* consists of four or five nodes, situated in the apex of the axillary a. They receive the efferent vessels of all the other groups, and their efferent vessels in turn te to form a single trunk, the subclavian, which empties into the thoracic duct on the left e and on the right side either into the vein directly or else after uniting with the jugular nk. (See pp. 758–760.)

(*b*) *The central group.* A little lower along the axillary artery is a group of three to f nodes, which makes a second center for the vessels of the other groups, and sends its effe to the subclavian group. It will be clear from fig. 605 that the separation of groups 1 and arbitrary.

FIG. 606.—THE LYMPHATICS OF THE FOREARM. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



(*c*) *The brachial group.*—This consists of four or five nodes, and, as its position towa the junction of the axillary and brachial arteries indicates, is the main station for the lymphat of the arm proper. It receives almost all the superficial and deep lymphatics of the arm, a its efferents pass to the central and subclavian groups, although a few pass directly to suprascapular group. Small, outlying nodes of this group may be intercalated along vessels following the brachial artery throughout its course.

(*d*) *The subscapular group.*—In this group are six or seven nodes, which follow the subular artery and its branch, the circumflex (dorsal) scapular. Belonging to it there are usually or three small nodes on the dorsal surface of the scapula, in the groove which separates the s major and minor. This group receives vessels from the dorsal surface of the thorax, as as from the arm, and its efferents pass to the brachial group.

(*e*) *The anterior pectoral group.*—This group consists of four or five nodes which lie along the er border of the pectoralis major and drain the mammary gland and front of the chest. ir efferent vessels pass to the central and subclavian groups.

(*f*) The *posterior pectoral group* consists of small nodes situated on the inner wall of the la, along the course of the long thoracic artery. They receive afferents from the lateral gument of the thorax and drain into the nodes of the central group.

2. THE LYMPHATIC VESSELS OF THE UPPER EXTREMITY

The lymphatic vessels of the upper extremity are divided into two sets—a perficial and a deep set.

The superficial vessels.—The superficial lymphatic vessels of the arm course two layers, the one quite subcutaneous, the other next to the deep fascia, with quent anastomoses between the two sets. The majority of these vessels main superficial throughout the arm, but some of them pass through the deep scia in the upper arm especially where the basilic vein pierces the deep fascia, join the deep lymphatics accompanying the brachial artery. The general stribution of the superficial lymphatics and their relations with the lymph-des are shown in figs. 604 and 606.

The capillary plexus is most dense in the volar surfaces of the fingers, where the meshes e so fine that they can only be seen with a lens. On the dorsal surface of the fingers and hand e plexus is less dense. From the plexus on the palmar side of the fingers vessels come together the base of the fingers where they pass dorsally to be joined by the dorsal vessels of the ger. They now follow two rather distinct curves: (1) those from the thumb and index ger and a part of the middle finger pass upward along the radial side of the forearm, course edially over the lower part of the biceps muscle, and empty into the axillary lymph-nodes. ne or two vessels follow the cephalic vein and, after traversing the deltopectoral node, pierce e costocoracoid membrane to enter the subclavian nodes, or pass over the clavicle into the ferior deep cervical nodes. (2) Those from the rest of the fingers course for a short stretch the dorsum of the forearm, when they turn toward the ulnar side, wind around to the volar le and either continue superficially along the upper arm to the axillary nodes, or pass into superficial cubital node, or, joining the efferents from these nodes, pass through the deep cia to unite with the deep lymphatics. (3) A set of vessels from the palm of the hand passes ward along the volar side of the forearm. Anastomoses are frequent between these groups of mphatic vessels, particularly in the cubital region.

It will thus be seen that the superficial cubital nodes receive lymph from the ulnar digits l from the palm of the hand, but not from the thumb and forefinger.

The superficial lymphatics from the rest of the arm join these three main groups at various els.

The deep vessels.—The deep lymphatic vessels of the upper extremity drain e joint-capsules, periosteum, tendons, and (if the work of Aagaard is correct) e muscles. They collect into vessels which, in general, accompany the arteries; the forearm, the radial, ulnar, anterior and posterior interosseous, and in the m the brachial. Above the elbow they are joined by numerous superficial mphatic vessels including efferents from the superficial cubital nodes. Along eir course in the forearm are intercalated small nodes (pin-head size), radial, lnar, anterior and posterior interosseous (Mouchet) and deep cubital; and, the arm, small brachial intercalated nodes. The deep vessels in the main enter he brachial group of axillary lymph-glands which lie behind the large vessels nd nerves, the efferents from which nodes pass either into the lower deep cer-ical lymph-nodes or directly into the subclavian trunk.

The lymphatics of the *shoulder-joint* have been described by Tananesco. He finds a ring f lymphatics in the joint capsule, whose efferents, in the main, following the arteries, run to e central and subclavian groups of axillary nodes.

C. THE LYMPHATICS OF THE THORAX

The lymphatics of the thorax will be considered under the following divisions: he superficial vessels, the deep nodes, and the deep vessels.

1. THE SUPERFICIAL LYMPHATIC VESSELS OF THE THORAX

The superficial lymphatics of the thorax pass almost exclusively to the axillary odes, and may be regarded as forming three sets, a ventral, a lateral, and a

dorsal. The **ventral set** drains the thoracic integument, which extends from the median line and the clavicle over to the lateral border of the chest, and includes the vessels of the mammary gland, which will, however, be described separately. The majority of the vessels from this area end in the anterior pectoral group of axillary nodes, a few, which arise beneath the clavicle, passing to the supraclavicular nodes, and a few perforating the intercostal spaces and ending in the chain of nodes along the internal mammary artery.

It has been shown that an injection into the subcutaneous plexus near the median line passes to the opposite side, and that, in addition to the anastomosis between the networks of the two sides of the thorax which this result manifests, there may also be a few collecting trunks crossing the median line, and, furthermore, anastomoses occur between the superficial networks of the anterior thoracic and abdominal walls. Thus while the main channel of lymphatic drainage is through the axilla, there are minor accessory channels (1) to the supraclavicular nodes, (2) to the axilla of the opposite side, (3) to the internal mammary chain, and (4) in isolated cases even to the inguinal nodes. These accessory channels may become more open in cases of obstruction to the main channels.

The **lateral set** of superficial thoracic lymphatics is much less extensive than the anterior, and its collecting vessels pass upward to open chiefly into the posterior pectoral group of axillary nodes.

The **dorsal set,** which occupies the subcutaneous tissue of the dorsal thoracic wall, sends its vessels to the subscapular group of axillary nodes.

The Lymphatics of the Mammary Gland (Figs. 605, 607)

The lymphatic network over the peripheral portions of the mammary gland is like that of the rest of the thoracic wall. In the areola, however, the capillaries are far more abundant, forming a double subareolar plexus. The superficial plexus is so dense that its meshes can be seen only with a lens. The deeper plexus not only drains the superficial plexus, but receives the vessels from the mammary gland itself, and from it arise usually two large trunks, one from the inferior and one from the superior part of the plexus. These two vessels pass to one or two of the nodes belonging to the anterior pectoral group of axillary nodes. In addition there may be—(1) one or two vessels passing to the nodes along the axillary artery; (2) in rare cases a vessel passing directly to the subclavian nodes. There is also a definite channel from the medial margin of the gland to the internal mammary nodes, the trunks following the perforating branches of the internal mammary vessels. It may also be noted that the crossed anastomosis and that with the abdominal network, mentioned in connection with the superficial thoracic vessels, may occasionally serve as channels for the mammary drainage.

There is also clinical evidence indicating that lymphatic vessels from the lower and medial aspect of the mammary gland may pass through the abdominal wall in the angle between the xiphoid process and the costal cartilages, establishing a communication with the lymphatics of the abdomen in the diaphragmatic region.

Lymphatics of the thoracic muscles.—The studies of Aagaard make it probable that muscles are provided with lymphatics. It is unquestioned that lymphatic vessels course through the pectoral muscles—some passing to the axillary, others to the subclavian, and still others to the internal mammary chain of nodes. This would suffice to explain the fact that cancer of the breast may extend into and through the pectoral muscles.

2. THE DEEP LYMPHATIC NODES OF THE THORAX

The lymphatic nodes of the thoracic cavity may be divided into the parietal and the visceral. The **parietal nodes** are arranged in two sets, the sternal and the intercostal nodes. Along the internal mammary artery are from four to six small **sternal nodes** which receive trunks from the anterior thoracic and the upper part of the abdominal walls, from the anterior diaphragmatic nodes which drain the liver, and from the medial edge of the mammary gland. The efferent vessels usually unite with the vessels of the anterior mediastinal and bronchial nodes, to form the bronchomediastinal trunk, which may join the thoracic duct on the left and the jugular or subclavian trunk on the right or may empty separately into the subclavian vein on either side or both.

The **intercostal nodes** (fig. 609) lie along the intercostal vessels, near the heads of the ribs. There are usually one or two in each space. They receive afferents from the deeper part of the thoracic wall and costal pleura. Their efferents enter the thoracic duct, those from the nodes of the lower four or five

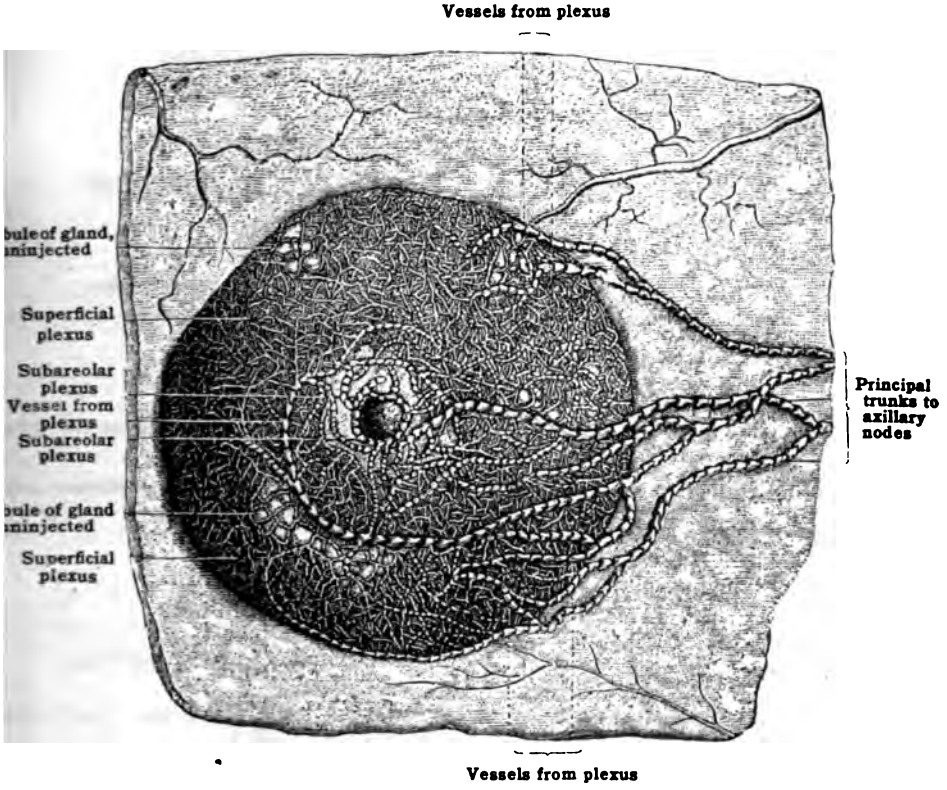
terspaces uniting usually to form a common trunk on each side, but more rked on the left side, which descends to the cisterna chyli.

The efferent lymph-vessels from the upper intercostal nodes often unite into common nks which drain several interspaces, and which may pass through a large gland near the racic duct before emptying into it. Occasionally such collecting vessels from the right side s the midline behind the aorta to reach a large gland to the left of the aorta.

The **visceral nodes** of the thorax are arranged in three groups:

1. The **anterior mediastinal nodes** are situated, as their name indicates, in the terior mediastinum, and are arranged in an upper and a lower set. The upper (superior mediastinal group) is situated along the arch of the aorta, and con- ts of eight or ten nodes, which receive afferents from the pericardium and the mains of the thymus gland. Their efferent vessels pass upward to join the onchomediastinal trunk. The lower set consists of from three to six nodes,

FIG. 607.—LYMPHATICS OF THE SUBAREOLAR PLEXUS OF THE BREAST. (After Sappey.)



uated in the lower part of the anterior mediastinum. They receive afferent icts from the diaphragm (for which reason they are sometimes termed the **aphragmatic nodes**) and also from the upper surface of the liver. Their ferents pass upward to open into the upper anterior mediastinal nodes.

2. The **posterior mediastinal nodes** eight or ten in number, are situated along e thoracic aorta, and receive vessels from the mediastinal tissue and from the oracic portion of the esophagus. Their efferents open directly into the thoracic ct.

3. The **tracheal** and **bronchial nodes** (fig. 608) form an extensive group lying ong the sides of the lower part of the trachea, and along the bronchi as far as the lus of each lung. According to their position they are termed tracheal (para- acheal), lateral tracheobronchial, inferior tracheobronchial (nodes of the bifur- tion), and pulmonary nodes. The latter occur within the lung, at the bifurca- on of the bronchial tubes. These groups receive the drainage of the lower part the trachea, the bronchi, the lungs, part of the esophagus, and, to a small tent, the heart. Their efferent vessels unite with those from the upper anterior ediastinal and internal mammary nodes to form the bronchomediastinal trunk.

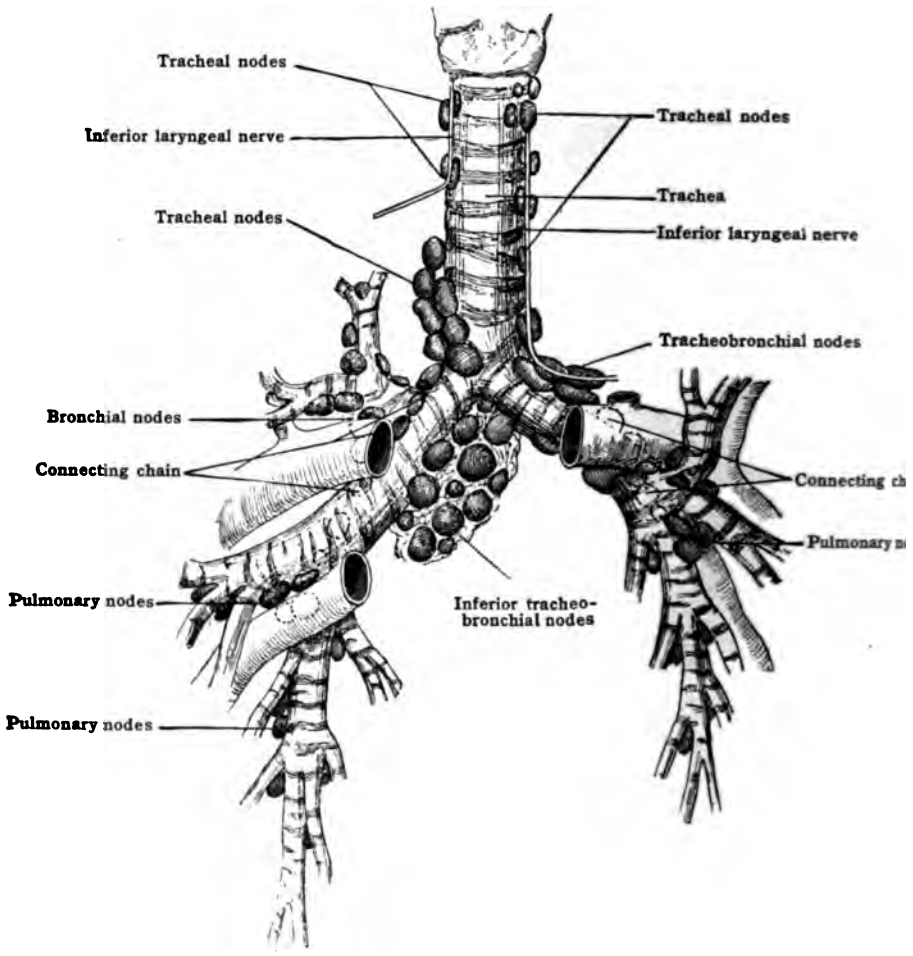
3. THE DEEP LYMPHATIC VESSELS OF THE THORAX

The deep lymphatics of the thorax will be taken up in the following ord the thoracic duct; the right terminal collecting trunks; the parietal vessels; a the visceral vessels.

The Thoracic Duct

The **thoracic duct** [ductus thoracicus] (fig. 609), which is the main collecti trunk of the lymphatic system, extends from the second lumbar vertebra al the spinal column and course of the aorta to the junction of the left internal ju lar and subclavian veins. It receives all the lymphatics below the diaphrag

Fig. 608.—The Tracheal and Bronchial Nodes. (Sukiennikow.)



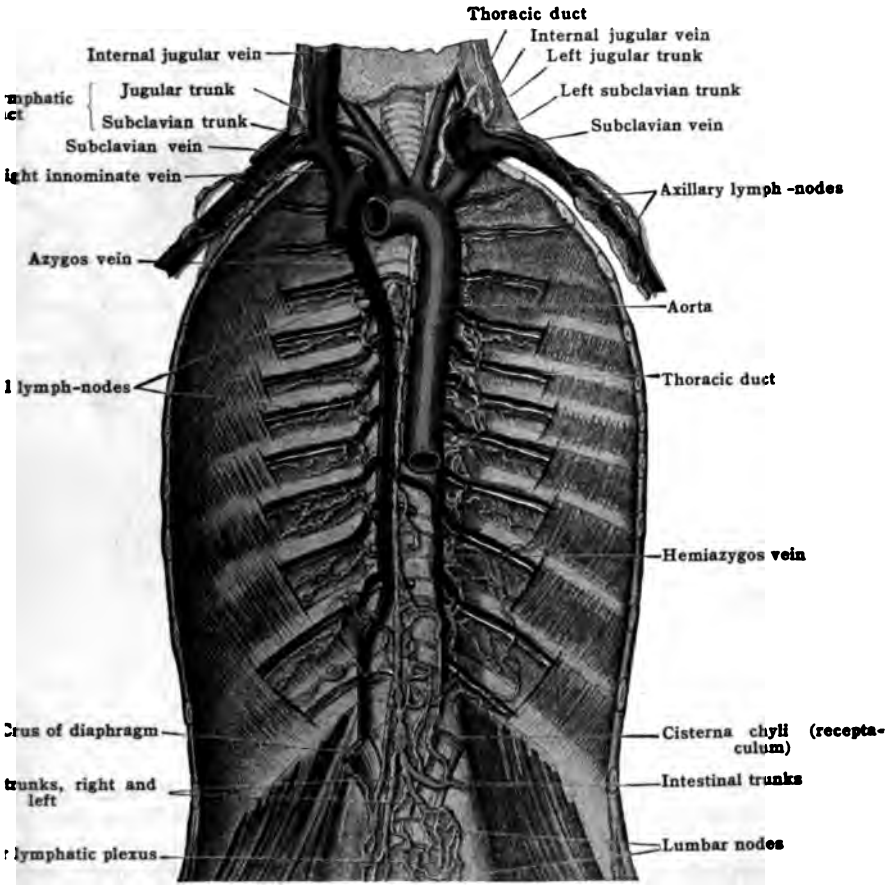
the deep lymphatics from the dorsal half of the chest wall; and also, when jo by the left bronchomediastinal, subclavian and jugular trunks, from the remai of the left half of the body, above the diaphragm. At the caudal end the du formed usually by the union of three collecting trunks, one from each of the bar groups of nodes, and an unpaired intestinal trunk. At its origin the frequently a dilated portion known as the **cisterna chyli** (or receptaculum ch This usually ends opposite the body of the eleventh thoracic vertebra, and here on the duct is from 4 to 6 mm. in diameter, until near its termination, w it is again wider.

In its caudal part, the duct lies dorsal to the aorta in the median line; it p through the aortic opening in the diaphragm, and then inclines to the right passes upward between the aorta and the azygos vein to about the fourth, fif

ıoracic vertebra, where it bends to the left and passes, continuing upward, .e apex of the left lung to the medial side of the left subclavian artery, and t of the root of the left vertebral artery and vein, and then curves down- o open into the left subclavian vein, close to its junction with the left .l jugular. The duct runs in the wall of the vein a short distance before

ıtions.—There is a wide range of variation from this usual course. The duct is fre- double throughout a part of its course, the two branches being connected by cross ıoses, and finally uniting into a single trunk before joining the veins. It may be ; or a single trunk may pass in front of the aorta instead of behind. In a few instances

)9.—The Thoracic Duct. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



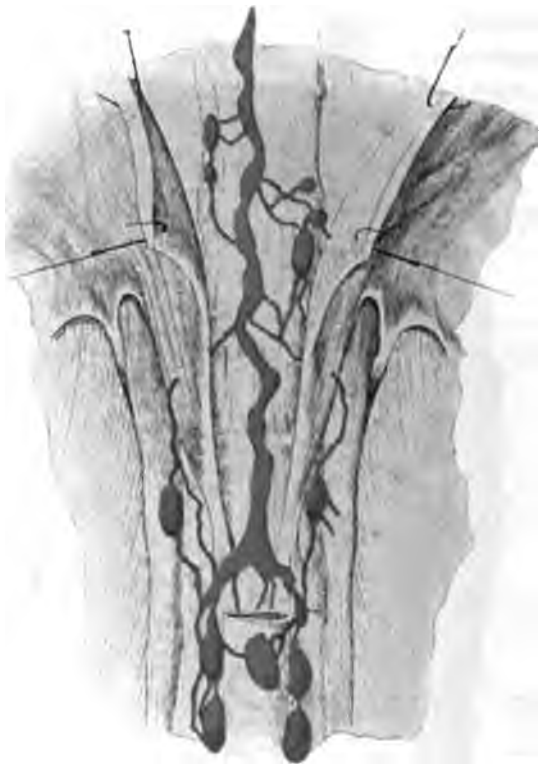
een found emptying into the right instead of the left subclavian vein. There is also a ıge of variation in the height to which the duct ascends in the neck before curving down- the vein. As regards the termination of the thoracic duct, variations are also frequent; bifurcate and end as two ducts. It often connects with the lowermost part of the jugular, or the beginning of the innominate. According to Henle, there is one un- l case reported of a thoracic duct ending in the azygos vein near the sixth thoracic a, the duct being obliterated above this point. At the terminal bend the thoracic duct the jugular trunk from the neck; it may also receive the subclavian and the broncho- inal trunks, but it is more usual for these last two to open either separately or together subclavian.

ations are extremely numerous in the region of the cisterna chyli. Several observers at, in the majority of cases in man, no definite receptaculum exists (cf. fig. 610). Bartels ne in only 25 per cent. of the cases studied. Instead, there is present a widening of each wo lumbar trunks, with several anastomoses between them (55 per cent., Bartels), or a g of these two stems without anastomosis (5 per cent.), or a much elongated widening from the growing together of the two lumbar trunks (10 per cent.). In cases where the trunks remain separate, the intestinal trunk joins the left one. One case has been d in which the thoracic duct ended at the level of the ninth thoracic vertebra. The

lymphatics from the body below this point collected into a duct which became superficial just below the termination of the left saphena magna vein, passed cranialward in the subcutaneous tissue of the left body wall, passed through the axilla, and joined the venous system at the usual place. (E. R. Clark.)

Development.—While the exact mode of its development is still in dispute, enough is agreed upon by the various investigators to explain most of the variations in the thoracic duct. As stated above, it is known that the lymphatics start in the neck in the form of a number of outgrowths from the veins in the region of the junction between the later internal jugular and subclavian veins. A variable number of these connections disappear, while the various combinations of one, two, three or four which are retained furnish the numerous variations in number and position of the ducts which empty into the vein in the adult. Thus the thoracic duct may have one, two or even three openings into the veins, while the jugular, subclavian and bronchomediastinal trunks may join the thoracic duct or may enter the veins separately or in various combinations.

FIG. 610.—ABDOMINAL PORTION OF THE THORACIC DUCT. (Poirier and Cunéo.)



The cisterna develops in connection with branches of veins in the upper lumbar region. All connections with the veins here are soon lost. Around the aorta there develops a plexus, which forms a connection between the anterior plexus and the cisterna. In this plexus two main vessels soon differentiate—the right and left thoracic ducts, which anastomose frequently with one another, and which join, respectively, the right and the left jugulosubclavian angle. Usually the cephalic part of the right and the caudal part of the left duct disappear, leaving the permanent vessel to the right of the aorta for the major part of its course but emptying into the left vein. However, the anterior part of the left duct may disappear, leaving the permanent duct to join the vein on the right side.

Most of the other variations—the frequent presence of longer or shorter doublings of the duct with anastomoses between the two parts and the numerous variations in the region of the cisterna chyli—are easily explained by the fact that they pass through a stage in development in which they form richly anastomosing plexuses around the aorta.

THE RIGHT TERMINAL COLLECTING TRUNKS

On the right side the jugular, subclavian, and bronchomediastinal trunks usually open separately into the subclavian vein, the orifices of the first two being near together. When the jugular and subclavian trunks unite, the common trunk is termed the right lymphatic duct. This is a rare form, and it is still

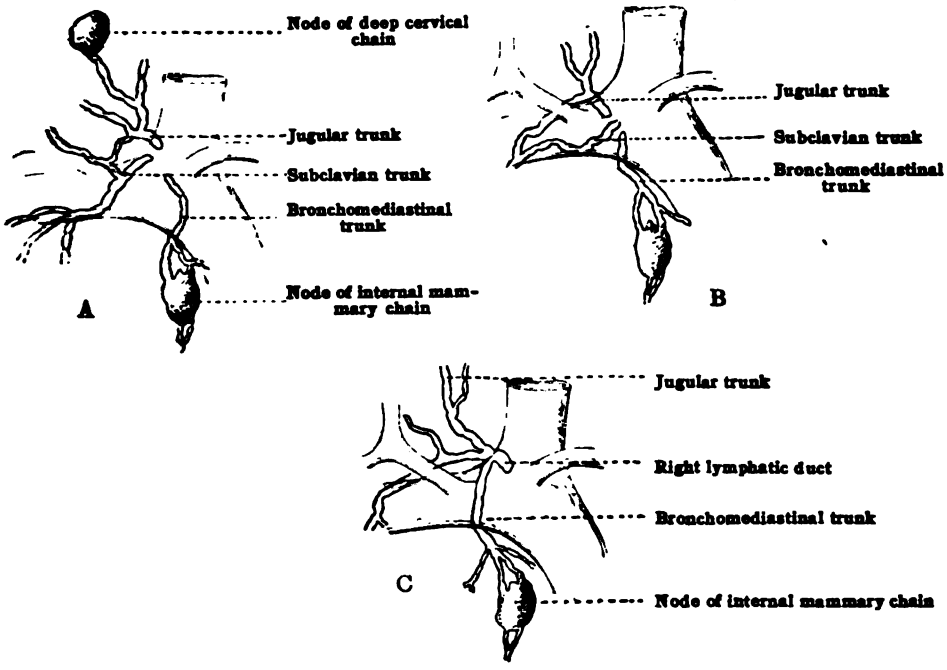
more rare for the three ducts to unite to form a common stem (fig. 611). These variations have the same explanation, embryologically, as was given for the corresponding variations on the left side.

The Deep Lymphatic Vessels

As with the nodes, the deep lymphatic vessels of the thorax may be divided into a parietal and a visceral group. To the former group may be assigned the lymphatics of the intercostal spaces and those of the diaphragm.

The intercostal lymphatics form plexuses in each intercostal space, which receive lymph from the periosteum of the ribs and from the parietal pleura, and from which the drainage is either ventral or dorsal. From the dorsal half of each space the drainage is to the intercostal nodes (fig. 609), while from the ventral half it is toward the internal mammary nodes.

Fig. 611.—Terminal Collecting Trunks on the Right Side. (Poirier and Cunéo.)



The lymphatics of the diaphragm.—There is an exceedingly rich plexus of capillaries both on the thoracic and on the abdominal surface of the diaphragm, especially in the region of the central tendon. These plexuses lie in the subserous layer and are freely connected by vessels which perforate the muscle. There is, however, only slight communication between the plexuses of the right and left sides of the diaphragm. The vessels lie between the coarse muscle-bundles, forming a very characteristic picture, in which the lymphatics stream outward radially, like the spokes of a wheel. The collecting vessels empty into three groups of small nodes on the convex thoracic surface.

The *ventral group* lies ventral to the central tendon. Two or three nodes in the center of this group receive afferents from the liver and none from the diaphragm, but the rest receive vessels from the ventral portion of the diaphragm and the efferents of all pass to the lower set of anterior mediastinal nodes.

The *middle group* consists of from three to six nodes, which lie, on the left side, near the point where the phrenic nerve enters the diaphragm; and on the right side, near the vena cava.

The *dorsal group* of four or five nodes is placed between the crura of the diaphragm. The vessels from the middle and dorsal groups pass to the posterior mediastinal nodes, and also to the upper celiac nodes, which likewise receive the drainage from the dorsal part of the abdominal surface of the diaphragm.

To the visceral group of thoracic lymphatics belong the vessels of the thymus, the lungs, the heart, and the esophagus.

lymphatics from the body below this point collected into a duct which became superficial just below the termination of the left saphena magna vein, passed cranialward in the subcutaneous tissue of the left body wall, passed through the axilla, and joined the venous system at the usual place. (E. R. Clark.)

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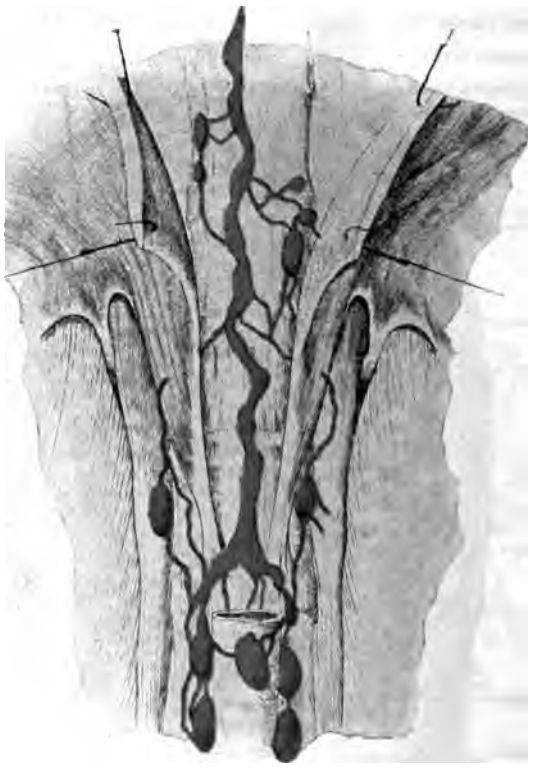

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growths from the thoracic ducts, those to the posterior third are outgrowths from the retroperitoneal sac, and that there is persistent drainage of this portion of the lung into preaortic nodes and cisterna chyli. No such line of drainage has been found in man.

Lymphatics of the heart.—The superficial (subepicardial) lymphatics of the heart collect to two main stems which accompany the main coronary vessels. The right stem accompanies the right coronary artery to its origin, passes on over the arch of the aorta and empties into one of the anterior mediastinal lymph-nodes. The left stem, formed by two stems accompanying the circumflex and anterior descending branches of the coronary vein, passes behind the arch of the aorta to an anterior mediastinal lymph-gland. Two small subepicardial intercalated nodes have been described along these trunks.

Subendocardial lymphatics have been described, which connect by vessels passing through the musculature with the superficial lymphatics. Parenchymatous lymphatics have been demonstrated by Bock. The course of their efferent vessels has not yet been described.

The lymphatic vessels of the esophagus may be divided into three sets, of which the uppermost pass to outlying nodes belonging to the deep cervical chain, those from the thoracic portion of the tube pass to the bronchial and posterior mediastinal nodes, while those from its lowermost part pass to the superior gastric nodes (fig. 612).

D. THE LYMPHATICS OF THE ABDOMEN AND PELVIS

In the following section there will be described successively the lymphatic nodes of the abdomen and pelvis, the lymphatic vessels of the abdominal walls, and the visceral lymphatic vessels.

1. The Lymphatic Nodes of the Abdomen and Pelvis

The lymphatics which connect directly with the thoracic duct, though complicated, may be described briefly by saying that they follow the aorta and its branches. In the abdomen there are four main chains along the aorta—(1) the left lumbar chain; (2) the right lumbar chain; (3) the preaortic chain; and (4) the postaortic chain.

The right and left lumbar nodes [lgl. lumbales], form an almost continuous chain along the abdominal aorta (fig. 613), resting upon the psoas muscles, some of those on the right side being ventral and some dorsal to the inferior vena cava. They receive: (1) the efferent lymphatics of the common iliac nodes, and hence drain the lower limb and external genitalia; (2) the efferent lymphatics that follow the lumbar arteries and thus drain the abdominal wall; (3) the efferents that follow the paired visceral aortic branches, namely, those from the kidneys, suprarenal, and internal reproductive organs. On the right side, the lymphatics from the reproductive organs pass to the nodes ventral to the vena cava; those of the abdominal walls pass to the dorsal set, while those from the kidney pass to both sets. The efferent vessels of the lower lumbar nodes pass to higher ones and so on up the chain, the vessels from the uppermost nodes uniting to form a single **lumbar trunk** on each side. These trunks pass to the thoracic duct, forming two of the so-called trunks of origin of that vessel (fig. 609).

The **preaortic nodes** (cf. fig. 615) of the lumbar chain are arranged in three groups at the root of each of the three unpaired visceral branches of the aorta—the celiac, the superior mesenteric, and the inferior mesenteric arteries. The **celiac nodes** are from one to three in number, and are in reality parts of chains of nodes extending along the branches of the artery and constituting the **hepatic, gastric,** and **splenic** nodes. They drain the stomach, duodenum, liver, pancreas, and spleen.

The **superior mesenteric** group is larger, and is continuous with the **mesenteric nodes** lying in the root of the mesentery. This group drains the remainder of the small intestine, the cecum and appendix, the ascending and transverse colons, and the pancreas.

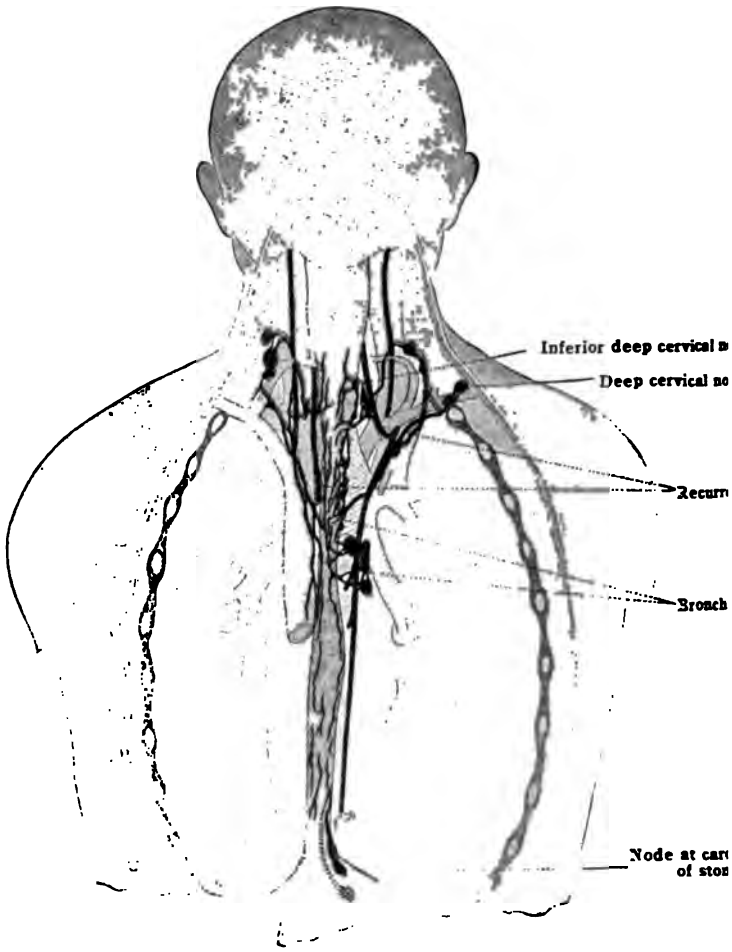
The **inferior mesenteric** group (fig. 613) usually has two nodes, one on either side of the artery. It drains the rectum and descending and sigmoid colons. All the nodes in the mesentery and intestinal walls may be considered as outlying

The **lymphatics of the thymus,** according to Severeanu, drain into thr of nodes, an anterior, a ventral and a dorsal group.

The *anterior* set, one gland on each side, lies lateral to the cephalic end of the thym drains into the jugular or subclavian trunk. The *ventral* set includes 4–6 of the anteri astinal lymph-glands. The *dorsal* set, 2 on each side, is made up of anterior mediastina lying between the thymus and the pericardium.

The **lymphatics of the lungs** are arranged in two sets, deep and sup The *deep lymphatics* fall into three groups: the lymphatics of (1) the b (2) the arteries; (3) the veins.

FIG. 612.—THE LYMPHATICS OF THE ESOPHAGUS. (After Sakata.)



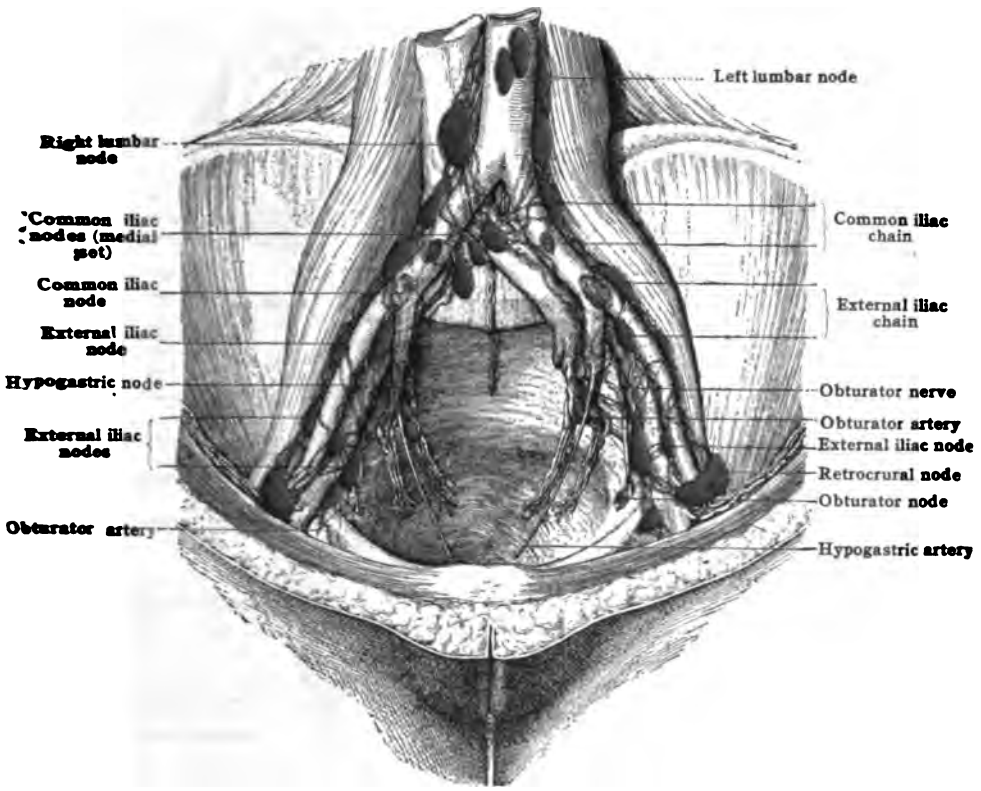
(1) The lymphatics of the bronchi take origin in plexuses which surround the bro bronchioles, and accompany the bronchi to the hilus, communicating with the bronc (fig. 608). (2) The lymphatics of the arteries originate from the lymphatics of the bronchus. Two branches, with numerous anastomoses, usually accompany each art The lymphatics of the veins have an origin similar to that of the arteries, from the lymphatics, at the point where the smaller bronchioles divide. They accompany th the hilus. An additional set of lymphatics, which have a deep origin, pass to the l company with the veins which go to the surface. There are no lymphatic capillaries ing the alveoli.

The *superficial lymphatics* consist of a rich plexus of vessels lying on the of the lung, beneath the pleura. They receive vessels from the deeper aties, and are drained by vessels which pass directly, and independently other sets, to the lymph-nodes of the hilus (W. S. Miller).

In studying the development of the lymphatics to the lung, R. S. Cunningham h that, in the pig, while the lymphatics to the anterior two-thirds of the lung are forme

The *intermediate* chain consists of two or three nodes behind the artery. When there are three, the lowest ('retrocrural') is likewise near the femoral ring. It receives vessels from the bladder, prostate, neck of the uterus, and upper portion of the vagina. The *medial* chain consists of three or four nodes, and is the continuation of the deep inguinal nodes. Its lowest nodes are likewise near the femoral ring, while the next node is large and constant, and usually lies within the pelvis. This chain receives many vessels: (1) from the superficial and deep inguinal nodes; (2) from the glans and clitoris through the femoral canal; (3) from the abdominal wall; (4) from the neighborhood of the obturator vessels; (5) from the neck of the bladder, the prostate, and membranous part of the urethra; (6) from the hypogastric chain.

FIG. 614—ILIAC AND HYPOGASTRIC NODES. (Cunéo and Marcille.)



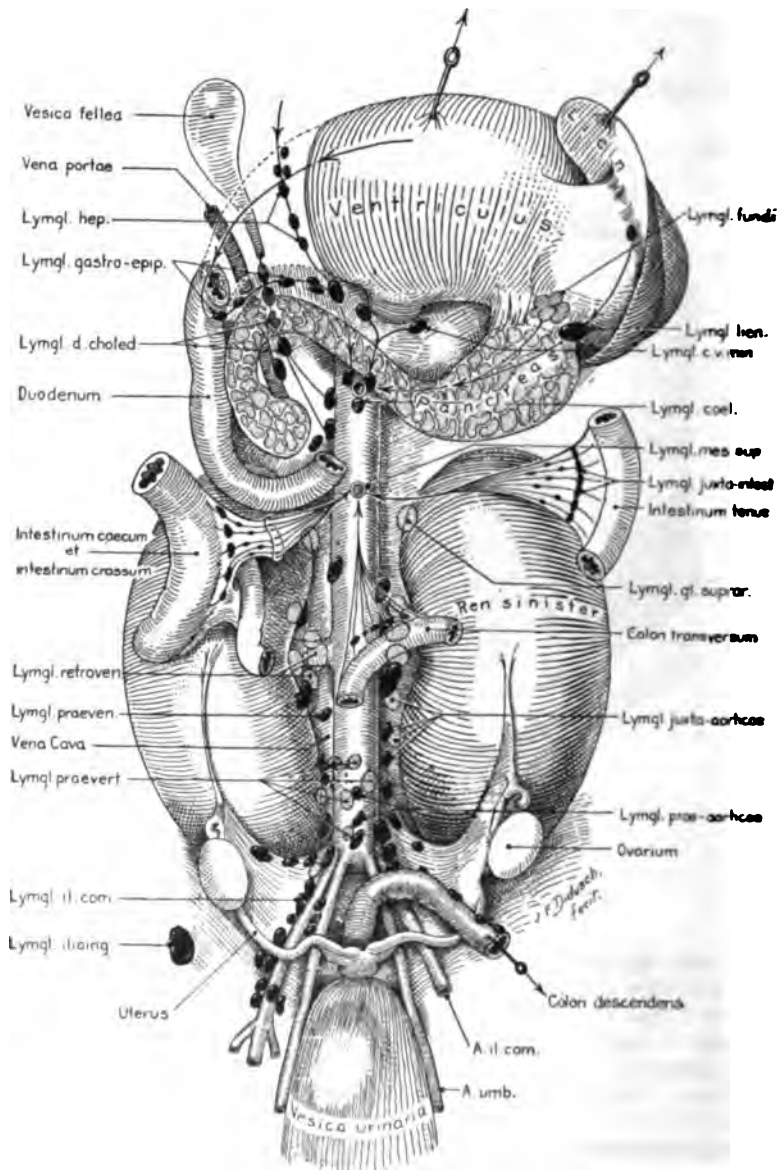
Thus, to sum up the nodes of the external iliac chains, they are a part of a chain which includes the lumbar, common iliac, external iliac, and inguinal nodes. It will be noted that this extensive chain stops, for the most part, with the deep inguinal group. The external iliac nodes receive the efferents of the superficial and deep inguinal nodes; the intermediate and medial groups receive vessels from the pelvis. The efferent vessels of all the nodes in the chain pass to the higher nodes.

The **hypogastric nodes** (figs. 614, 622–625).—These nodes are in groups near the origin of the branches of the hypogastric (internal iliac) artery. Thus they occur near the origin of the obturator, the uterine, or prostatic, the trunk of the inferior gluteal (sciatic) and pudic, the middle hemorrhoidal, and the lateral sacral arteries. All the nodes are beneath the pelvic fascia, and are connected by numerous anastomoses. They receive lymphatics from the structures supplied by the corresponding arteries, namely, from the pelvic viscera, the perineum, and the posterior surface of the thigh and gluteal region. Their efferent vessels pass partly to the middle group of the common iliac nodes, and partly to the posterior nodes of the same chain.

The sacral nodes.—These nodes, 5 or 6 in number, lie in the hollow of the sacrum, in or near the mid-line. They receive afferent vessels from rectum and prostate, and their efferents pass to the hypogastric and lumbar nodes.

Development—Miss Sabin and Reichert have shown, in the pig, that the primary lymph-glands of the abdomen develop out of the primary lymph-sacs, in two fundamental groups (1) the group of glands, ventral to the aorta, extending from the celiac artery to the bifurcation

FIG. 615.—ABDOMINAL LYMPH-NODES OF A 20 CM. PIG FETUS. Solid black: derivatives of the retroperitoneal sac; stippled: derivatives of the iliac sac. (After Reichert.)



of the aorta, which form from the retroperitoneal sac, and (2) the groups of glands dorsal and dorsolateral to the aorta, extending from the level of the suprarenals to the bifurcation of the aorta, with extensions along the iliacs, which develop from the paired iliac sacs. In general, the ventral group receives the drainage from the structures situated within the abdominal cavity, while the dorsal and dorsolateral groups drain organs and structures outside the abdominal cavity, including body-wall and lower extremities. There is, however, an intermediate group of organs—diaphragm, kidney, suprarenal, ureter, and ducts of sex glands—which drain into both sets. Secondary sets, such as the mesenteric, gastric and hepatic glands, develop at a distance from the primary sets (cf. fig. 615).

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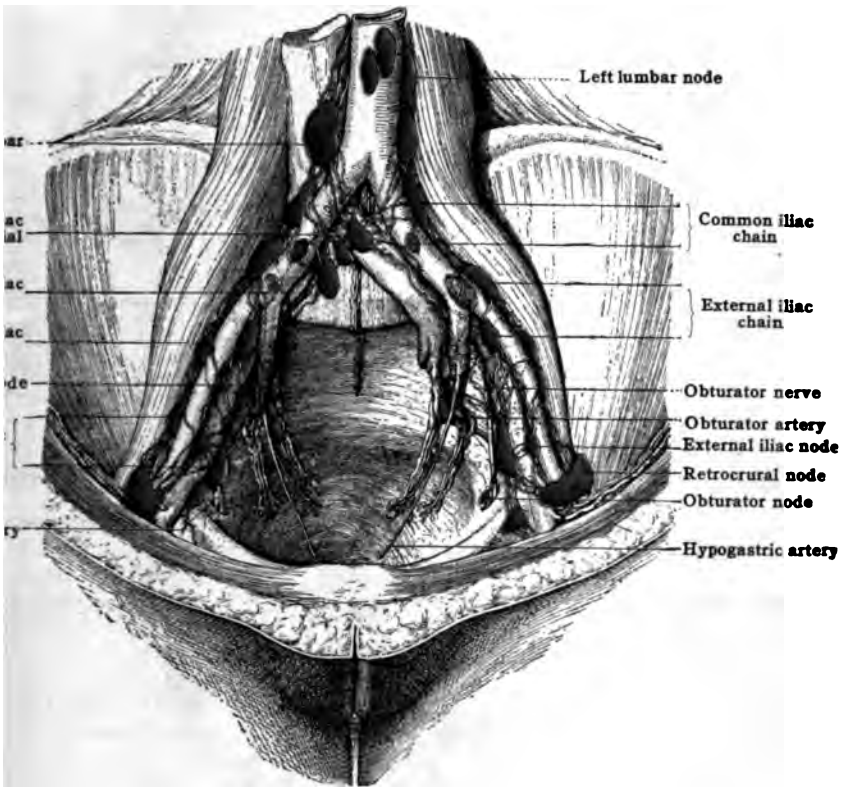

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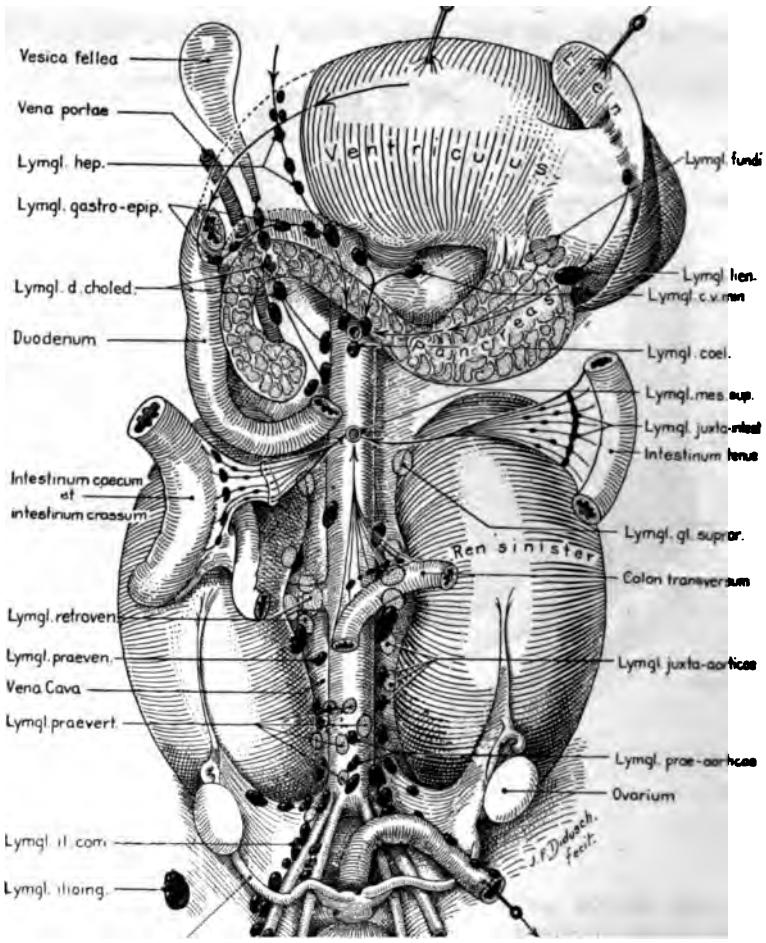

Vesica fellea
Vena portae
Lymgl. hep.
Lymgl. gastro-epip.
Lymgl. d. choled.
Duodenum
Intestinum caecum et intestinum crassum
Lymgl. retroven.
Lymgl. praeven.
Vena Cava
Lymgl. praevert.
Lymgl. il. com.
Lymgl. iliaing.
Ventriculus
Pancreas
Ren sinister
Lymgl. fundi
Lymgl. lien.
Lymgl. c.v.mes
Lymgl. coel.
Lymgl. mes. sup.
Lymgl. juxta-intest
Intestinum tenue
Lymgl. gl. suprar.
Colon transversum
Lymgl. juxta-aortica
Lymgl. prae-aortica
Ovarium
J. F. Didusch. fecit.

THE LYMPHATIC VESSELS OF THE ABDOMINAL WALLS

e lymphatic vessels of the abdominal walls are arranged in two sets, one of is subcutaneous and the other deep or aponeurotic. The **subcutaneous** s form a rich network through all the subcutaneous tissue of the abdomen, mosing above with the subcutaneous plexus of the thorax, which drains pper part of the anterior abdominal wall. The vessels chiefly converge d the inguinal region, those from the posterior wall curving forward along est of the ilium, and terminate in the superficial inguinal nodes (fig. 629). e **deep** vessels drain along four principal lines. (1) A set of collecting s follows the line of the deep epigastric artery to terminate in the lower al iliac nodes; (2) a second set follows the deep circumflex iliac vessels to me nodes; and (3) a third set follows the lumbar vessels to terminate in the of the lumbar chain; (4) the upper part of the anterior abdominal wall into the sternal nodes, following the superior epigastric vessels.

oup of small **epigastric nodes,** which may be regarded as offsets from the iliac chain, on the lymph-vessels which accompany the deep epigastric vessels, not far from their ation, and a second less constant group of usually three small **umbilical nodes** occurs in inity of the umbilicus in the network covering the posterior layer of the sheath of the abdominis muscle.

IE VISCERAL LYMPHATICS OF THE ABDOMEN AND PELVIS

he lymphatics to the viscera follow along the course of the blood-vessels. e point where the artery of an organ branches from the aorta there is a of nodes which represents the main regional group, and a second chain of extends along the artery. The final arrangement of nodes and vessels with each organ. The lymphatics (vessels and nodes) of the alimentary suprarenal gland, urinary and reproductive tracts will be successively dered.

almost all organs there is a peripheral or capsular lymphatic plexus, which anastomoses he parietal lymphatics, these anastomoses being particularly well developed in the case liver. In addition there are one or two deep plexuses in the great majority of the organs drain partly directly to their regional nodes and partly by way of the peripheral plexus.

THE LYMPHATICS OF THE ALIMENTARY TRACT

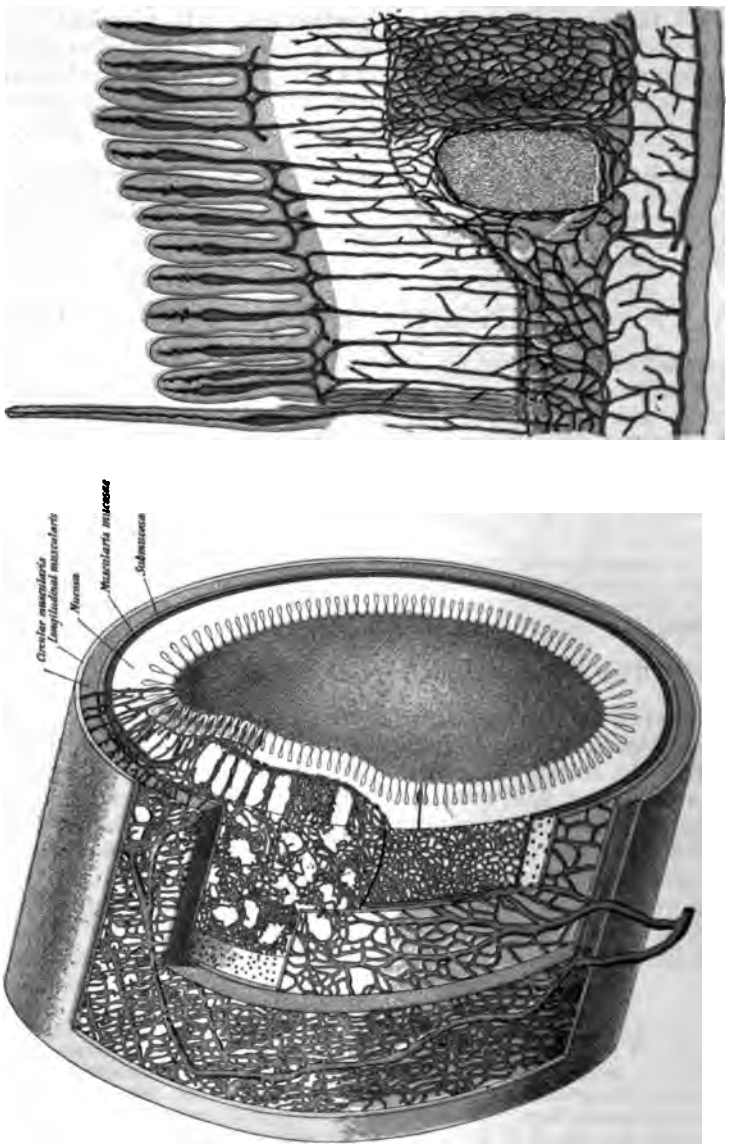
he lymphatics of the mouth, pharynx, and esophagus have already been ibed (pp. 749, 763). In general, throughout the abdominal part of the ali- ary canal, the distribution of nodes is as follows: (1) There are primary nal nodes situated at the roots of the arteries (celiac and the superior and or mesenteric arteries); these nodes drain large segments of the intestine; roups of definite and constant nodes placed along the branches of the arteries n the mesentery; these drain a definite smaller segment of the intestine; hains of nodes along the anastomotic loops of the arteries, close to the in- al wall; these are of the type called 'intercalated nodes'; (4) solitary or ound follicles, situated within the submucosa or capillary zone of the hatics.

hat may be taken as the typical arrangement of the lymphatic vessels in the intestine may n in fig. 616. There are three zones in which the capillary plexuses are spread out, namely, subserosa, the submucosa, and the mucosa. There is an abundant plexus of large cap- just beneath the serosa; in the submucosa the plexus is also formed by large capillaries, the mucosal plexus is finer. The lymph-follicles lie in the zone of the mucosal plexus, and om this that the central chyle vessels of the villi arise. The spiral tips of the central ls shown in fig. 616 are probably artefacts. The collecting vessels are formed by the union els from the submucous and subserous plexuses. They traverse the three sets of nodes scribed.

he lymphatics of the stomach (fig. 617).—The stomach differs from the rest alimentary canal in its blood-supply in having a ventral anastomotic loop, **ly,** that along the lesser curvature. Along this loop is the **superior gastric** [lgl. gastricæ superiores] of nodes, lying between the folds of the lesser **tum,** some of them being on the posterior surface of the stomach. This is ost important group of nodes draining the stomach, and it has been shown he lymph-vessels from the pylorus run obliquely across the stomach to the

main mass of nodes near the cardia, an important point in the surgery of pylorus. The efferent vessels of the chain pass to the celiac nodes. The ve of the greater curvature pass to a group of **inferior gastric nodes** [lgl. gast inferiores], situated along the right gastroepiploic artery, while those of the fu follow the short gastric and left gastroepiploic vessels to the nodes whic along the splenic artery [lgl. pancreaticolienales], both these sets of nodes draining to the celiac group. There is a zone half-way between the lesser

FIG. 616.—THE LYMPHATIC VESSELS OF THE INTESTINE. (After Mall.)

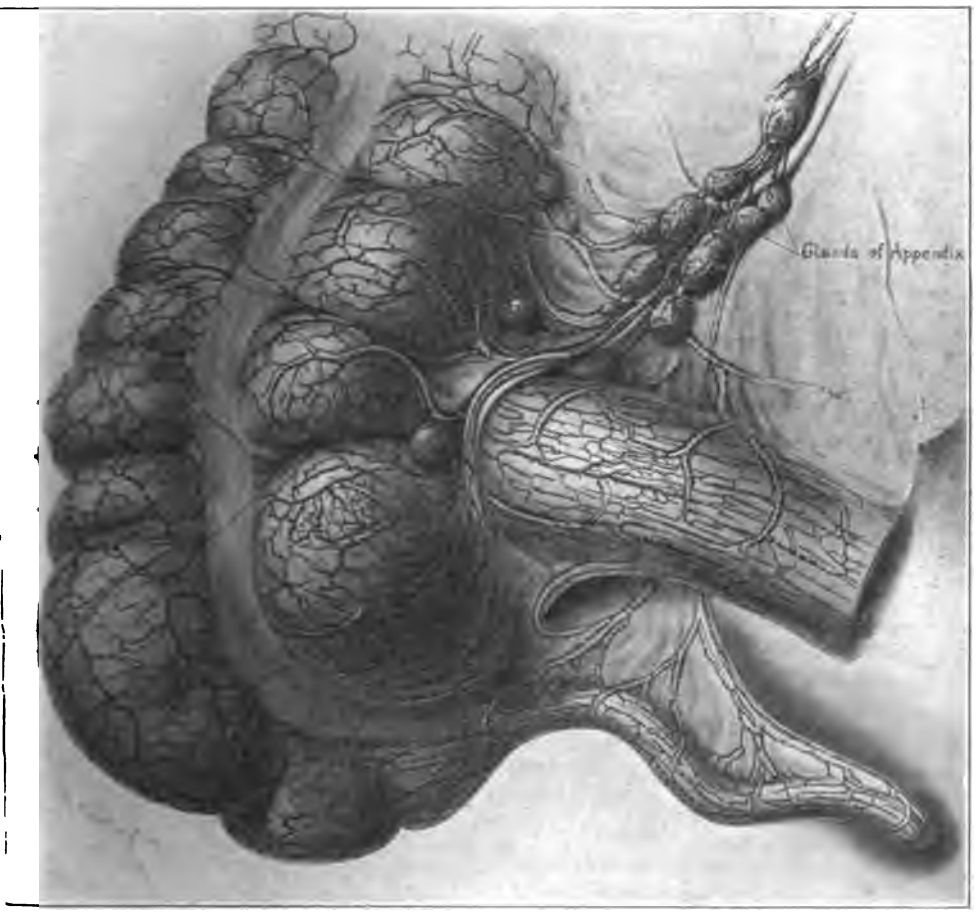


greater curvatures, in which the lymphatics are scanty. **The lymphatics** cardia connect with those of the esophagus, and **the mucosal plexus of the p** is continuous with that of the duodenum.

The lymphatics of the duodenum.—The lymphatics of the duodenum somewhat from the type, owing to its relations with **the pancreas and th** ducts. The collecting vessels end: (1) in nodes **ventral to the pancreas,** follow the pancreaticoduodenal artery to the hepatic **chain; (2) in nodes do** the pancreas, which follow the superior mesenteric **artery to the superior** teric nodes. There are anastomoses between the **lymphatics of the duo**

The superficial lymph-vessels of the liver have been studied by Sappey. Those from the superior surface include three sets. From the dorsal part vessels pass through the diaphragm with the vena cava, and end in the adjacent posterior mediastinal nodes. Some of these vessels from the right lobe pass in the coronary ligament to the celiac nodes, and some from the left lobe to the superior gastric nodes. The second set of vessels from the superior surface runs over the ventral border to the hepatic nodes situated in the portal fissure. The third and most important set arises near the falciform ligament, and passes partly dorsalward to the anterior mediastinal group of nodes on the upper surface of the diaphragm, and to the nodes around the vena cava, and partly ventralward to the hepatic nodes of the portal fissure.

FIG. 619.—THE LYMPHATICS OF THE ILEOCECAL REGION, ANTERIOR VIEW. (After Kelly.)



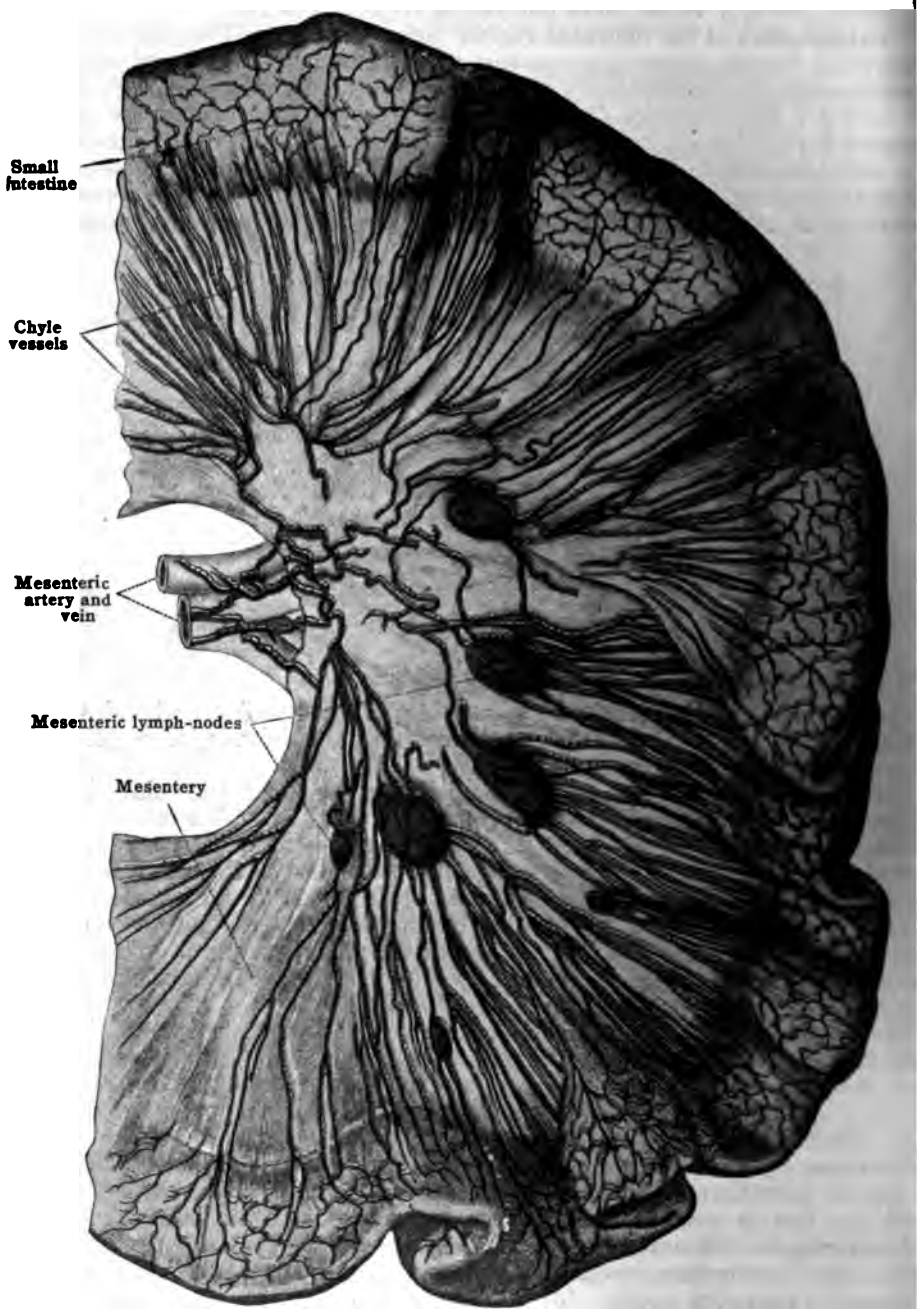
The collecting vessels of the inferior surface of the liver pass to the nodes situated in the portal fissure, either along the artery or the bile-ducts.

The lymphatics of the **gall-bladder** join the hepatic nodes along the cystic and common bile-ducts, and also the superior pancreatic nodes.

Lymphatics of the pancreas.—The lymph-vessels which drain the pancreas fall, according to Bartels, into four groups: left, anterior (upper), right and posterior (lower). (1) The left group drain the tail of the pancreas and pass to the splenic lymph-nodes, at the hilus of the spleen. (2) Anteriorly lymphatics pass to the superior pancreatic, superior gastric and hepatic nodes. (3) To the right, lymphatics pass to the pancreaticoduodenal lymph-nodes. (4) Posteriorly lymphatics pass to the aortic, mesenteric, mesocolic, and inferior pancreatic nodes. The splenic, superior pancreatic, inferior pancreatic, and pancreaticoduodenal nodes form a closely associated group [lymphoglandulæ pancreatico-

ondary group of three to six **hepatic nodes,** situated along the hepatic artery. Some of these nodes are along the hocizontal part of the artery, parallel to the superior border of the pancreas, while the rest follow the artery in its vertical course along with the portal vein, and become continuous at the portal fissure

FIG. 618.—LYMPHATICS OF THE SMALL INTESTINE. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



with two distinct chains of nodes, one of which follows the hepatic artery i portal vein, and the other the cystic and common bile-ducts. These nodes variable, but one constant node is at the junction of the cystic and hepatic du A part of the drainage of the liver is also through the diaphragmatic no of the anterior and posterior mediastinal groups.

superficial lymph-vessels of the liver have been studied by Sappey. m the superior surface include three sets. From the dorsal part vessels ugh the diaphragm with the vena cava, and end in the adjacent posterior al nodes. Some of these vessels from the right lobe pass in the coronary to the celiac nodes, and some from the left lobe to the superior gastric The second set of vessels from the superior surface runs over the ventral the hepatic nodes situated in the portal fissure. The third and most t set arises near the falciform ligament, and passes partly dorsalward to ior mediastinal group of nodes on the upper surface of the diaphragm, e nodes around the vena cava, and partly ventralward to the hepatic the portal fissure.

–THE LYMPHATICS OF THE ILEOCECAL REGION, ANTERIOR VIEW. (After Kelly.)

ollecting vessels of the inferior surface of the liver pass to the nodes n the portal fissure, either along the artery or the bile-ducts.
ymphatics of the **gall-bladder** join the hepatic nodes along the cystic and bile-ducts, and also the superior pancreatic nodes.
hatics of the pancreas.—The lymph-vessels which drain the pancreas rding to Bartels, into four groups: left, anterior (upper), right and (lower). (1) The left group drain the tail of the pancreas and pass to ic lymph-nodes, at the hilus of the spleen. (2) Anteriorly lymphatics he superior pancreatic, superior gastric and hepatic nodes. (3) To the phatics pass to the pancreaticoduodenal lymph-nodes. (4) Posteriorly cs pass to the aortic, mesenteric, mesocolic, and inferior pancreatic The splenic, superior pancreatic, inferior pancreatic, and pancreaticonodes form a closely associated group [lymphoglandulæ pancreatico-

lienales]. Anastomoses exist between the lymphatics of the pancreas and of the duodenum.

The **lymphatics of the spleen** form a subcapsular plexus from which v pass through the hilus to the **splenic nodes** (of the pancreaticolienal group). nodes are variable in number and are situated along the course of the s vessels. In addition to the spleen, they drain the fundus of the stomach part of the pancreas.

FIG. 620.—THE LYMPHATICS OF THE ILEOCECAL REGION, POSTERIOR VIEW. (After

THE LYMPHATICS OF THE SUPRARENAL GLAND AND OF THE URINARY

The lymphatics of the suprarenal gland.—The lymphatic vessels comi the capsular and parenchymatous plexuses pass, on the right side, into three anterior para-aortic nodes, and a small retrovenous gland, near the cru diaphragm; on the left side, into para-aortic nodes, and, in part, throu diaphragm, in company with the splanchnic nerve, to a posterior med gland, lying between the ninth thoracic vertebra and the aorta. Anast occur with the lymphatics of the kidney.

In addition to the capsular lymphatics proper, Kumita describes a subserous plexu is present over both kidney and suprarenal, which anastomoses with the lymphati liver and diaphragm. The efferents of this plexus collect, on the right side, to a glar

FIG. 621.—LYMPHATICS OF THE KIDNEY. (After Poirier and Cunéo.)

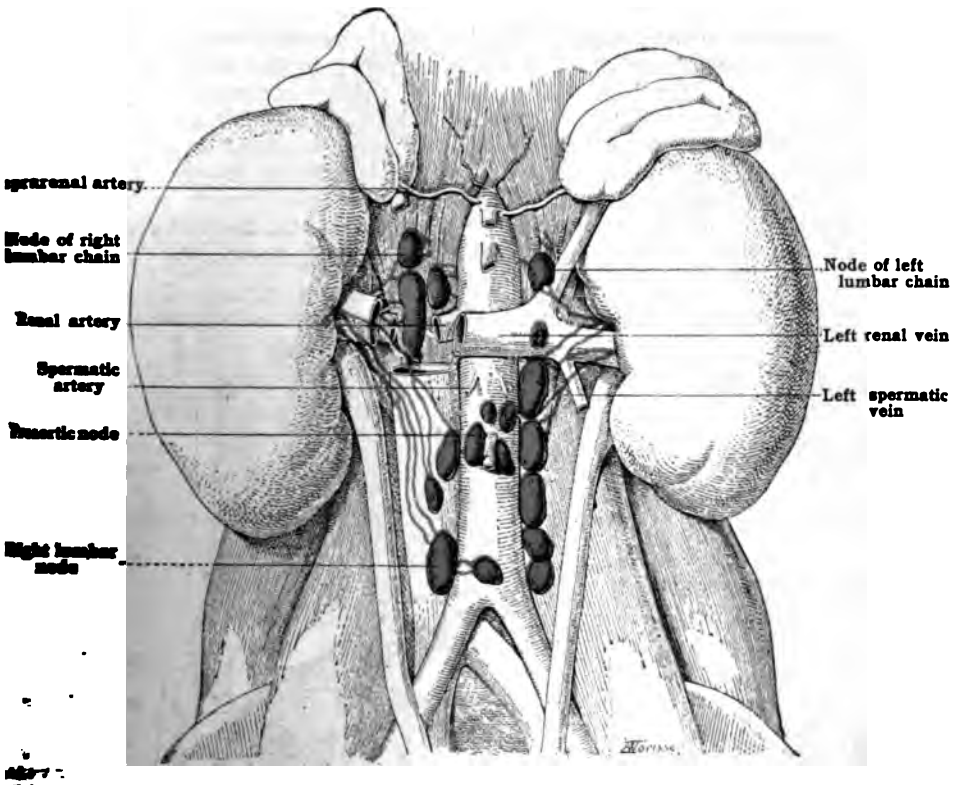
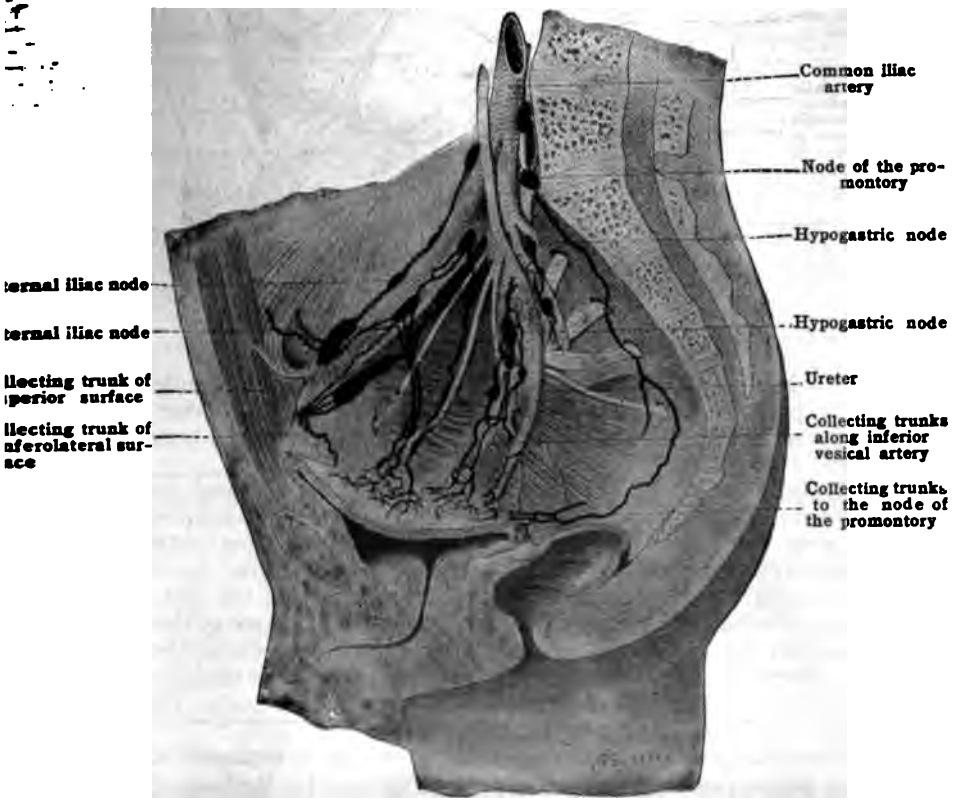


FIG. 622.—LYMPHATICS OF THE BLADDER. (After Cunéo and Marcille.)

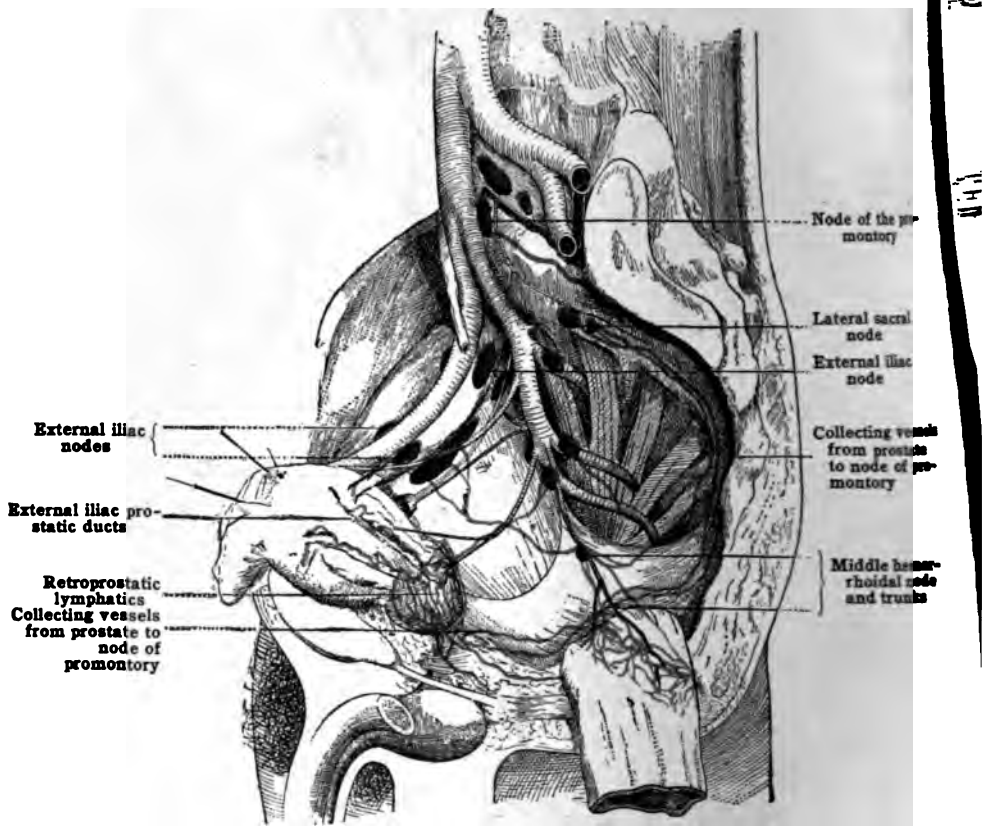


to the right of the inferior vena cava, anterior to the right renal vein, and on the left side to a gland anterior to the left renal vein.

The lymphatics of the kidney.—The lymphatic vessels from the deep capsular and parenchymatous lymphatics of the kidney run to the nodes of the lumbar chain (fig. 621). On the right side, part of the nodes concerned lie ventral and part dorsal to the renal vein; one of the nodes lies as far caudalward as the bifurcation of the aorta; and one or two vessels may pass to preaortic nodes. On the left side the vessels end in four or five nodes of the lumbar group. The efferents of these nodes end in the thoracic duct.

The lymphatics of the ureter.—According to Sakata, the lymphatics of the ureter fall into three groups: (1) An anterior (upper) group, which run to the

FIG. 623.—THE LYMPHATICS OF THE PROSTATE. (After Cunéo and Marcille.)

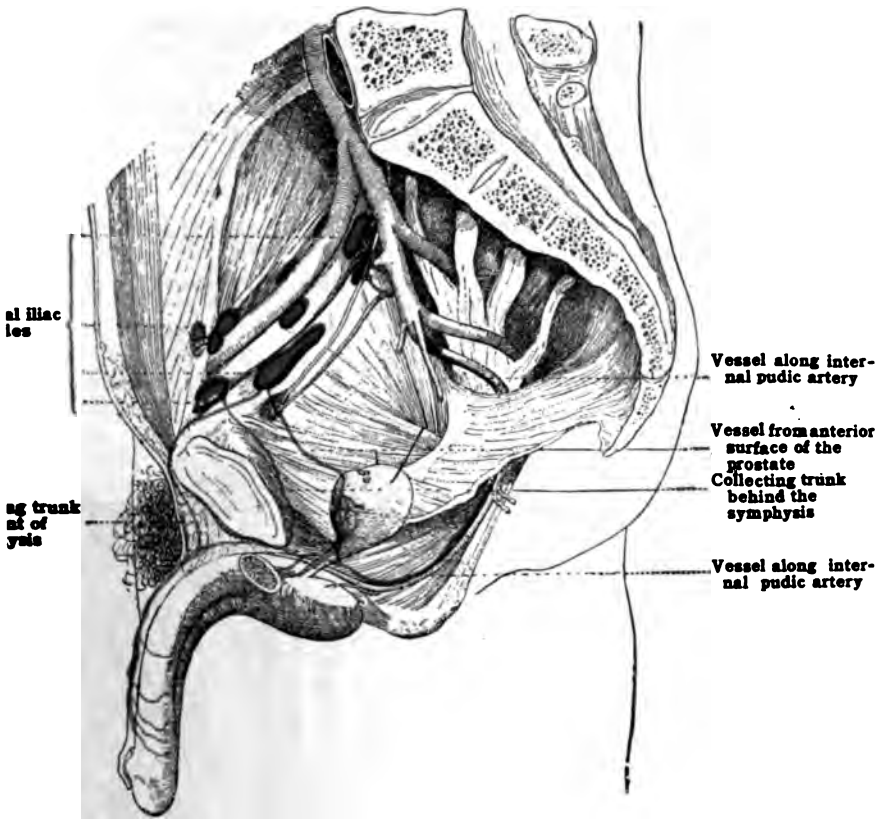

Node of the promontory
Lateral sacral node
External iliac node
External iliac nodes
Collecting vessels from prostate to node of promontory
External iliac prostatic ducts
Middle hemorrhoidal node and trunks
Retroprostatic lymphatics
Collecting vessels from prostate to node of promontory

anterior lumbar nodes, or join the renal lymphatics; (2) a middle group which pass to the posterior lumbar and interiliac nodes; (3) a posterior (lower) group which pass to hypogastric nodes and which anastomose with lymphatics of the bladder.

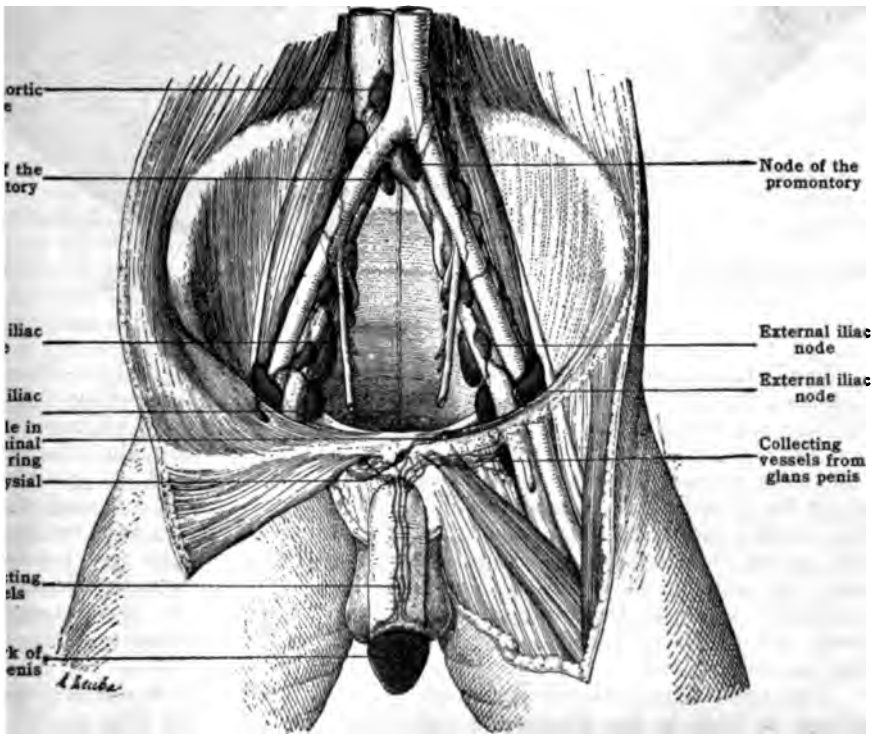
The lymphatics of the bladder (fig. 622).—The collecting vessels from the anterior part of the inferolateral surface pass to a node of the external iliac group, situated near the femoral ring; those from the upper part of the inferolateral surface and anterior part of the superior surface pass to the middle node of the middle group of the external iliac chain; and those from the rest of the superior surface and the base of the bladder pass either to the hypogastric nodes or beyond these to the nodes at the bifurcation of the aorta (nodes of the promontory). In this latter group end also the vessels from the neck of the bladder. Along some of the lymphatics of the bladder are intercalated lymph-nodes, which have been termed anterior and lateral vesical nodes.

The lymphatics of the prostate (fig. 623).—The lymphatics of the prostate have been studied in the dog by Walker and in man by Bruhns. The collecting

:.—Lymphatics of the Cavernous and Membranous Portions of the Urethra (After Cunéo and Marcille.)



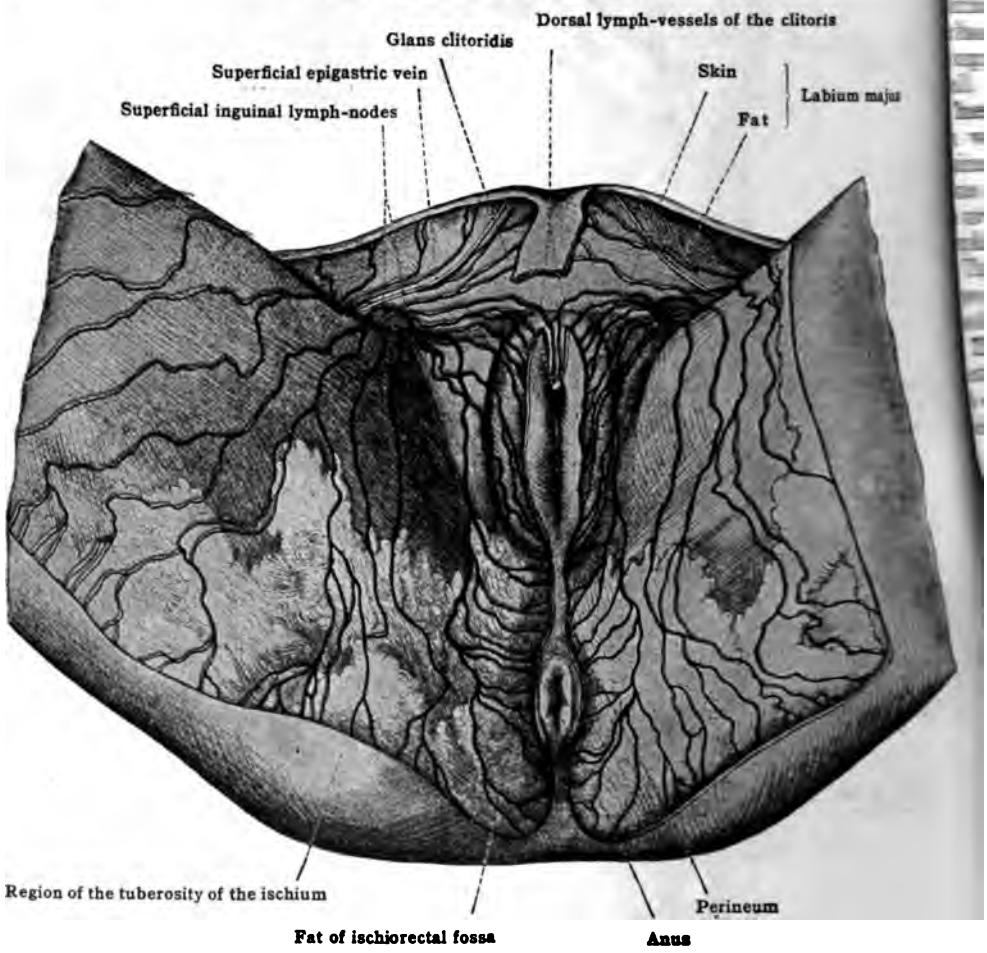
.—Lymphatics of the Glans Penis in a New-born Child. (Cunéo and Marcille.)



vessels, six to eight on each side, pass along the prostatic artery to the nodes along the hypogastric artery.

These nodes are connected with those along the external and common iliac arteries, and it is possible, from an injection of the prostate, to fill the entire chain of nodes as far as the renal artery. A trunk from the posterior surface runs up over the bladder and curves outward to the middle node of the middle group of the external iliac chain, and still other vessels from the posterior surface run first downward, pass around the rectum, and then ascend to the lateral sacral nodes. From the anterior surface a descending trunk may follow the deep artery of the penis, and the internal pudic to the hypogastric nodes (fig. 623). The lymphatics of the prostate anastomose with those of the bladder, ductus deferens and rectum.

FIG. 626.—LYMPHATICS OF THE PERINEUM. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



The lymphatics of the urethra.—1. *In the Male* (figs. 624, 625).—The capillary plexus of the urethra is in the mucous membrane. The collecting vessels from the mucous membrane of the glans follow the dorsal vein. Those from the cavernous and membranous portions of the urethra start from the inferior surface and curve around the corpora cavernosa, as seen in fig. 624, to join the others along the dorsal vein. These vessels run with the vein to the symphysis, where they form a plexus in which there may be some small intercalated nodes. From this plexus vessels pass in various directions: Three or four vessels pass to the deep inguinal and external iliac nodes, and one vessel enters the inguinal canal and ends in one of the external iliac nodes. There is also a communication, along the dorsal vein of the penis, with the prostatic plexus and the external iliac nodes (fig. 624).

The vessels from the membranous portion either follow the internal pudic artery, or pass to the symphysis and end in the external iliac nodes, or pass

the surface of the bladder and thence to the external iliac chain. The hatics of the prostatic urethra run with the prostatic vessels. The lymics of the urethra anastomose with those of the bladder and those of the glans. *In the female* the lymphatic vessels of the urethra end in the external iliac hypogastric nodes.

Lymphatics of the Reproductive Organs

In the Male (Figs. 623–625)

he lymphatics of the external genitalia will be first described and then those e internal organs.

he lymphatics of the scrotum form a rich plexus which has been pictured by hmann (fig. 587). The collecting vessels, ten to fifteen on either side, arise the raphe and pass to the root of the penis, where some curve lateralward to superior medial superficial inguinal nodes; while others, coming from the al surface of the scrotum, pass to the corresponding inferior nodes.

he lymphatics of the penis.—(1) The cutaneous lymphatics form a plexus which collecting vessels follow the dorsal vein and end in the superficial inal nodes. (2) The lymphatics of the glans form an exceedingly rich us from which vessels follow the dorsal vein of the penis, as described under urethra, and end in the deep inguinal and external iliac nodes. (3) The hatics of the erectile structures are little known.

he lymphatics of the testis are both superficial and deep, the latter being edingly hard to inject. The collecting vessels follow the spermatic cord and d-vessels to end in the lumbar nodes.

he lymphatics of the ductus deferens and vesiculæ seminales.—In the us deferens only a superficial set has been injected, and its vessels pass to external iliac nodes. The plexus of the vesiculæ seminales is double, super- and deep, and its vessels pass to the external iliac and hypogastric nodes.

Lymphatics in the Female (Figs. 626–628)

he lymphatics of the vulva.—Throughout the vulva there is an exceedingly superficial lymphatic plexus, from which collecting vessels pass to the symis and there turn lateralward to the medial superficial inguinal nodes (fig. The fact that the capillary plexus is continuous from side to side and that is a plexus of the vessels in front of the symphysis makes the nodes of both liable to infection from a unilateral lesion.

he lymphatics of the clitoris.—The lymphatics of the glans of the clitoris an abundant network from which collecting vessels pass toward the symphyubis, and thence principally to the deep inguinal nodes, one or two, however, ng through the inguinal canal to terminate in the lower external iliac nodes.

he lymphatics of the ovary.—The ovary has a remarkably rich lymphatic s, from which from four to six vessels leave the hilus and follow the ovarian l-vessels to the lumbar nodes. One vessel may run in the broad ligament to the internal iliac group.

he lymphatics of the uterine (Fallopian) tube form three capillary networks which collecting vessels run in part with those of the ovary, and in part with terine lymph-vessels.

he lymphatics of the uterus.—According to Poirier, the lymphatics of the s arise from three capillary plexuses, a mucous, a muscular, and a peritoneal. collecting vessels from the *body of the uterus* (fig. 627) are in three sets: Those from the fundus, consisting of four or five vessels, run lateralward gh the broad ligament and the suspensory ligament of the ovary and follow varian vessels to the lumbar and preaortic nodes. They anastomose with ymphatics from the ovary opposite the fifth lumbar vertebra; (2) some small ls from the fundus follow the round ligament of the uterus and terminate e inguinal nodes; and (3) others from the body of the uterus pass laterally the uterine vessels and terminate in the iliac nodes.

he collecting vessels from the *cervix* (figs. 627, 628), five to eight in number, a large lymphatic plexus just after leaving the cervix. From this plexus run

FIG. 627.—LYMPHATICS OF THE INTERNAL GENITAL ORGANS IN THE FEMALE. (After Poirier.)

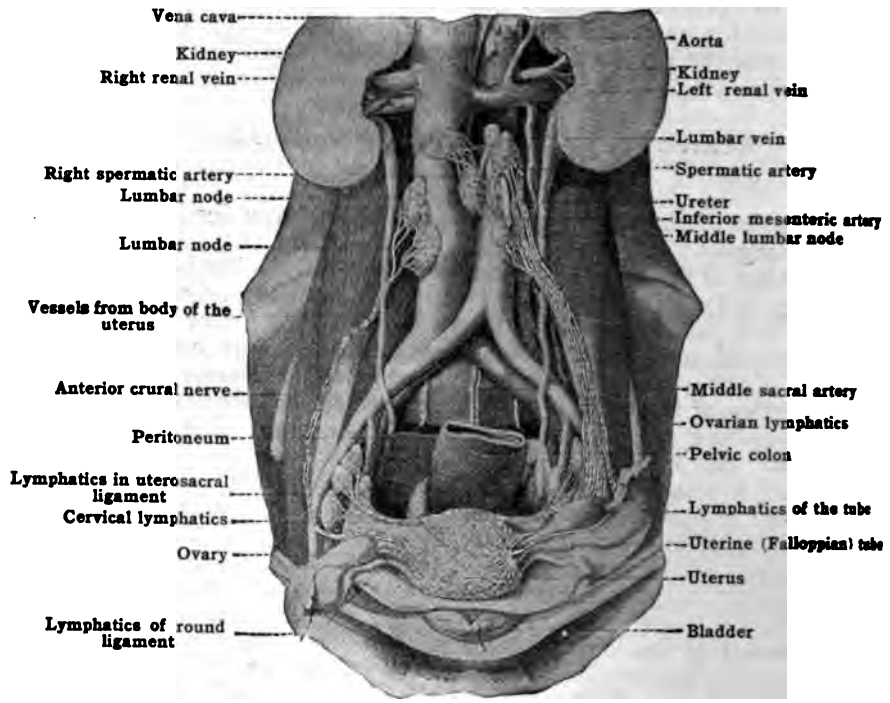
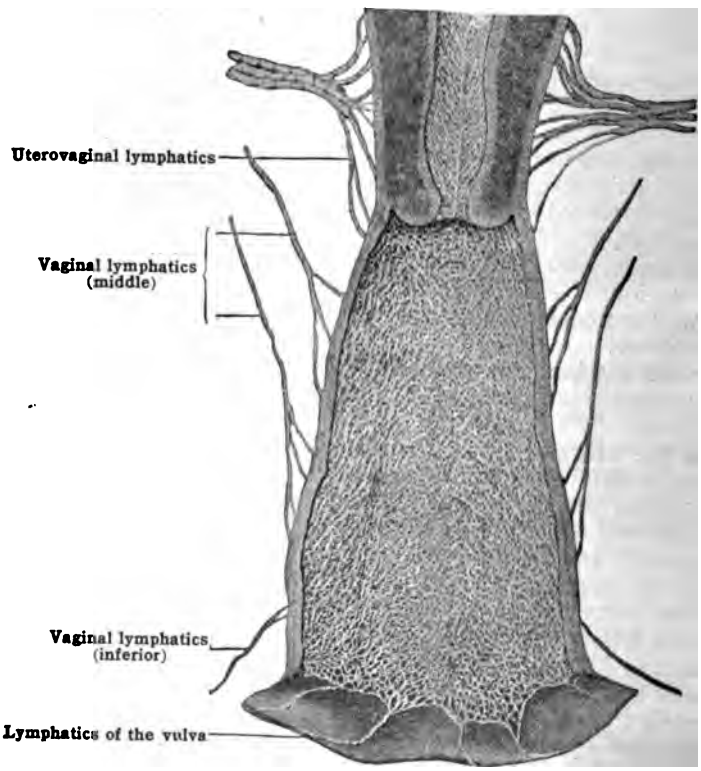


FIG. 628.—LYMPHATICS OF THE VAGINA. (After Poirier.)



three sets of vessels. Two or three vessels pass lateralward with the uterine artery in front of the ureter, and end in the external iliac nodes; a second set passes behind the ureter and ends in a node of the hypogastric group; and a third set from the posterior surface runs downward over the vagina and then backward and upward to end in the lateral sacral nodes and node of the promontory of the sacrum.

The lymphatics of the vagina (fig. 628).—There are two lymphatic plexuses in the vagina, a superficial and deep—the latter, the mucosal plexus, being exceedingly rich. The collecting vessels are in three groups. The superior set (uterovaginal) drains the upper third of the vagina and takes the same course as those from the lower cervical portion of the uterus; the middle set follows the vaginal artery to the hypogastric nodes; and the inferior set runs to the lateral sacral nodes and to those of the promontory. The capillary network of the lower part of the vagina is continuous with the plexus of the vulva, which drains to the inguinal nodes.

E. THE LYMPHATICS OF THE LOWER EXTREMITY

1. THE LYMPHATIC NODES OF THE LOWER EXTREMITY

The principal group of nodes of the lower extremity is situated in the inguinal region, and hence is known as the **inguinal group** (figs. 629, 630). It is in many respects similar to the axillary group, although it is not quite equivalent to it developmentally. The nodes composing it are divisible into a superficial and a deep group, the former containing many more and larger nodes than the latter. Furthermore, it is convenient to divide each of these groups into an upper and a lower set, the dividing line being an arbitrary line drawn horizontally through the point where the saphenous vein pierces the fascia of the fossa ovalis. The nodes above this line are termed collectively the **inguinal nodes** [lgl. inguinales], while those below it are known as the **subinguinal nodes** [lgl. subinguinales).

The superficial inguinal nodes lie along the base of the femoral trigone immediately below Poupart's ligament, superficial to the fascia lata. Their number varies from ten to twenty. They receive the subcutaneous drainage of the anterior and lateral abdominal walls, the gluteal region, the external genitalia and the perineal region. Their efferents descend to the fossa ovalis, which they perforate along with the saphenous vein and terminate in the lower external iliac nodes.

The **superficial subinguinal nodes** occupy the lower part of the femoral trigone and receive the entire superficial drainage of the lower extremity, as well as a few vessels from the gluteal region and from the perineum. Their efferents pierce the fossa ovalis and pass partly to the deep subinguinal nodes and partly directly to the lower external iliac nodes.

The deep inguinal nodes.—The deep nodes are small, and vary from one to three. They lie medial to the femoral vein, the highest one (node of Cloquet or of Rosenmüller) being placed in the femoral ring and being of especial surgical interest in that, when enlarged, it may simulate a strangulated hernia. The lowest node is below the point where the great saphenous joins the femoral vein. These deep nodes receive the deep lymphatics of the lower extremity, also vessels from the glans penis or clitoris, and some of the vessels from the superficial subinguinal nodes. Their efferent vessels enter the external iliac nodes.

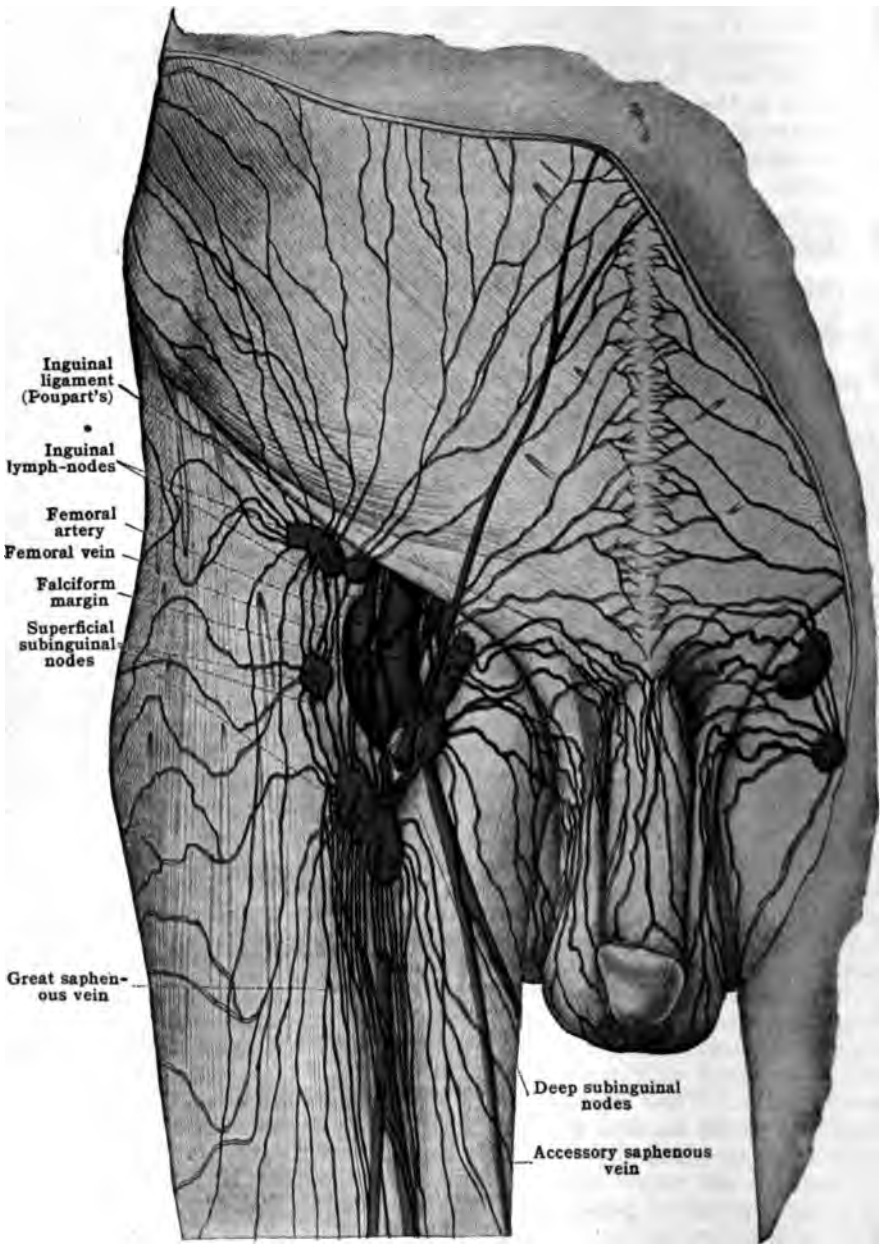
In addition to the inguinal group of nodes there are some other nodes in the lower limb situated along the course of the deep vessels. Thus there is an inconstant node in the course of the anterior tibial vessels below the knee, and there is a small group of **popliteal nodes** [lgl. popliteæ], in the popliteal space (fig. 631), which receive the lymphatics accompanying the lesser saphenous vein, also those which accompany the posterior tibial and peroneal vessels, and those which drain the knee-joint.

2. THE LYMPHATIC VESSELS OF THE LOWER EXTREMITY

As in the upper extremity, the subcutaneous capillary plexus of the lower varies greatly in complexity, being most abundant in the soles of the feet. The collecting vessels form two main groups. The medial, larger group (fig. 630) follows the great saphenous vein, and ends in the superficial subinguinal nodes,

while the lateral group curves around to join the medial, partly in the leg and partly in the thigh. Two or three vessels from the heel follow the lesser saphenous vein to the popliteal space. The vessels from the upper and dorsal part of the thigh curve around on both sides to reach the superficial inguinal nodes. The vessels of the anus and perineum, as well as those from the external genitalia,

FIG. 629.—THE SUPERFICIAL INGUINAL NODES. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



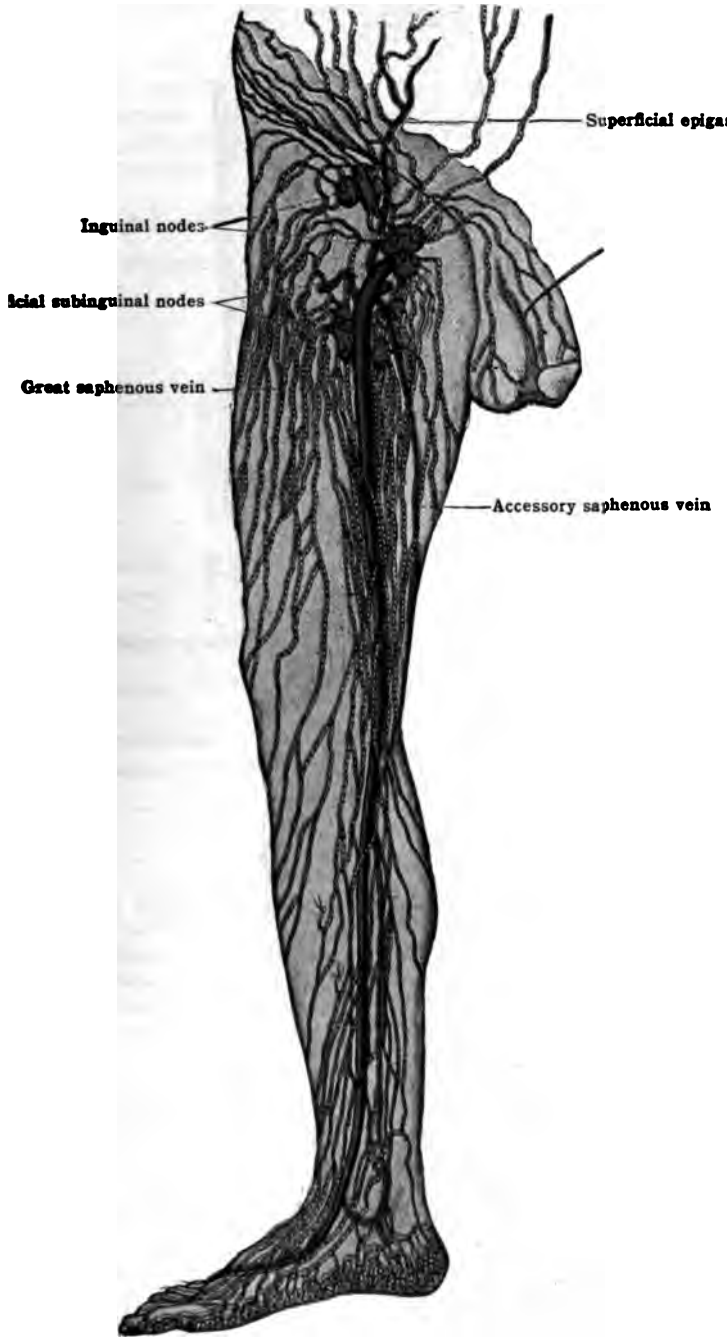
except from the glans penis or the clitoris, pass to the medial nodes of the superficial inguinal group.

The deep vessels follow the course of the arteries of the lower extremity, t accompanying the dorsalis pedis and anterior tibial arteries coming into rel with the anterior tibial node (when present), and then passing backward to the vessels which accompany the posterior tibial and peroneal arteries. T terminate in the popliteal nodes, from which efferents follow the course of femoral artery and terminate in the deep inguinal nodes. The deep lymp

ɔmpanying the gluteal and obturator arteries pass to the hypogastric

cs of the hip-joint.—According to Clermont, they accompany, in the main, the ıt the joint. (1) Satellites of the anterior circumflex artery, draining almost the l surface, pass to the lateral inferior external iliac node. (2) Satellites of the pos-

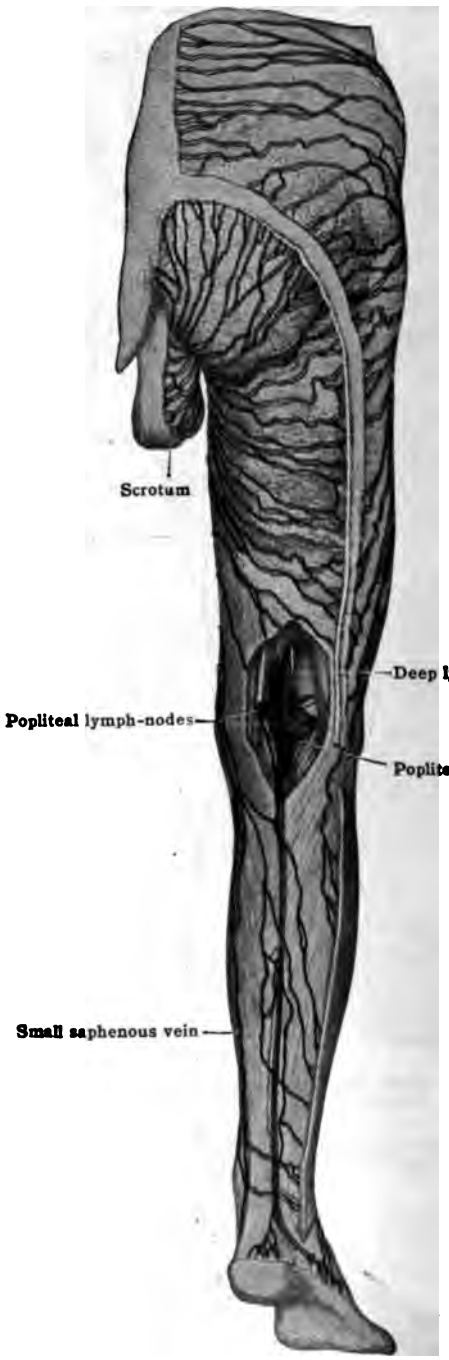
'HE SUPERFICIAL LYMPHATICS OF THE LOWER EXTREMITY. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



ıflex artery, draining the dorsal and medial surfaces, empty into the medial inferior e node, occasionally into one of the deep inguinal nodes. (3) Satellites of the sel, draining the round ligament, empty into the obturator or hypogastric nodes. s of the inferior gluteal vessels, draining the dorsal surface, empty into three small

nodes along the internal pudic and inferior gluteal arteries. Less important ('acce vessels are: satellites of the superior gluteal artery leading to a gluteal node; vessels fr dorsal surface which cross the lateral border of the pectineus to reach the medial i external iliac node; and vessels from the ventral surface, crossing parallel to the cotyloid passing under the psoas to the lateral inferior external iliac or one of the deep inguinal

FIG. 631.—THE LYMPHATICS OF THE BACK OF THE LOWER EXTREMITY. (After Toldt, 'A Human Anatomy,' Rebman, London and New York.)

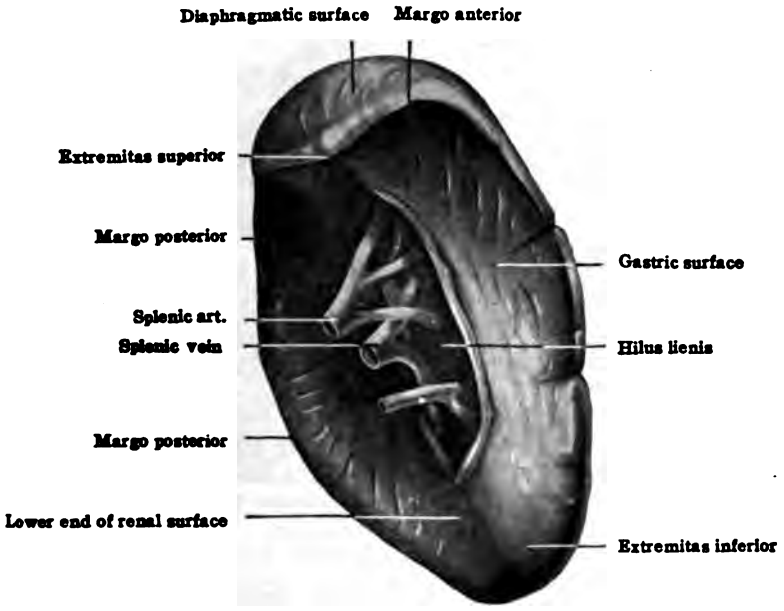


Lymphatics of the knee-joint.—According to Tanasesco the lymphatics draining tl tures around the knee-joint in the main follow the arteries about the joint and pass la the more deeply placed of the popliteal nodes. Some (superficial) follow the great sa vein to the subinguinal nodes, and sometimes deep vessels pass the popliteal nodes companying the femoral artery, run to the deep inguinal or inferior external iliac.

SPLEEN

The spleen [lien] has approximately the shape of an elongated, ovoid body, **hat** of a slightly curved wedge (figs. 632, 633), with three (or four) surfaces, **l** three rounded borders. Its largest surface is the convex, **diaphragmatic face** [facies diaphragmatica], posterolaterally facing the curve of the dia-**agm** (figs. 635, 636). The latter separates the spleen from the pleural cavity **l** ribs. The deeply concave, **gastric surface** [facies gastrica] rests ventro-**dially** against the fundus of the stomach. It includes the **hilus,** which re-**ves** the splenic vessels, and behind which the spleen is in contact with the **l** of the pancreas (fig. 635). The slightly concave, **renal surface** [facies renalis] **ts** posteromedially against the convex, anterior surfaces of the left kidney **g.** 636) and suprarenal. The more caudal portion of this area touches to a **riable** extent the left colic flexure. An enlarged basal or **colic surface** often **es** the spleen a more tetrahedral shape.

FIG. 632.—WEDGE-SHAPED SPLEEN, VISCERAL SURFACE.



The spleen has an anterior and a posterior border. The anterior border **argo anterior**] forms a rather sharp, considerably convex line, on which some-**es** slight serrations (lobulations) are noticeable. The posterior or dorsal **der** [margo posterior] is almost straight and more rounded than the anterior **rgin.** The anterior border touches the fundus of the stomach, the posterior **l** lumbar region of the diaphragm. In the tetrahedral spleen, an **inferior der** separates the colic from the diaphragmatic surface. The spleen also shows **uperior extremity** and an **inferior extremity,** the latter occupying a more **ıtral** position. Between the gastric and renal surfaces of the spleen, usually **newhat** on the gastric surface, runs an elevated ridge, sometimes called the **ermediate** border, which may present a distinct tubercle (fig. 634). Along **margins** of this ridge is attached the visceral layer of the peritoneum. This **rounds** the entire organ and is reflected as the gastrolienal and phrenolienal **ıments.**

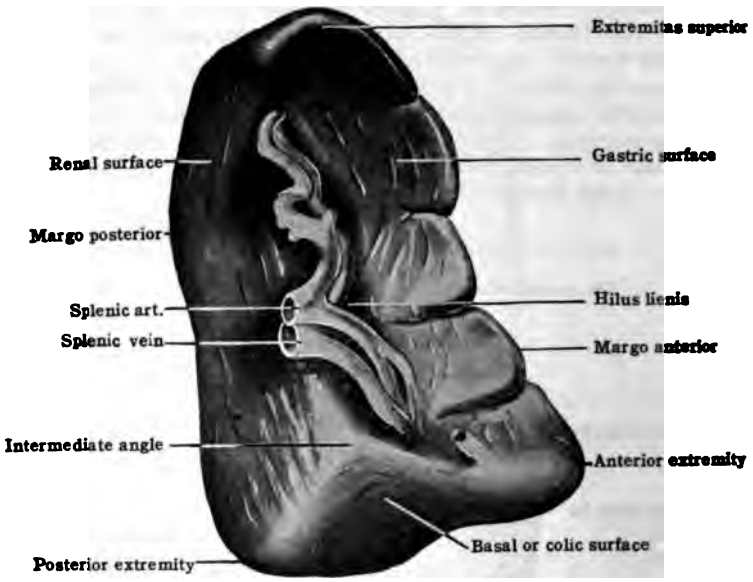
The shape of the spleen varies considerably in different individuals. Even **he same individual** it changes its shape to some extent in accommodating itself **the surfaces of the** contracted or distended viscera. When the stomach is **pty and the colon** distended, the tetrahedral form is more pronounced. In **opposite case, the** colic surface may disappear entirely.

The spleen has a rather dark, brownish red color, which after death soon changes to a **plish tint. Its consistency** is soft. It is surrounded by a tough, fibrous capsule, con-

taining many elastic elements, which allow for considerable expansion of the splenic substance, and numerous smooth muscle-fibers. The latter are present, to some extent, in the trabeculæ and assist in the rhythmical contractions of the organ. The peritoneum is closely applied to the capsule.

The size of the spleen is also subject to great individual variation. It easily enlarges under blood-pressure. A few hours afer meals its size is also increased. The length of the organ

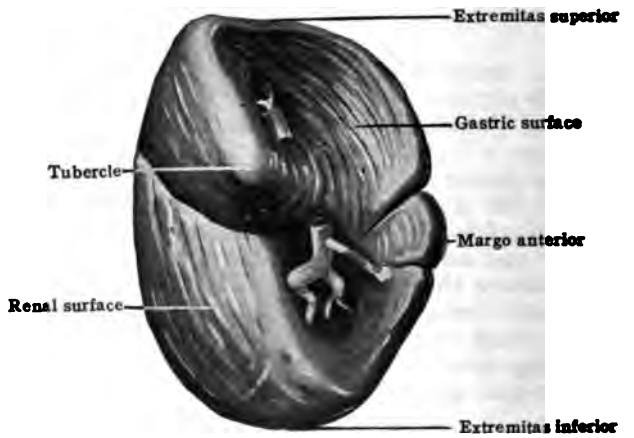
FIG. 633.—TETRAHEDRAL SPLEEN, VISCERAL SURFACE.



varies from 10 to 14 cm.; the width from 6 to 10 cm.; the thickness from 3 to 4 cm.; and the weight varies from 80 to 300 grams or more. After the age of 40 years, a slight involution of the spleen sets in.

Topography.—The spleen lies in the left hypochrondiac region (fig. 965), its cranial end sometimes reaching into the epigastric region. It is situated in a shallow excavation, formed dorsally by the kidney and suprarenal, laterally by the costal part of the diaphragm, cranially by the dome of the diaphragm, caudally

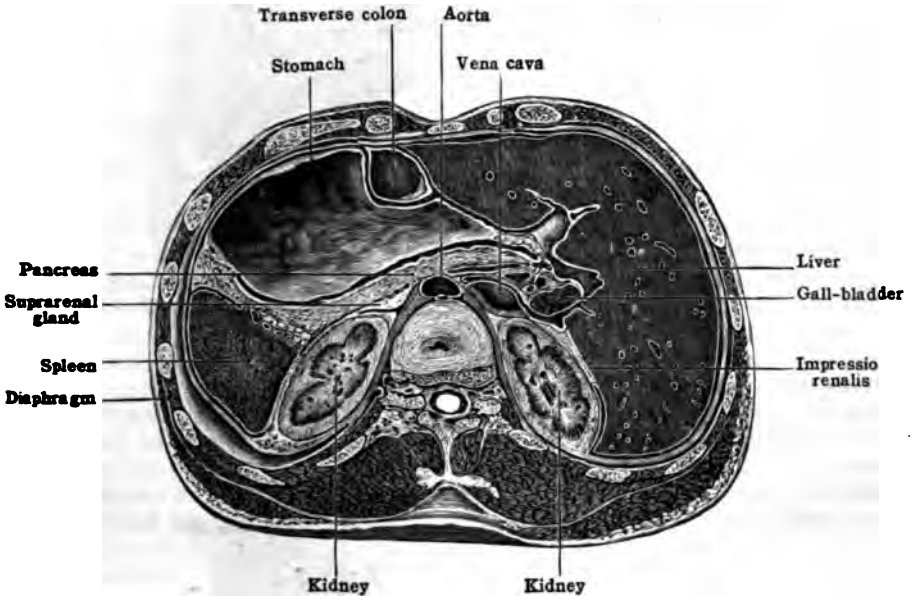
FIG. 634.—SPLEEN SHOWING TUBERCLE ON THE INTERMEDIATE BORDER.



by the left colic flexure and phrenocolic ligament, ventromedially by the stomach. The long axis of the organ runs about parallel with the tenth rib (fig. 1115), the spleen lying laterally to a line drawn from the left sternoclavicular articulation to the tip of the eleventh rib. The upper extremity lies in the region of the costal angle, the lower nearly reaches the midaxillary line. The width of the spleen extends through the 9th and 10th intercostal spaces. (See p. 1375.)

Nowhere, except near the hilus, is the spleen attached to the peritoneum. refore it easily slides in its bed and follows the movements of the diaphragm. important suspensory ligament of the spleen is the **gastrolienal ligament,** se peritoneal layers are continued from the anterior (greater sac) and pos- or (lesser sac) surfaces of the stomach to the anterior and posterior borders he hilus, respectively. The anterior layer is continued over the entire surface he spleen, and then meets the posterior layer to be reflected from the hilus of spleen to the adjacent surface (fig. 920). This double reflection forms the rt **phrenolienal** (lienorenal) ligament which carries the splenic vessels and tail of the pancreas. This ligament is variable in form and extent. The **enocolic** ligament, although not attached to the spleen, supports the lower remity ofthe organ (fig. 924).

635.—Cross-section of the Body at the Lower Part of the Epigastric Region. (Rüdinger.)



Blood-supply.—The *splenic artery* and *vein* run in the phrenolienal ligament to the hilus. artery is rather tortuous, especially in older persons, and lies above the vein. It branches ral (about six) times into the vessels of the superior and inferior group before reaching the n. The splenic vein is likewise formed outside the hilus by several tributaries.

At the hilus some *lymph-vessels* are found which send a few branches into the capsule and er trabeculæ. No lymph-vessels go through the splenic tissue proper. About 8 orr 10 ph-nodules, connected with these vessels, are found near the hilus, betweenthe layecrs of gastrolienal ligament (splenic nodes), and some along the superior border of the pancreas ncreaticosplenic nodules).

Nerve-supply.—Nerve-fibers from the median and anterior parts of the celiac plexus, in the n of a dense network, the *splenic plexus*, follow the splenic artery into the organ. Also rs from the right vagus can be traced in. The few medullated fibers are probably sensory.

Development.—The spleen develops in the mesenchyma of the dorsal mesogastrium. A use accumulation of leucoblasts is noticeable at the beginning of the second fetal month o 10 mm. embryos). This area very soon becomes considerably vascularized, especially the s forming loose capillary plexuses. Later, angioblasts are carried into this zone, and the en begins to assume its hemopoietic function. During fetal life, red as well as white blood- s are formed in the spleen. After birth the formation of erythrocytes ceases. For further ils on the development of the spleen, see p. 36.

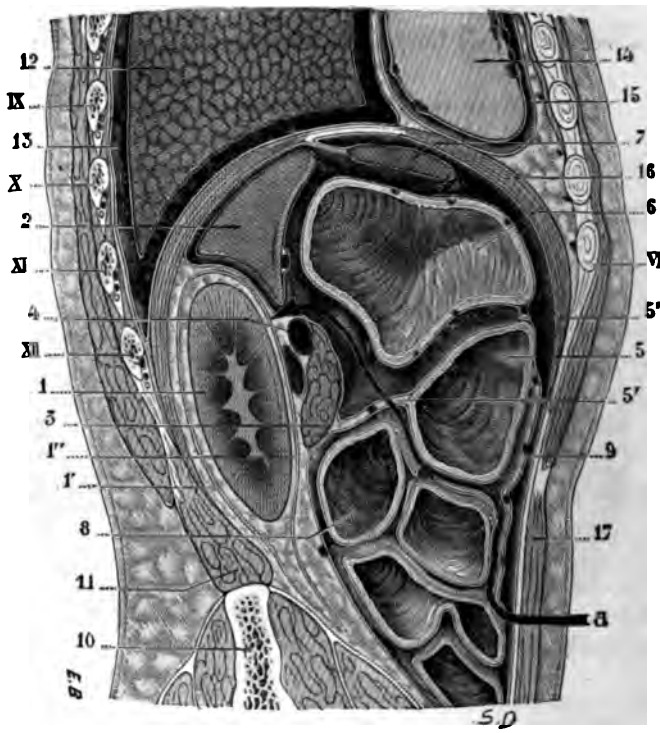
Variations.—Sometimes *lobulated spleens* are found, in which the above-mentioned notches g the anterior border are exaggerated. Also on the diaphragmatic surface and on the pos- or border deep incisions may appear, so that the entire organ seems to be divided up into s. Such a spleen probably represents an atavistic type, the organ being lobated in the r vertebrates and even in some mammals.

Another, not uncommon, abnormality is the formation of *accessory spleens.* These are lly small nodules in the neighborhood of the main organ. Sometimes their number is quite sive. In man over 400 have been counted in a single individual, widely distributed ugh the peritoneal cavity; in dogs and cats, over 800. Sometimes a group of such small ules (isolated lobules) takes the p ace of th main organ. Whether in the above mentioned

cases all these numerous nodes actually represent *accessory spleens* or *hemal nodes* is still open question. It is difficult to make a differential diagnosis of very small nodules. There however, no doubt that the body of the spleen can break up into its units. A congenital sence of the spleen is extremely rare.

References for lymphatic system.—(*Development*): Sabin, Amer. Jour. Anat., vols. 1, 9, also in Keibel and Mall's Human Embryology; Lewis, Amer. Jour. Anat., vols. 5, 9; H ington and McClure, Amer. Jour. Anat., vol. 10; Clark, E. R., Amer. Jour. Anat., vol. Clark, E. R., and E. L., Carnegie Inst. Contrib. to Embryol., No. 45, 1920. (*Regenerat* Meyer, Johns Hopkins Hosp. Bul., vol. 17. (*General*): Bartels, in von Bardeleben's Hand

FIG. 636.—SAGITTAL SECTION THROUGH THE LEFT SIDE OF THE BODY, SHOWING RELATIONS OF THE SPLEEN. IX, X, XI, XII, corresponding ribs. 1, Left kidney; 2, splee pancreas; 4, splenic vessels; 5, transverse colon; 6, stomach; 7, left lobe of liver; 12, lung heart; 16, diaphragm. Line *a* indicates inferior surgical route. (Testut and Jacob.)



d. Anatomie; Sappey, Description et Iconographie des Vaisseaux Lymphatiques, Paris Teichmann, 'Das Saugadersystem,' Leipzig, 1861. (*Muscle, etc.*): Aagaard, Anat. Bd. 47. (*Connective tissue*): von Recklinghausen, Die Lymphgefässe u. ihre Beziehu Bindegewebe, Berlin, 1862. (*Stomata*): MacCallum, Johns Hopk. Hosp. Bull., 1903, 1 (*Lung*): Miller, Anat. Rec., vol, 5; Cunningham, R. S., Carnegie Inst. Contrib. to Em No. 12. (*Teeth*): Schweitzer, Arch, f. mikr. Anat., Bd. 74. (*Hemal nodes*): A. W. Proc. Am. Ass. of Anat., Anat. Rec. vol. 2, p. 62; and Amer. Jour. Anat., vol. 21. (S Mall, Am. Jour. Anat., vol. 2, 1903; Weidenreich, Arch. f. mikr. Anat., Bd. 58, 1901; Sh Jour. Anat. and Physiol., vol. 37, 1902; Mollier, Arch. f. Mikr Anat. Bd. 76, 1911; S Keibel-Mall, 1911.

SECTION VIII

THE NERVOUS SYSTEM

REVISED FOR THE SIXTH EDITION

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HE nervous system of man, both anatomically and functionally, is the most highly developed and definitely distributed of all the organ-systems of the body. It consists of an aggregation of peculiarly differentiated tissue-ents, so arranged that through them stimuli may be transmitted from and to he other tissue systems or functional apparatuses. It is a mechanism with s so adjusted that stimuli affecting one tissue may be conveyed, controlled, ified, and distributed to other tissues so that the appropriate reactions result. e protoplasm will react without nerves, while muscle will contract without nediation of nerves, yet the nervous system is of the most vital importance to igher organisms in that the stimuli required for the functioning of the organs so distributed throughout their component elements that the necessary ionious and coordinate activities are produced. For this purpose the ous system permeates every organ of the body; nerve cell-bodies, accu-ted into groups, give rise to the nerves which ramify and divide into smaller smaller branches till the division attains the individual nerve-fibers of which nerves are composed, and even the fibers bifurcate repeatedly before their termination upon their allotted elements from which they receive and to h they impart stimuli. So intimate and extensive is the distribution through-that could all the other tissues of the body be dissolved away, still there would ft in gossamer its form and proportions—a phantom of the body composed ely of nerves.

he parent portion or **axis** of the system extends along the dorsal midline of ody, surrounded by bone and, in addition, protected and supported by a s of especially constructed membranes or meninges, the outermost of which e strongest. The cephalic end of the axis, the **encephalon,** is remarkably ged in man, and is enclosed within the largest portion of the bony cavity, ranium, while the remainder of the central axis, the **spinal cord,** continues gh the foramen magnum and lies in the vertebral canal.

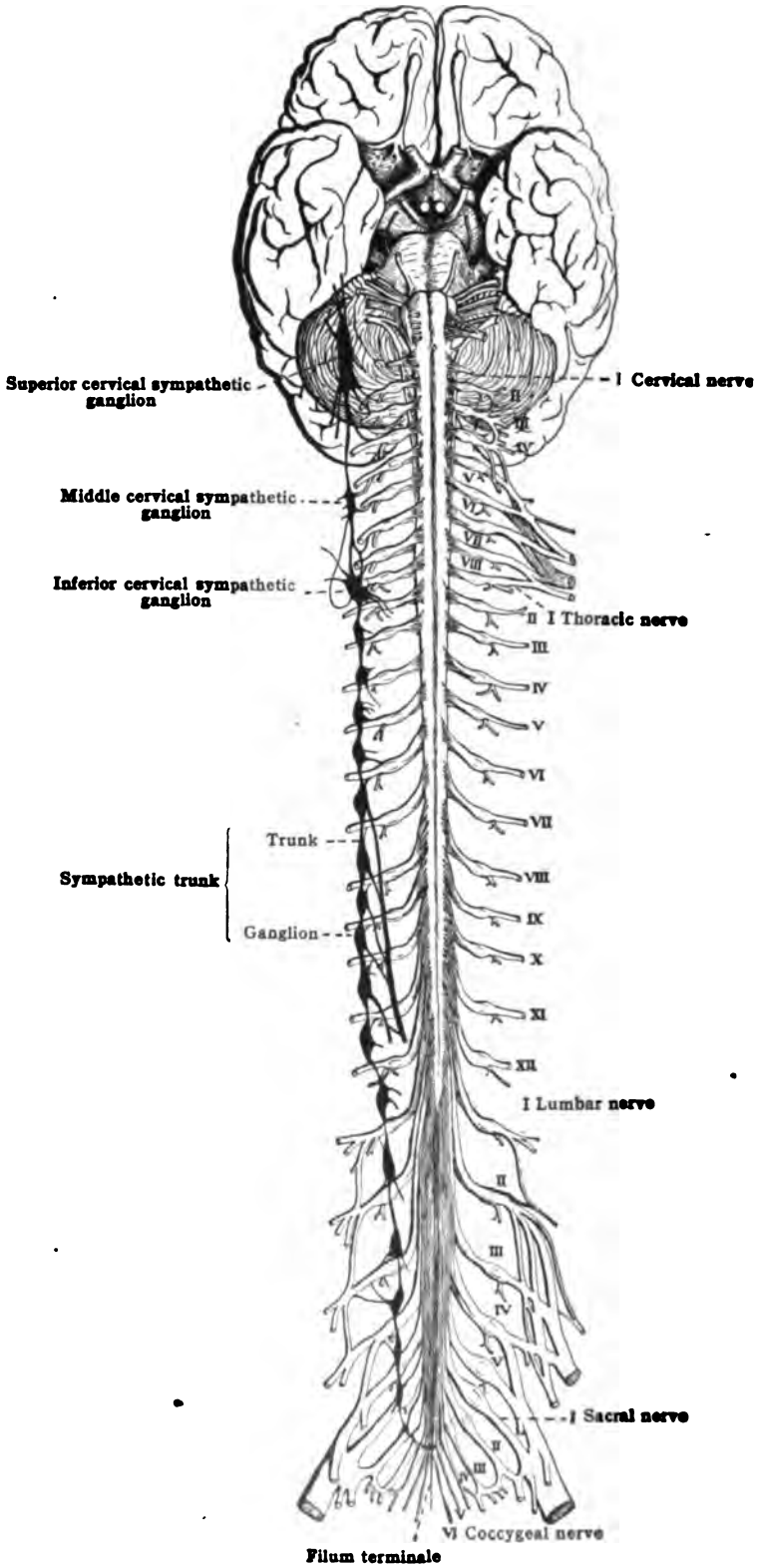
he intimate connection of the axis with all the parts of the body is attained eans of forty-six pairs of nerves, which are attached to the axis at somewhat ar intervals along its extent. They course from their segments of attach-through the meninges and through their respective foramina in the bony y to the periphery. Of these *craniospinal nerves,* fifteen pairs pass through ranium and are attached to the encephalon, and thirty-one pairs to the l cord. Some of the cranial nerves and all of the thirty-one pairs of spinal s contain both *afferent fibers,* which convey impulses from the peripheral es to the central axis, and *efferent fibers,* which convey impulses from the axis e peripheral tissues. The different pairs of nerves possess the two varieties ers in varying proportions.

pon approaching the spinal cord, each spinal nerve is separated into two roots posterior or *dorsal root* and its anterior or *ventral root.* The afferent fibers the axis by way of the dorsal roots, which are, therefore, the sensory roots, he efferent fibers leave the axis by way of the ventral or motor roots.

s usually studied, the nervous system is referred to in two main divisions:—
) The *central nervous system,* composed of—(*a*) The spinal cord, or medulla lis, and (*b*) the brain or encephalon.

FIG. 637.—SHOWING THE VENTRAL ASPECT OF THE CENTRAL NERVOUS SYSTEM, WITH THE PROXIMAL PORTIONS OF THE CRANIOSPINAL NERVES ATTACHED AND THE RELATION OF THE PROXIMAL PORTION (SYMPATHETIC TRUNK) OF THE SYMPATHETIC NERVOUS SYSTEM. THE ENCEPHALON OR BRAIN IS STRAIGHTENED DORSALWARD FROM ITS MORE HORIZONTAL POSITION WITH REFERENCE TO THE SPINAL CORD. THE SPINAL GANGLIA AND THE DORSAL AND VENTRAL ROOTS OF THE SPINAL NERVES MAY BE NOTED.

(Composite drawing in part after Allen Thompson from Rauber—modified.)



(2) The *peripheral nervous system*, composed of—(*a*) The craniospinal nerves, and (*b*) the sympathetic nervous system.

All these parts are so intimately connected with each other that the division is purely arbitrary. The craniospinal nerves are anatomically continuous with the central system; their component fibers either arise within or terminate within the confines of the central system, and thus actually contribute to its bulk. The sympathetic system, however, may be more nearly considered as having a domain of its own. By communicating rami, it is intimately associated with the craniospinal nerves and thus with the central system, both receiving impulses from the central system and transmitting impulses to portions of its structure. But, while its activities are largely under the control of the central system, it is thought possible that impulses may arise in the domain of the sympathetic system and, mediated by its nerves, produce reactions in the tissues it supplies without involving the central system at all. For this reason, as well as because of the structural peculiarities of the sympathetic system, the nervous system is sometimes divided into—(1) the craniospinal system, consisting of (*a*) the central system and (*b*) the craniospinal nerves; (2) the sympathetic nervous system, consisting of (*a*) its various peripheral ganglia and their outgrowths forming its plexuses (sympathetic system proper) and (*b*) efferent fibers arising within the central system and terminating in sympathetic ganglia (visceral efferent, "autonomic" or preganglionic fibers).

Within and closely proximal to the central system or axis are grouped the parent cell-bodies whose processes comprise the nerve-fibers of the craniospinal nerves. Other groups of nerve cell-bodies, distributed in the periphery without the bounds of the central system, give rise to the fibers, nerves and plexuses of the sympathetic proper. Any group of such cell-bodies situated in the periphery, whether belonging to the craniospinal or sympathetic system, is known as a *ganglion*.

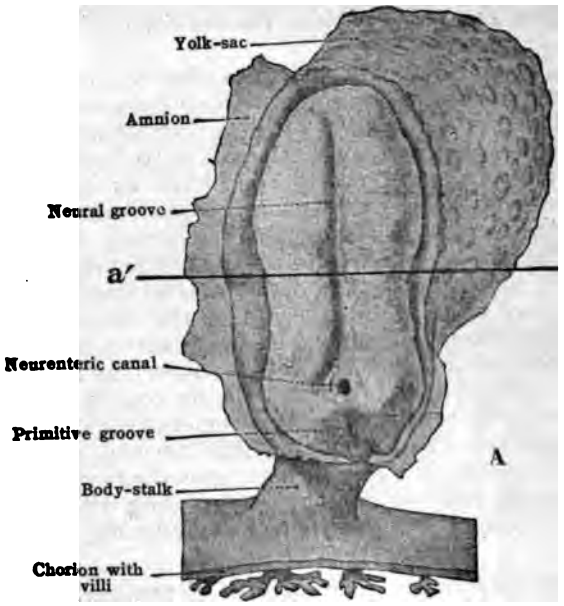
THE DEVELOPMENT OF THE NERVOUS SYSTEM

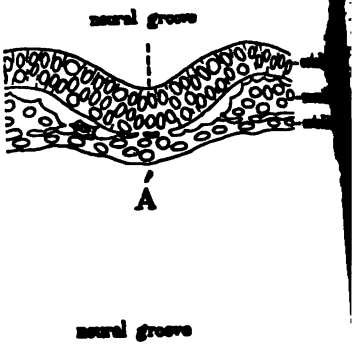
The essential elements of the nervous system, the nerve cell-bodies and the essential portion of all nerve-fibers, central, craniospinal and sympathetic, develop from one of the embryonic germ layers, the ectoderm, and all arise from a given region of that germ layer. Further a small portion of the supporting tissue of the nervous system, the neuroglia, is considered as of the same origin.

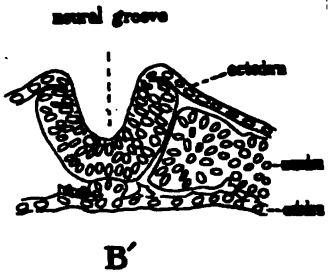
In its development the nervous system is precocious. It is the first of the functional apparatuses to begin differentiaton and is the first to acquire its form. The first trace of the embryo appears on the developing ovum as the *embryonic area*, and the rapidly proliferating cells of this area shortly become arranged into the three germinal layers:—the outer layer or *ectoderm*, the middle layer or *mesoderm*, and the inner layer or *entoderm*. Early in the process of this arrangment there is formed along the axial line of the embryonic area a thickened plate of ectodermal cells, the *neural plate*. In the further proliferation of these cells, the margins of the neural plate, which lie parallel with the long axis of the embryonic area, rise slightly above the general surface, forming the *neural folds*, and the floor of the plate between the folds undergoes a slight invagination, the process resulting in the *neural groove* (fig. 638, A, A′ and B, B′). As development proceeds and the embryonic area assumes the form of a distinct embryo, the neural folds or lips of the groove gradually converge, and beginning at the oral end, finally unite. Thus the groove is converted into the *neural tube*, extending along the dorsal midline and enclosed within the body of the embryo by the now continuous ectoderm above (fig. 638, C′ and D, D′).

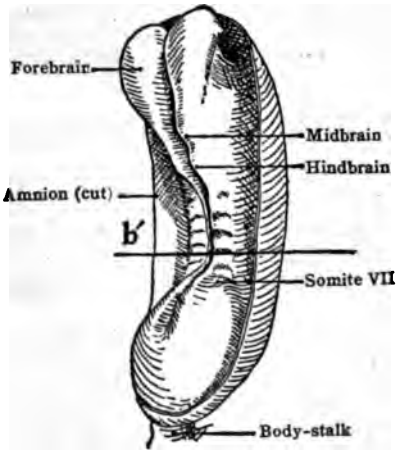
For a time the neural tube remains connected with the inner surface of the general ectoderm along the line of fusion by a residual lamina of ectodermal cells. This lamina is known as the *ganglion-crest* (neural crest). It is a product of the proliferation of the ectoderm during the process of fusion, consists of the cells which composed the transition between the closing lips of the original groove and the general ectoderm, and whose fusion aided in the closure of the tube. The ectoderm soon becomes separated from the ganglion crest and the cells of the crest become distinctly differentiated from the cells of the neural tube. The essential elements of the entire nervous system together with the neuroglia are derived from the cells of the neural tube and the cells of the ganglion-crest.

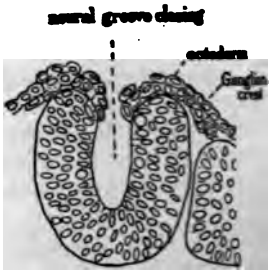
Before the caudal extremity of the tube is entirely closed, its oral end undergoes marked enlargement and becomes distended into three vesicular dilations, the anterior, middle, and posterior primary *brain-vesicles*. The anterior of these primary vesicles give off a series of secondary vesicles and by these, followed by further dilations, flexures of its axis, and by means of localized thickenings of its walls, the portion of the tube included in the three primary vesicles develops into the encephalon or brain of the adult. The remainder of the tube becomes the spinal cord. This latter portion retains the simpler form. By the proliferation and migration laterally of the cells lining this portion of the tube, there results a comparatively even bilateral thickening of its walls so that the mature spinal cord retains a cylindrical form throughout its length.

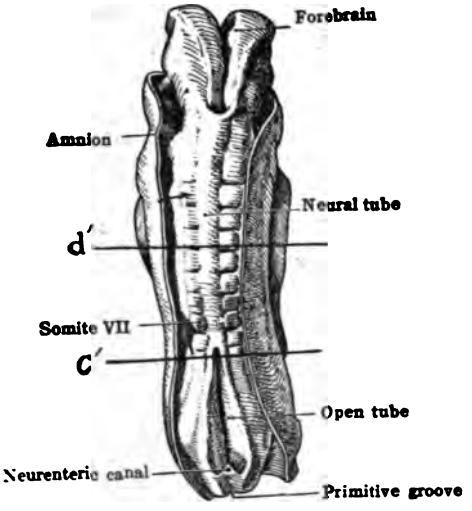

Yolk-sac
Amnion
Neural groove
a′
Neurenteric canal
Primitive groove
Body-stalk
Chorion with villi
A

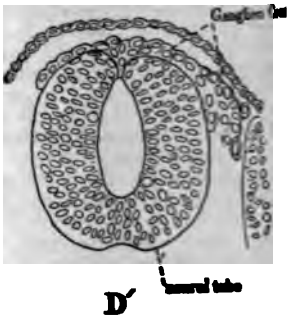

neural groove
A′


neural groove
ectoderm
B′


Forebrain
Midbrain
Hindbrain
Amnion (cut)
b′
Somite VII
Body-stalk
B


neural groove closing
ectoderm
C′

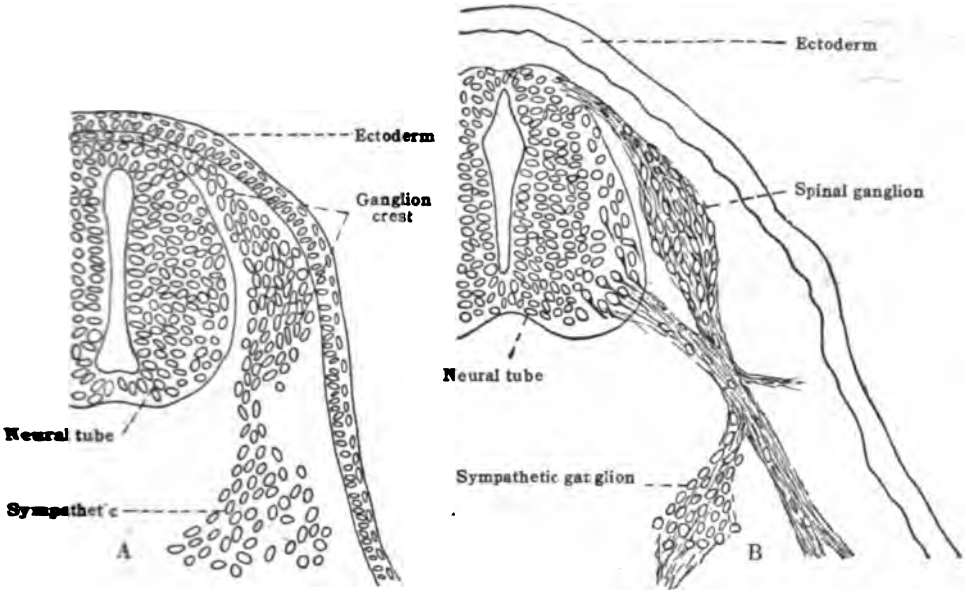

Forebrain
Amnion
Neural tube
d′
Somite VII
C′
Open tube
Neurenteric canal
Primitive groove
D


neural tube
D′

The proliferating and migrating cells of the wall of the neural tube are known as *germinal cells*. Their cell-boundaries are soon lost and the entire wall becomes a syncytium. The products of their division are apparently indifferent at first, but later they become differentiated into two varieties: (1) *spongioblasts*, or those nuclei which will control the development of neuroglia, and (2) *neuroblasts*, or those which will increase in size, give off processes and become

FIG. 639.—DIAGRAMS OF TRANSVERSE SECTIONS OF EMBRYONIC SPINAL CORDS SHOWING THE MIGRATION OF THE ELEMENTS OF THE GANGLION CREST TO FORM THE SPINAL AND SYMPATHETIC GANGLIA AND THE ORIGIN OF THE DORSAL AND VENTRAL ROOTS OF THE SPINAL NERVES.

A, a stage following D′ of fig. 638. B, a later stage in which the ganglia and the components of the nerve are assuming their form resulting from the further migration and from processes being given off by the neuroblasts.



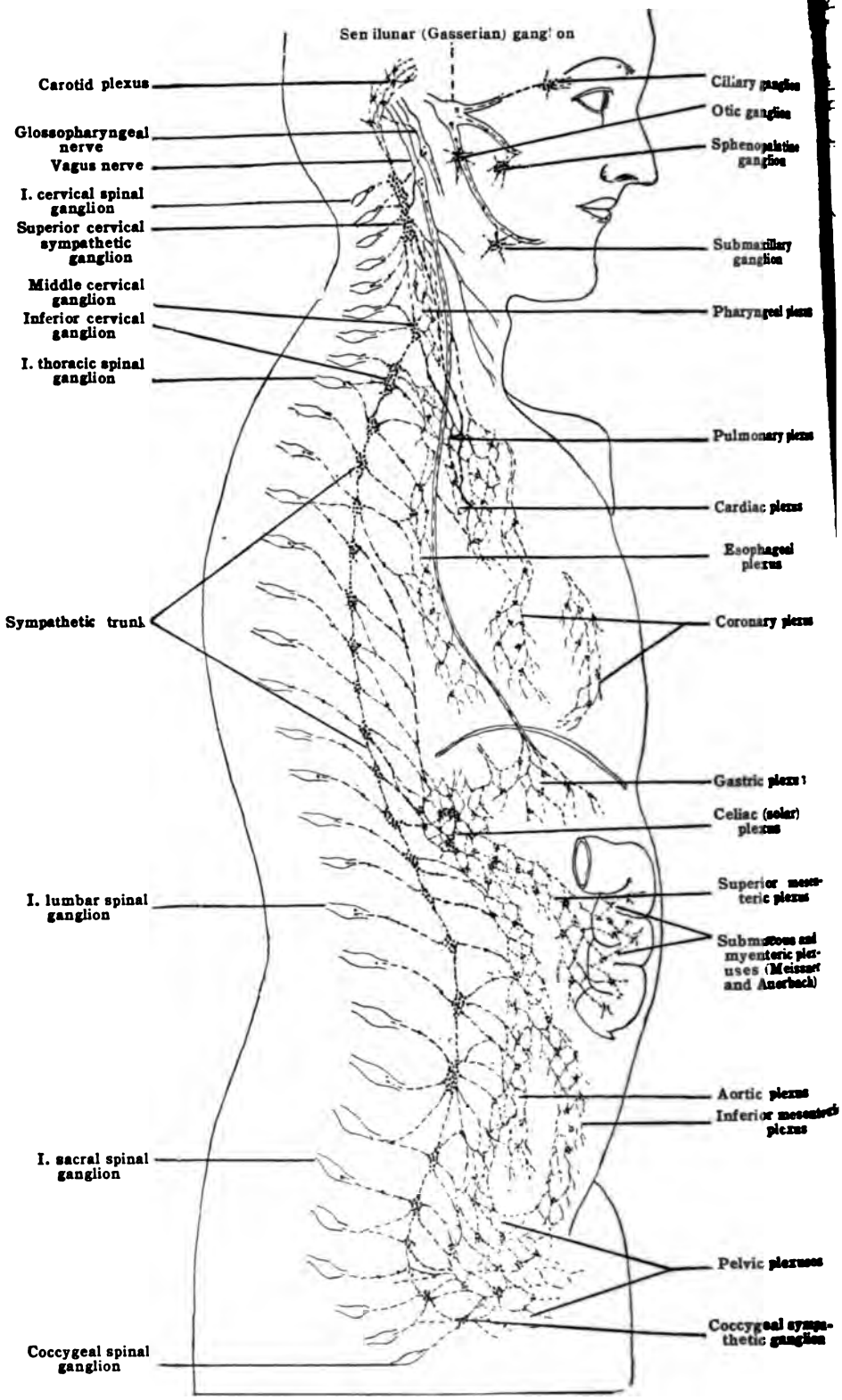
nerve cell-bodies. As described below, the processes given off by a neuroblast are of two general characters: (1) a long process or axone which goes to form nerves, nerve-roots, and nerve-fasciculi, and (2) dendritic processes which are numerous, branch much more frequently and extend but a short distance from the cell-body. An adult cell-body with all its processes is known as a *neurone* and the neuroblasts of the developing system become transformed into the neurones of the varying sizes, shapes, and arrangements of processes characteristic of different divisions and localities of the nervous system. Usually the first process to be noted is that which will become the axone or nerve fiber.

Neurones whose cell-bodies belong to the peripheral nervous system are not developed within the walls of the neural tube or central nervous system at all. These, comprising the spinal ganglion neurones and those of the sympathetic system, are derived from the cells of the ganglion-crest. The wedge-shaped lamina of cells, comprising the ganglion-crest, through rapid cell division, gradually extends outward and ventralward over the surface of the neural tube along either side. Soon the proliferation becomes most active in regions proximate to the mesodermic somites or body segments and this activity, together with the stress of the growing length of the body, results in the ganglion-crest (originally a lamina) becoming segmented also. The segments or localized ganglion-masses thus formed are the beginning not only of the spinal ganglia, but also of the ganglia of the entire sympathetic system. The elements of the crest migrate to assume a more lateral position, and then occurs a separation of their ranks. A portion of them remain in a dorsolateral position near the wall of the neural tube and develop into the neurones of the *spinal ganglia* (the sensory neurones of the spinal nerves), but others wander further out into the periphery and become the neurones of the

FIG. 638.—DORSAL SURFACE VIEWS OF HUMAN EMBRYOS AND DIAGRAMS OF TRANSVERSE SECTIONS ILLUSTRATING THE DEVELOPMENT OF THE NEURAL TUBE.

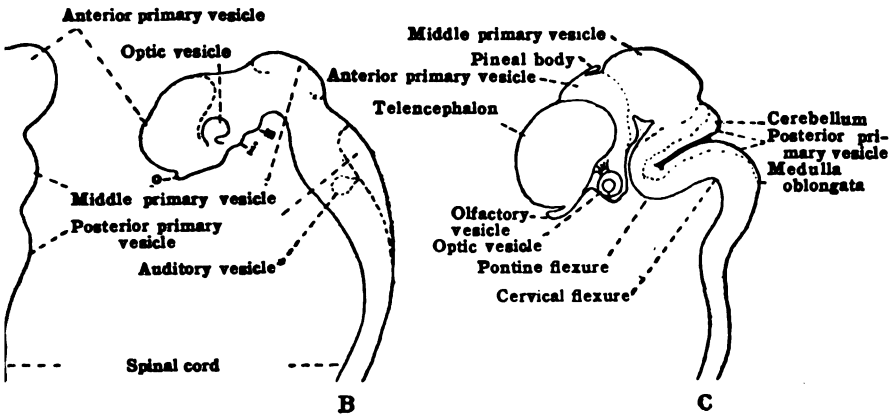
A, dorsal view of human embryo at beginning of infolding of neural plate to form neural groove. Amnion partly removed. (Graf Spee, from Keibel and Mall.) A′, diagram of portion of a transverse section of an embryo as though taken through A at the line a′. B, dorsal view of human embryo of 7 somites, neural tube not yet closed, Mall Collection. (Dandy, from Keibel and Mall.) B′, diagram of portion of a transverse section of an embryo as though taken through B at the line b′. C′, diagram of portion of a transverse section of an embryo as though taken through D at line c′. D, dorsal view of human embryo of 8 somites, 2.11 mm. long, neural tube closed except at caudal end. (Kollmann, from Keibel and Mall.) D′, diagram of a portion of a transverse section of an embryo as though taken through D at line d′.

FIG. 640.—DIAGRAM SHOWING THE CHIEF PATHS OF MIGRATION OF THE CELLS FROM THE EMBRYONIC GANGLIA OF THE SPINAL AND CRANIAL NERVES TO FORM THE ADULT SYMPATHETIC SYSTEM (AFTER SCHWALBE, MODIFIED.)

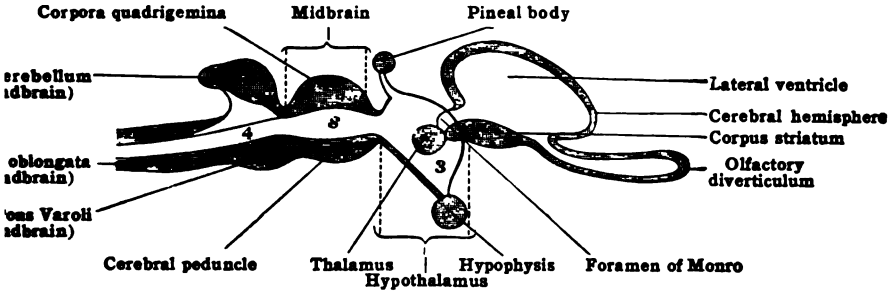


hetic. Certain of those in this more nomadic group settle within the vicinity of the al column and by sending out their processes, form the *sympathetic trunk* or the proximal f sympathetic ganglia; others migrate further, but in more broken rank, and become glia of the *prevertebral plexuses* (as the cardiac, celiac and hypogastric plexuses), or the d intermediate chain of ganglia; while still others wander into the very walls of the

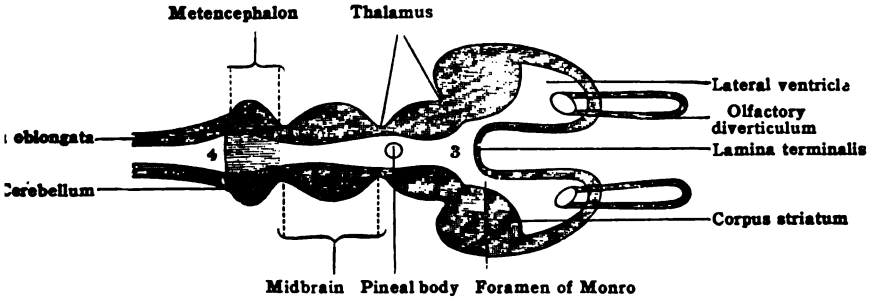
1.—Diagrams of Portion of Human Neural Tube Showing the Three Primary AIN Vesicles and Some of the Secondary Vesicles Derived from Them.
ram of dorsal view of early stage. B, lateral view at about the third week. C, lateral w at about the eighth week. After His, modified. m, mamillary vesicle; i, infundibular ess; o, olfactory vesicle.



IG. 642.—Diagrammatic Sagittal Section of a Vertebrate Brain. (After Huxley)
4, fourth ventricle; *s*, cerebral aqueduct; 3, third ventricle.



3.—Diagrammatic Horizontal Section of a Vertebrate Brain. (After Huxley.)
4, fourth ventricle; 3, third ventricle.



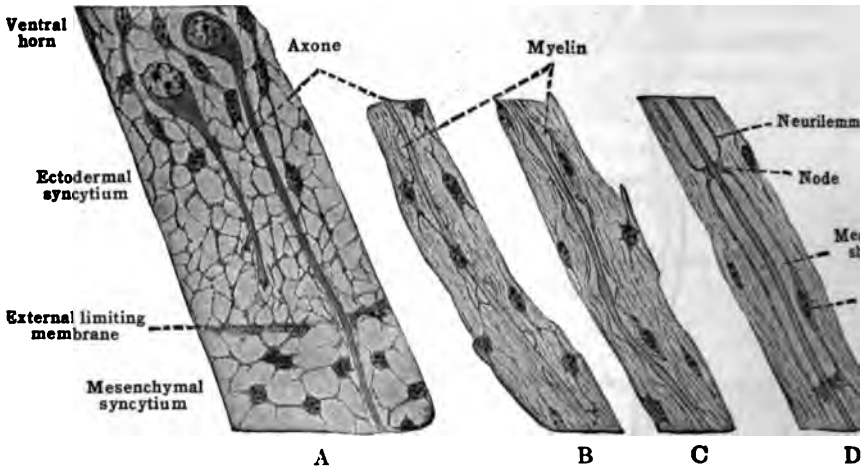
ral organs and occur singly or in groups in such plexuses as those of Auerbach and Meissthin the tunics of the walls of the alimentary canal. Scattered along between these al, intermediate, and distal groups there are to be found small straggling ganglia, many h contain so few cell-bodies that they are indistinguishable with the unaided eye. All ympathetic neurones, however, are probably directly anatomically associated with and he control of the neurones of the central system through *visceral efferent fibers* passing n by way of the rami communicantes or by way of the peripheral distribution of the and cranial nerves.

from the ectodermal syncytium, while the white and elastic fibrous tissues are derived
mesodermal or mesenchymal syncytium. Before any connective tissue fibrils are dev
either syncytium, before and at the time of the ingrowth of blood-vessels into the de
ganglia and the neural tube from the mesenchyme about them, there occurs an invasi
mesenchymal syncytium into the ectodermal syncytium. This invasion occurs both
pendent ingrowths and fusions at the periphery of the neural tube and by the mese
tissue being carried in by the ingrowing blood-vessels. After the mixture of the nuclei
from this fusion of the syncytia from the two sources, nuclei of mesodermal origin c
distinguished from those of ectodermal origin. Further, axones outgrowing from
bryonic ganglia and neural tube carry with them adhering portions of the ectodermal sy
into the surrounding mesenchymal (fig. 646, A).

As development proceeds further, each syncytium becomes resolved into a reti
granular endoplasmic processes, containing the nuclei, with transparent exoplasm o
its meshes. Fibers soon form in the exoplasm and from these develop the connecti
fibers, whether neuroglia within the central nervous system or mesenchymal fibrous tis
without and within it. Certain of these fibrils of course surround the axones imbedde

FIG. 646.—DRAWINGS ILLUSTRATING THE ORIGIN OF THE AXONE AND THE DEVELOP
THE MEDULLARY SHEATHS.

A, ventral portion of transverse section of an embryonic spinal cord involving a smal
of the future ventral horn and part of the mesenchymal (mesodermal) syncyti
side the external limiting membrane of the cord. B, later stage of ventral root (pe
axone with myelin droplets adhering to it and fibrillated stroma surrounding it.
in which myelin droplets, supported by fibrils of stroma, have increased and accu
to form a practically continuous myelin or medullary sheath. D, final stage with
lary sheath of even thickness, showing a node, and showing a neurilemma, sheath
and fibrous framework of the myelin ('neurokeratin') derived from the fibrils of the
stroma.



them and from condensations of such fibrils are derived the fibrous sheaths of the s
sheath nuclei being acquired from the adjacent nuclei of the original syncytium. The
become more dense or pronounced as the axones extend and the fibrous tissue inc
growth, but there are always present fine marginal fibrils by which the sheaths gra
looser fibrous tissue about them. It is generally believed that the tissue giving ri
axone sheaths is of mesodermal origin. However, in amphibian larvæ, Harrison has
some sheath nuclei at least are derived from the nuclei of the ectodermal syncyt
ganglion crest, and Neal has noted in elasmobranchs the fact that nuclei migrate fro
tral wall of the neural tube along with the axones growing out to form the ventral r
spinal nerves. Whether all or any of these nuclei are originally ectodermal, and, if s
such ectodermal tissue gives rise to all axone sheaths, especially in the higher a
questionable contentions.

Axones possessing only fibrous sheaths comprise the *non-medullated nerve-fi*
majority of the sympathetic fibers are of this variety, and Ranson has found num
medullated fibers present in the spinal and cranial nerves and spinal cord. The
accepted form of non-medullated sympathetic fibers may be seen in fig. 652, C.

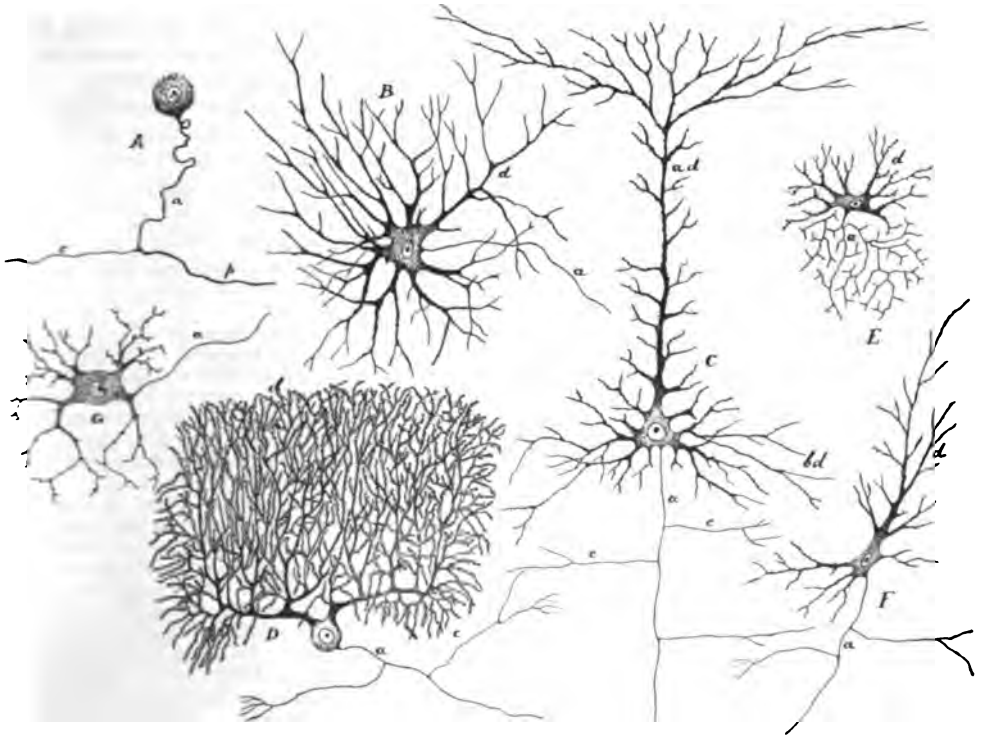
Medullated fibers are those which possess an investing coat of fat or myelin in
the fibrous sheath. Most of the fibers in the central nervous system and most of th
ing to the craniospinal nerves proper acquire myelin sheaths. Myelin begins to a
axones shortly after the beginning development in the syncytium of the fibrils of
connective tissue, and thus after the beginnings of what will become the fibrous she
fibrous portions of the sheaths in the central nervous system develop less rapidly
more scant than those of the medullated fibers of the peripheral nerves. Probab
of this, it has been claimed that myelin begins to appear on the axones of the cen
before the appearance of the fibrous sheath. In man, the first appearance of myeli

about the fourth month, but myelinization is not completed till after birth. The craniospinal nerves contain completely medullated fibers before the central system does.

Myelin first appears as small droplets adhering to the axone at irregular intervals. These droplets increase in size and number and gradually accumulate to form a practically continuous sheath of fat immediately investing the axone. They probably result from the coalescence of finer droplets floating in the surrounding fibrillated stroma. However, collecting upon the axone, the myelin retains the form of an emulsion, and as it increases in amount it incloses the adjacent fibrils which serve as a framework supporting the droplets of the emulsion in its meshes. Thus supported, the increasing myelin does not inclose the adjacent nuclei and endoplasm of the original syncytium. Probably because of the fibrous support of the myelin thus obtained, medullating fibers may be often seen presenting the beaded appearance shown in fig. 646, C, instead of an even distribution of the emulsion after it has become continuous along the axone. The 'beads' probably represent the uneven beginning of the accumulation indicated in B

FIG. 647.—SHOWING SOME OF THE VARIETIES OF THE CELL-BODIES OF THE NEURONES OF THE HUMAN NERVOUS SYSTEM, INCLUDING THE DENDRITES AND SMALL PORTIONS OF THE AXONES. AXONE SHEATHS NOT INCLUDED.

A. From spinal ganglion. *B*. From ventral horn of spinal cord. *C*. Pyramidal cell from cerebral cortex. *D*. Purkinje cell from cerebellar cortex. *E*. Golgi cell of type II from spinal cord. *F*. Fusiform cell from cerebral cortex. *G*. Sympathetic ganglion cell. *a*, axone; *d*, dendrites; *c*, collateral branches; *ad*, apical dendrites; *bd*, basal dendrites; *p*, peripheral process.



of this figure. Increasing further, the myelin becomes a cylinder of even thickness, the adjacent nuclei being pressed away against its surface and the adjacent fibrils also condensed upon it. Thus, there is good reason to believe that the fibrous portion of the sheath, the *primitive sheath* or *neurilemma*, of the medullated axone arises as a condensation of the fibrils of the surrounding stroma during development, that the sheath cells represent certain of the nearest nuclei incorporated from the original syncytium, and that the so-called *neurokeratin* of the myelin represents the fibrous framework of the myelin inclosed by it during its accumulation upon the axone. The theory that the myelin arises as a differentiated portion of the axone and the theory that it is formed by the neurilemma have been advanced. That it is accumulated from the immediately surrounding fluid of the stroma and adheres to the axone, added droplets coalescing there, in preference to other tissue elements because of some physical or chemical peculiarity of the axone, is more probably correct.

As the medullary sheath approaches completeness, constrictions may be observed at more or less regular intervals at which the myelin emulsion is absent. These are the *nodes of Ranvier*. The process by which they arise is not clearly understood. While the fiber is growing in length, new myelin is added at the nodes. The internodal segments of the sheath increase in length with age, and each segment may possess from one to several sheath nuclei.

In adolescence, fibers whose medullary sheaths are in various stages of completeness may be found both in nerve bundles in the central system and in the craniospinal nerves, and in

both, the sheaths of some axones certainly never acquire myelin. Also, in the adult, fibers whose medullary sheaths present the beaded appearance may be observed, probably representing cases of arrested accumulation of myelin. According to Westphal there is a slight increase in the thickness of the sheath with age. Larger axones acquire thicker sheaths of myelin than smaller ones. For the craniospinal fibers, in transverse sections, the area of the section of the medullary sheath averages equal to the area of the section of the axone (Donaldson and Hoke.) Some fibers of the sympathetic system are medullated but in such the myelin sheath is relatively thinner than in the craniospinal system. Beaded sheaths are frequent in sympathetic rami, though non-medullated fibers are most abundant.

FUNDAMENTALS OF CONSTRUCTION

The functionally mature nervous system consists of peculiarly differentiated essential cell elements held in place by two forms of supporting tissue and supplied with abundant blood-vessels.

The nervous element is distinguished from all other units of the structure of organs in that its cell-body gives off outgrowths or processes of peculiarly great length and characteristic form. Knowledge of the possible lengths and complexity of these processes is comparatively recent and, to include them together with their parent cell-body, which has long been known as the *nerve-cell*, the term neurone is used. The **neurone**, therefore, may be defined as the nerve cell-body with all its processes, however numerous and far reaching they may be. As a class of tissue elements, all neurones possess characteristics distinguishing them from other tissue elements, but the varieties within this class vary greatly. They vary in form both according to function and according to their locality in the nervous system. They vary in different animals, those in the higher animals being more complex in form. Fig. 647 gives illustrations of the external form of the cell-body of a few of the types found in the human nervous system.

The cell-body of the neurone gives off two general types of processes, dendrites and axone:

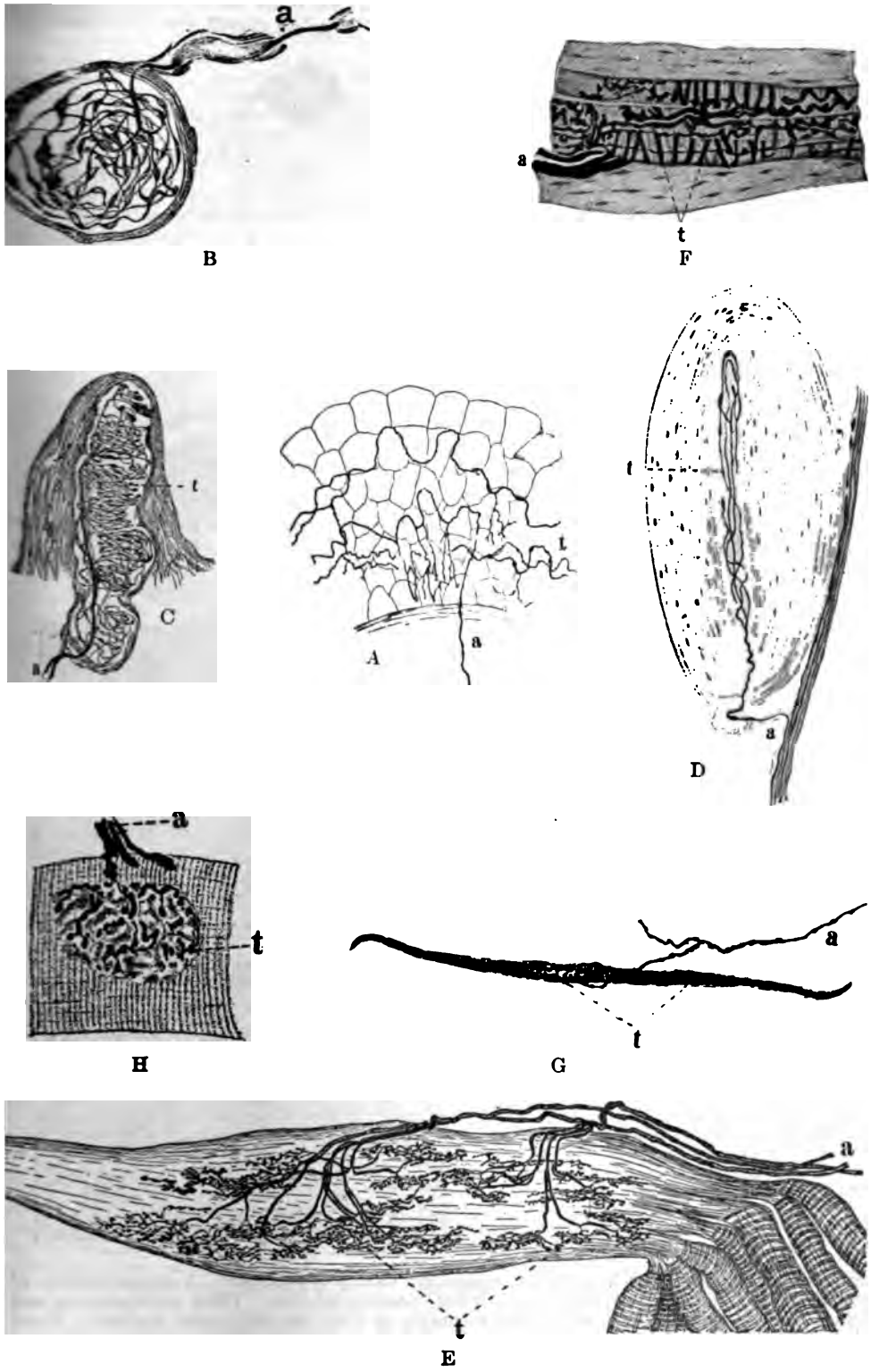
(1) The dendritic processes or **dendrites.** These are the more numerous, the shorter, and the more frequently branching processes. They branch dichotomously and with rapid decrease in diameter as they branch. They serve to increase the absorbing surface of the cell-body for purposes of nutrition. Nerve impulses transmitted to the neurone are received by them and, therefore, they also serve to increase the recipient surface of the neurone. They never acquire medullary sheaths. Since they convey impulses toward the cell-body, they are known as *cellipital processes.* Their absorbing and receptive surfaces are further increased by the presence of thickly placed, very minute projections known as 'pin-head processes' or *gemmules.*

(2) The **axone** (neuraxis). Each neurone possesses properly but one of these processes. It arises from the cell-body more abruptly and quickly becomes smaller in diameter than are most dendrites before the latter decrease by branching. It is the longest process, in most cases very much longer than dendrites. Computation shows that some axones may contain nearly 200 times the volume of the parent cell-body of the neurone. Occasionally the axone gives off a few small branches near the cell-body. These are known as *collaterals* and are given off at practically right angles instead of dichotomously. Regardless of its branching, the axone maintains a practically uniform diameter throughout its long course. Its usual nervous function is to convey the impulses away from the cell-body, either to transmit them to the other neurones by contact upon their dendrites or cell-body proper, or to appropriate elements of the other tissue systems of the body. Thus the axones are the *cellifugal processes.* There is one well-known partial exception to this, namely, a part of the axone of the spinal ganglion type of neurone, the peripheral sensory neurone. The axone of this bifurcates a short distance from the cell-body into a peripheral and a central branch. See fig. 647, A, and fig. 653. The peripheral branch collects sensory impulses from the tissues of the body, the skin, etc., and, in conveying them to the central system, must necessarily convey them toward the cell-body as far as the point of bifurcation. Thence the impulse goes on in the central branch, still toward the central system but now, in conformity, away from the cell-body of the neurone. While the continued vitality of the axone is dependent upon the cell-body, in the peculiar case of the spinal ganglion neurone the impulse does not necessarily pass through the cell-body. Experiments with the lower animals have shown that the impulses pass in the fiber from the peripheral tissues to the central system when the cell-body has been cut away.

Terminations of axones.—At its final termination, well beyond its collateral branches and usually a considerable length from its cell-body, the axone practically always divides into two or more *terminal branches*, and each of these breaks up, now dichotomously, into numerous terminal twigs. These terminal twigs are known as *telodendria.* Telodendria vary in number and character of form according to the tissues in and upon which they terminate. Functionally, they are of three classes: Those terminating upon and in the other (peripheral) tissues of the body are either (1) *sensory* or (2) *motor.* In order to transmit impulses from one neurone to another, telodendria of the axone of one neurone are placed in contact with the dendrites or cell-body of another neurone forming (3) *synapses.* Upon approaching its termination, every axone loses its sheath, its telodendria being necessarily bare.

FIG. 648.—SHOWING SOME VARIETIES OF PERIPHERAL TERMINATIONS OF AXONES.

A. 'Free termination' in epithelium (after Retzius). B. Krause's corpuscle from conjunctiva (after Dogiel). C. Meissner's corpuscle from skin (after Dogiel). D. Pacinian corpuscle (after Dogiel). E. Termination upon tendon sheath (Huber and DeWitt). F. Neuromuscular spindle (after Ruffini). G. Motor termination upon smooth muscle-fiber. H. Motor 'end-plate' on skeletal muscle fiber (after Böhm and von Davidoff). a, axone; t, telodendria.



Sensory or afferent axones, receiving impulses from the skin or other epithelial surfa
break up into very numerous telodendria each of which terminates directly upon the sur
of the epithelial cell, such as the cells of the germinative (Malpigian) layer of the ski
those of its basal or columnar layer. Such telodendria are known as *free terminations*.

FIG. 649.—SCHEMES SHOWING TWO FORMS OF SYNAPSES OR THE TERMINATION OF AXONES
CELL-BODIES OF OTHER NEURONES.

A. In ventral horn of spinal cord. B. In spinal ganglia.

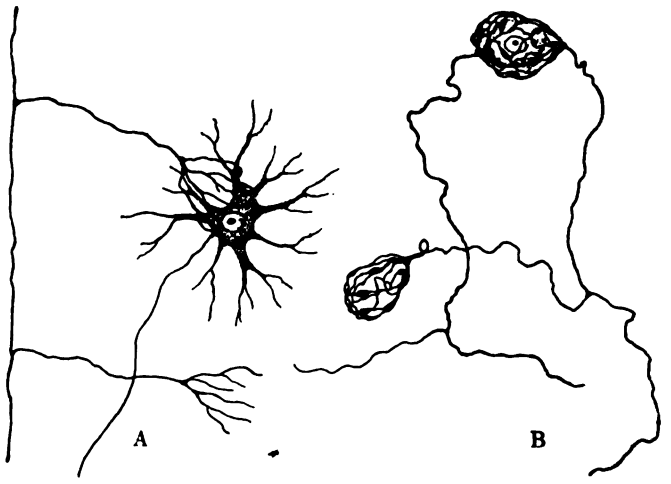
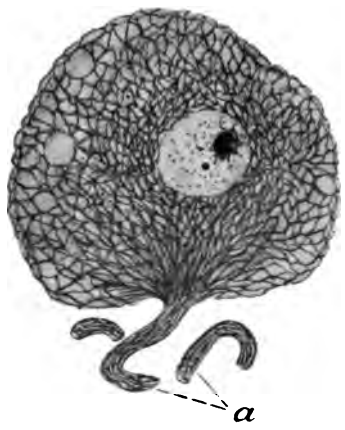
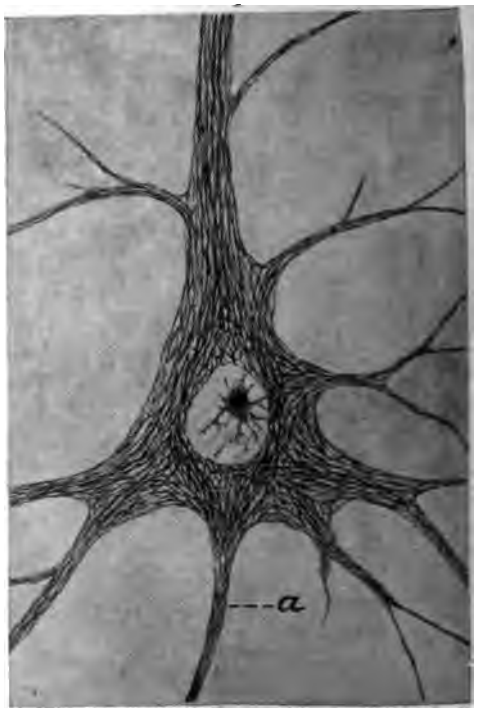


FIG. 650.—TWO GENERAL TYPES OF ARRANGEMENT OF NEUROFIBRILLÆ IN THE CELL-BODIES OF NEURONES.

A, cell-body of spinal-ganglion neurone. B, selected 'giant pyramidal cell' from cerebra cortex,' human. a, axone.



A



B

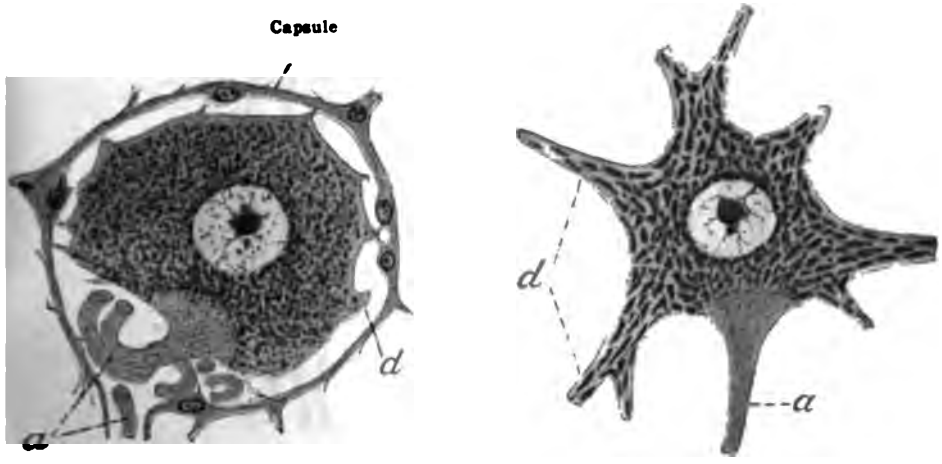
terminations are also to be found in the connective tissues of the body. A second variety of peripheral termination of afferent axones is the *encapsulated form*. These are known as 'end organs' and 'corpuscles' and are named according to their complexity and position. Three of the different forms of them are shown in fig. 648, B, C, and D. These are always situated n fibrous connective tissue from which their capsules are derived. Their most elaborate form

lamellated or Pacinian corpuscle. Besides the motor axones terminating upon the of voluntary or skeletal muscle, sensory impulses are carried from this tissue and one of forms of telodendria for this purpose terminates upon the muscle-fiber. This is known as 'neuromuscular spindle.' In it, the axone penetrates the sarcolemma and breaks into dendria which coil spirally about the muscle-fiber. The most extensive and eleborate form sensory telodendria are those which spread out in plate-form upon tendons sheaths.

Motor peripheral axones terminate upon muscle and upon the secretory cells of glands secretory axones). The motor craniospinal axones terminate upon skeletal (voluntary) muscle- ers and upon the cell-bodies of sympathetic neurones, the axones of which latter terminate son cardiac muscle, smooth muscle-fibers, and (secretory) in glands. Upon skeletal muscle, e terminal branch of the axone loses its sheath and breaks up into numerous telodendria which mselves branch and show very evident, irregular varicosities, the whole of which spread out plate-form, and lie in contact with the substance of the muscle-fiber. In man and all mam- ls, the area covered is usually somewhat oval and is marked by a granular differentiation of muscle substance. This with the telodendria is known as a *motor end-plate*. The teloden- ia of sympathetic axones ending upon cardiac and smooth muscle-fibers are fewer and simpler an those of craniospinal axones upon skeletal muscle. They consist of a few fine fibrils, with

IG. 651.—DRAWINGS ILLUSTRATING THE ABUNDANCE AND GENERAL ARRANGEMENT OF THE TIGROID MASSES IN CELL-BODIES OF NEURONES IN RESTING CONDITION.

cell-body from spinal ganglion. B, large cell-body from ventral horn of spinal cord. a, axone. d, dendrites.



A B

very small varicosities along them and at their ultimate terminations, which run longitudinally along the muscle-fiber in close relation with its substance. Those upon gland-cells are similar in character except that they often form a loose pericellular plexus about and upon the cell. The varicosities of telodendria are sometimes called *end-feet* and closer study of them has shown that they themselves consist of fine plexuses of the neurofibrils described below as contained in the cell-body of the neurone and extending throughout all its processes. Boek has found that a sympathetic axone may sometimes accompany a craniospinal axone to an end-plate on a skeletal muscle-fiber.

Synapses.—Every functionally complete nerve pathway consists of two or more neurones arranged in series, a *neurone chain*. Very often, the series consists of many more than two, the impulses being transmitted from neurone to neurone. The axone, bearing the impulse away from the cell-body of one neurone, gives off terminal branches, each of which loses its sheath and breaks up into telodendria which twine themselves upon the dendrites or cell-body of another neurone. The impulse is transferred from one neurone to another by means of contact rather than by direct anatomical continuity of the parts of the two neurones. Such terminations of axones are known as synapses.

In the terminal arrangement of the telodendria, synapses assume forms varying from compact '*pericellular baskets*' and '*climbing fibers*' to the more open arborizations composed of fewer twigs in simpler arrangements, '*end-brushes*.' In case of the spinal ganglion type of neurone, the cell-body of the majority of which has no dendritic processes, the telodendria of the visiting axone form an anastomosing pericellular plexus inclosing the entire cell-body. This and the simple end-brush form of synapses are illustrated in fig. 649. It should be mentioned that, contrary to the general belief that impulses are transmitted by simple contact of the neurones in the series, it has been claimed that the ultimate twigs of the telodendria frequently penetrate the substance of the receiving cell-body and are fused in continuity. If during the processes of growth this becomes true, instead of being an appearance produced by the technique employed, it is better considered as merely an exception to the general rule.

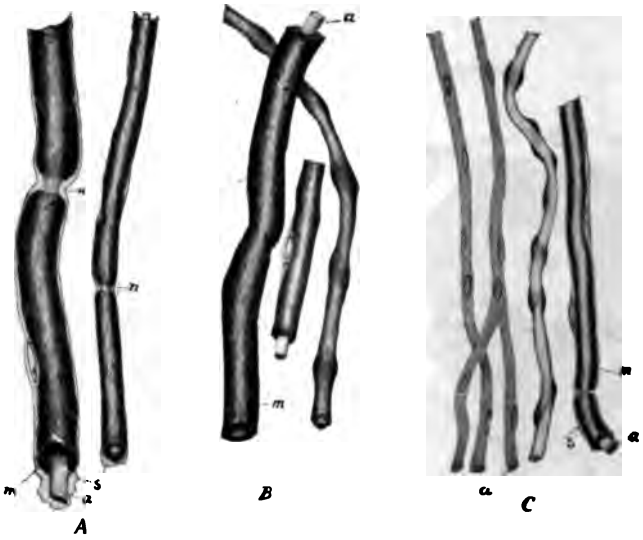
Internal structure of the neurone.—The cell-body of the neurone consists of a large, spherical, vesicular nucleus and a cytoplasm continuous into its axone and dendritic outgrowths. Its nucleus is further characterized by having most usually but one nucleolus, large, spherical and

densely staining, situated in a karyoplasm containing otherwise a remarkably small an chromatin. Of the cytoplasm, the two most interesting structures are its fibrillar and i ular components.

The **fibrillar structure**, known as the *neurofibrillæ*, represents a growth and elabor the spongioplasmic reticulum of the original embryonal cell. The filaments increase i ness during the development of the neurone, and, in the sending out of its processes, the of the original reticulum become so drawn out in the processes as to give the appear more or less parallel arrangement of threads. The reticular or net-like arrangement is more nearly retained in the cytoplasm immediately about the nucleus, since here the the outgrowing processes is less directly applied. In the cell-body of the spinal gangli of neurone, when no dendrites are given off, the net-like arrangement is apparent throug cytoplasm except in that region giving rise to the axone. On the other hand, in the ty called 'pyramidal cell' of the cerebral cortex, from which two chief processes, the axone apical dendrite, are given off from opposite poles, the more reticular arrangements at nucleus if often practically obliterated by the opposing growth stress.

FIG. 652.—SHOWING PIECES OF AXONES.

A. From a craniospinal nerve. *B*. From the spinal cord. *C*. From the sympathe axones; *m*, medullary sheath; *n*, node of Ranvier; *s*, neurilemma or sheath of Schwa occasional sheath-nuclei.



So manifest does the parallel appearance of the neurofibrillæ in the processes oft that it has been interpreted as a series of individual and independent fibrils. In the i of gold chloride and similar methods to the neurones of lower forms, the reduced reage precipitated upon the fibrils in parallel, seemingly independent lines. And, assum istence of independent fibrils, it has been contended that the neurone is not the func of the nervous system but is itself composed of numerous functional units, indivi each for the conduction of nerve impulses. More recent and trustworthy method show that the neurofibrillæ retain their original reticular form, the threads anast all planes, and that the meshes of the net may, in the processes, be so drawn in o that a parallel appearance predominates. Further, it is now held that the neuropl more fluid substance in which the fibrils lie throughout, is capable, and probably i able, of conducting impulses as the fibrils.

Of the **granules** in the cytoplasm, the most interesting are those first described Nissl. These are the most abundant of those in the cell-body and are known as tig or *Nissl bodies*. They consist of numerous basophilic granules collected into clump of varying size. They are known to disappear during fatigue of the nervous system a more abundant in animals after a period of rest. They are distributed throughou plasm of the cell-body with the interesting exception that they are not found in the i the immediate vicinity of its place of origin from the cytoplasm, leaving a free regio the *axone hillock*. As accumulated masses, they show characteristic shapes and a which are interpreted as signifying the shapes and arrangement of the spaces or n occupy in the reticulum of the neurofibrillæ. In cell-bodies of the varieties found in horns of the spinal cord or in the cerebral and cerebellar cortex, for example, the mas immediately about the nucleus are smaller, more numerous and of irregular shape. in the beginnings of the dendrites, they are larger and mostly of fusiform or diam Farther out in the dendrites, they become more and more thin and attenuated; and tant reaches of the dendrites they are invisible or absent. In the cell-body of the spir they are of irregular shape, smaller and more numerous throughout the cytoplasm, be smaller and more thickly placed in the immediate vicinity of the nucleus. In a several hours postmortem, they appear in fewer and larger masses and it was in thi

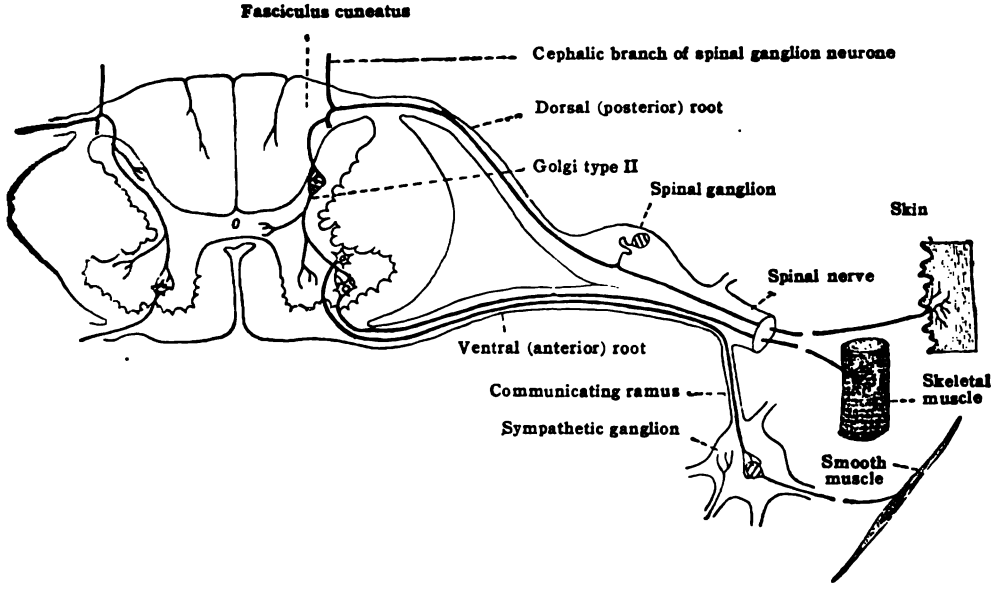
Nissl originally described them in man. Closely examined, the masses of all sizes are found to be accumulations of finer granules. Functionally they are supposed to be of nutritive significance, substances in unstable chemical equilibrium, energy stored in the cytoplasm, capable in need of being split into simpler forms usable in the activities of the neurone. The fact that tigroid masses are absent from the axone hillock, the axone, and the distant reaches of the dendrites may signify that the substance is chiefly present here only in the split and usable form. So, in the axone especially, the neurofibrillæ are so closely arranged that the meshes of their net here are too small to contain masses of appreciable size. Close examination of the axone hillock and longitudinal sections of the axone in deeply stained preparations usually shows a few very minute basophilic granules.

A second form of granules described for the neurone is that included within the name, *mitochondria*. These granules are chemically different from the tigroid masses and are thought to be present in all protoplasm, animal and plant. They are considered composed of a phosphatid, lecithin combined with a small amount of albumin, and, like tigroid masses, to represent a form of stored energy.

Pigment-granules are also found in nerve cells, probably representing an insoluble form of the waste products of the cell metabolism.

Sheaths of the Axone.—The great majority of axones acquire sheaths about them which isolate and protect them in their course through other tissues or in company with other axones.

FIG. 653.—DIAGRAM OF TRANSVERSE SECTION OF SPINAL CORD WITH ROOTS OF SPINAL NERVE AND NEIGHBORING GANGLIA ATTACHED, ILLUSTRATING SIMPLEST FORMS OF NEURONE CHAINS.



A *nerve-fiber* is an axone together with its sheaths. In transverse sections, the axone comprises the central portion of the nerve-fiber or its so-called 'axis-cylinder.' It is of course the essential portion of the fiber. As noted above in describing their development, nerve-fibers are classified according to the character of the sheaths. Those which possess sheaths of myelin, a peculiar form of fat, are known as *medullated fibers*, and those in which the sheaths are merely membranes of condensed fibrous tissue, void of myelin, are *non-medullated fibers*. A medullated fiber also possesses a fibrous membrane outside its myelin sheath, known as the *neurilemma* or sheath of Schwann. The neurilemma is of the same origin and general structure as the sheath of the non-medullated fiber, and both possess nuclei scattered along them. Medullated fibers, at more or less regular intervals, show constrictions at which the myelin sheath ceases, but over which the neurilemma continues. These constrictions are the *nodes of Ranvier*. The myelin is in the form of an emulsion, whose fat droplets are supported in a fine fibrous reticulum (neurokeratin), while the neurilemma without serves to hold it in place. The neurilemma possesses from one to three or four sheath-nuclei between adjacent nodes of Ranvier.

There is no sharp line of separation between medullated and non-medullated fibers, for in any division of the nervous system there may be found axones in all degrees of medullation. Most of the fibers belonging to the sympathetic system (processes of sympathetic neurones) are non-medullated, but both partially medullated and completely medullated sympathetic fibers may be found. (See fig. 652.) The myelin sheaths of completely medullated sympathetic fibers are always thinner and less well developed than those of medullated craniospinal fibers. Most of the fibers belonging to the craniospinal nerves and to the central nervous system are medullated, but among the fibers belonging to either there are to be found numerous non-medullated fibers. As indicated in fig. 652, nodes of Ranvier are absent in the medullated fibers of the central system.

In all the higher vertebrates, the myelin sheath always begins on the axone a short distance from its parent cell-body. The neurilemma of the medullated and the fibrous membrane of the non-medullated fiber are each faintly continuous with the fibrous connective tissue sur-

rounding it, and, in the craniospinal and sympathetic ganglia, in which each cell-body of the neurone has a fibrous capsule about it, the fibrous membrane or the neurilemma, as the case may be, is directly continuous into the capsule of the cell-body. Upon approaching its final termination, in other tissues or upon the dendrites or cell-body of other neurones, the nerve-fiber always loses its sheath, the telodendria of the axone always being bare when placed in contact with the other element. In losing the sheath, the myelin sheath, if present, always ceases and the fibrous membrane becomes continuous with the tissue investing the receiving element, whether the capsule of the ganglion cell, the sarcolemma of the skeletal muscle fiber, the corium of the skin, or the connective tissue capsule of the encapsulated terminal corpuscle.

The **connective tissue** of the nervous system is of two main varieties—*white fibrous connective tissue* and *neuroglia*. White fibrous tissue alone supports and binds together the peripheral system, and it is the chief supporting tissue of the central system. As connective tissues, these two varieties are quite similar in structure, each consisting of fine fibrillæ, either dispersed or in bundles, among which are distributed the nuclei of the parent syncytium. In both tissues nuclei are frequently found possessing varying amounts of cytoplasm which has not yet been transformed into the essential fibrils.

In addition to its enveloping membranes, the three meninges, which are of white fibrous tissue, the white fibrous tissue supporting the central system within is quite abundant. It is all sent in from without, either as ingrowths of the developing pia mater, the most proximal of the membranes, or is carried in with the blood-vessels, of the walls of which it is an abundant component. Pratically, the neuroglia as a connective tissue proper differs from white fibrous tissue only in origin and in its chemical or staining properties. Based upon the latter, there are methods of technique by which the two may be distinguished. The epithelioid lining the central canal of the spinal cord and the ventricles of the encephalon, with which the canal is continuous, is the remains of the mother tissue of the neuroglia, and in the adult is the only vestige representing its origin. The cells of this lining are known as *ependymal cells*, and they are usually classed as a variety of neuroglia.

Axones, with their medullated or non-medullated sheaths (nerve-fibers) comprise all nerves in the periphery and all nerve tracts in the central system.

White substance [substantia alba] ('white matter') consists of a portion of nervous tissue in which medullated fibers predominate. The myelin sheaths, being in the form of a fat emulsion, reflect the entire spectrum and thus appear white.

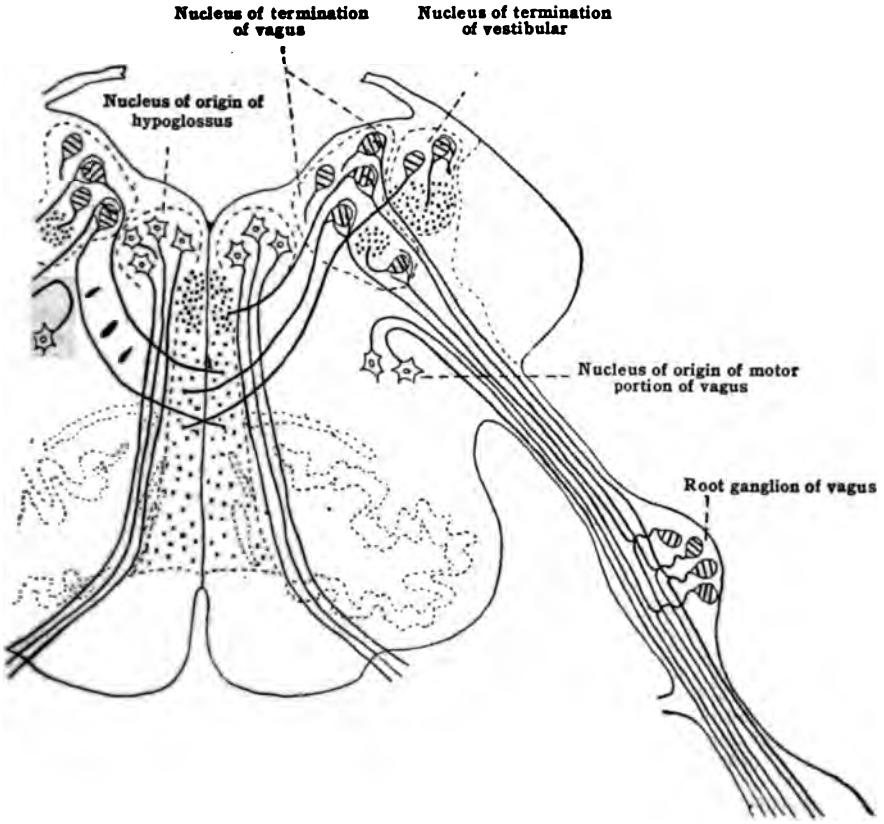
Gray substance [substantia grisea] ('gray matter') is an aggregation of nervous tissue in which medullated axones do not predominate. Thus sympathetic ganglia and sympathetic nerves may be gray, though the term is usually applied to gray portions of the central system, such as the cerebral cortex, the central gray column of the spinal cord, etc. Such gray regions contain more cell-bodies of neurones than other regions, though at least half of their volume may consist of neuroglia, white fibrous connective tissue, blood-vessels, and axones of both varieties.

Neurone chains.—As noted above, the numerous neurones comprising the nervous system are functionally and anatomically related to all the other tissues of the body and to each other. A functionally complete *nerve pathway* extends from the tissue in which the nerve impulse is aroused to the tissue in which a resultant reaction occurs. It is known that the simplest possible of such paths necessarily comprises at least two neurones. The great majority involve a greater number. The axone of one neurone bearing impulses from the peripheral tissue transfers the impulses to the dendrites or cell-body of another by synapsis, and the axone of this, in the same way, transfers them to another and so on till the final neurone receives the impulses and the telodendria of its axone transfer the impulse to the tissue element which reacts in response to the stimulus brought. Neurones are thus linked together in chains. A neurone chain may be defined, therefore, as a number of neurones associated with each other in series to form a functionally complete nerve pathway. Examples of the simplest forms of neurone chains as contained in the spinal cord are illustrated in fig. 653. An impulse aroused in the skin is borne by the spinal ganglion neurone to the spinal cord where, in the left half of the figure, telodendria of one of the terminal branches of its axone form synapses with a neurone in the ventral horn, and the axone of this bears the impulse out of the spinal cord to transmit it probably direct to skeletal muscle. This arrangement involves but two neurones and is supposed to be relatively rare. In the right half of the figure, a third neurone is seen interposed. This is a neurone, numerous in gray substance everywhere, whose axone is relatively short and branches frequently, making possible several synapses in the near neighborhood of its parent cell-body. Its type is referred to as the *Golgi neurone of type II*. This interposed, gives a chain of three neurones between the origin of the impulse in the periphery and the contraction of muscle in response. Simple chains like these can result only in reflex activities and such chains are often called *reflex arcs*. Another chain is indicated in the figure in which the reflex action involves involuntary or smooth muscle. This must involve at least one sympathetic neurone, and, should the Golgi neurone of type II form synapses with the ventral horn neurone involved, a chain composed of four neurones results. In the more extensive and complex neurone chains, such as those in which the impulse from the skin, as above, ascends to the cerebral cortex and the resultant muscular contraction is thrown under cerebral control, each of the several neurones or links in the series is not only referred to by name according to the position of its cell-body, but each is often called according to its order in the series, as 'neurone of first order,' 'second order,' 'third order,' etc.

A given axone may break into a considerable number of branches each of which forms apses with a different second neurone, or, if peripheral, the telodendria of each branch may minate upon a separate peripheral tissue element. Thus, a given impulse aroused in a pheral tissue element may be transmitted to an ever increasing number of neurones, and initial neurone may comprise the first link in a number of neurone chains. Such is quite eral in the structural plan of the nervous system throughout. It is thought possible to sider each neurone interposed in a chain as a separate source of energy, a sort of relay the nerve path; that the impulse passing through the axone is gradually weakened in overing resistance, but, when transferred to another neurone, it incites a splitting into usable n of the substance represented by the tigroid masses and mitochondria and thus a liberation nergy or a reinforcement of the impulse. Further, thus is made possible the economy of neurone serving as a link in a number of neurone chains.

The axones (nerve-fibers) taking part in the various neurone chains course in bundles of ying size, the larger of which have names. And there is a general tendency with axones of same function, the same functional direction and the same origin to course in company with

FIG. 654.—DIAGRAM OF TRANSVERSE SECTION OF MEDULLA OBLONGATA, ILLUSTRATING NUCLEI OF TERMINATION AND NUCLEI OF ORIGIN.


Nucleus of termination of vagus
Nucleus of termination of vestibular
Nucleus of origin of hypoglossus
Nucleus of origin of motor portion of vagus
Root ganglion of vagus

another. A fiber bearing impulses from the peripheral tissues to the central system is an *ent fiber* or sensory fiber. A fiber bearing impulses out of the central system to peripheral is an *efferent fiber* or motor fiber. Efferent fibers which bear impulses to skeletal muscle known as *somatic efferent fibers*, while those which terminate upon the cell-bodies of sympaic neurones and thus bear impulses destined for smooth muscle, cardiac muscle and glands retory) are *visceral* or *splanchnic efferent fibers*.

A nerve is a closely associated aggregation of parallel nerve-fibers coursing in the *periphery*. ay be spinal, cranial or sympathetic according to its attachment or according to the origin e majority of its fibers. It may contain several functional and structural varieties of fibers. spinal nerves contain all structural varieties. Nerve-roots are those bundles of fibers which to form a nerve. Most of the cranial nerves have but one root. Nerve-roots, in their turn, formed by the junction of smaller *root-filaments*. *Nerve-branches* result from the division he nerve, the separation of its component fibers into separate bundles. Some branches of sufficient size and significance to be called nerves and given separate names. The ller branches are called *rami*, twigs, etc.

In the *central system*, a given bundle of fibers of similar origin and functional direction is called sciculus, while two or more adjacent fasciculi coursing parallel with each other, but often of erent origin and functional directions, comprise a funiculus, a bundle of bundles. The cennervous system is bilaterally symmetrical throughout its length. A bundle of fibers arising n cell-bodies situated on one side and crossing the mid-line transversely to terminate in

the opposite side is a **commissure.** The commissures vary greatly in size and contain fibers crossing in both directions. Scattered fibers which cross the mid-line are *commissural fibers.* Fibers of varying length, arising from cell-bodies situated in one locality of the central system, which do not cross the mid-line, but terminate in other localities of the same side, above and below the level of their origin or in a different region of the same level, form **association fasciculi.** The shortest association fasciculi, not extending beyond the bounds of a given division of the central system, are known as **fasciculi proprii.** When bundles of the same origin, functional direction and significance, running one on either side of the mid-line, cross the mid-line they are said to decussate and the crossing is known as a **decussation.** In the decussations, the direction of the crossing is oblique rather than transverse.

The cell-bodies of neurones whose axones go to form certain nerve roots, fasciculi and certain commissures show a tendency to accumulation in localized masses. In the *peripheral system,* such an accumulation of cell-bodies is known as a **ganglion;** in the *central system* such is distinguished as a **nucleus.** Thus, there are the *sympathetic ganglia* which give rise to sympathetic nerves and sympathetic roots of nerves; and on the beginning of each spinal nerve there is a *spinal ganglion* which gives rise to the afferent fibers of its dorsal root and in its nerve trunk. There are *ganglia on* the *cranial nerves* which give rise to the afferent or sensory axones in them and which are of the same significance as the spinal ganglia. Every ganglion, therefore, has connected with it bundles of nerve-fibers. Some of these fibers bear impulses from neighboring ganglia or from the tissues of the neighboring organs and transmit them to the cell-bodies of the ganglion; others arise from the cell-bodies in the ganglion and bear impulses to the central system or, in case of the sympathetic, to the tissues of the peripheral organs. Necessarily, the larger the ganglion, the larger will be the bundles of fibers connected with it.

Nuclei may be considered in two general classes: (1) Recipient nuclei or nuclei of termination, and (2) Nuclei of origin. (See fig. 654.)

A nucleus of termination is an accumulation of cell-bodies in which the axones of a given fasciculus or of a nerve-root terminate, that is, cell-bodies which, by synapses, receive the impulses borne by the terminating axones. In most cases the impulses transferred to a nucleus so named are sensory in character. The nucleus may be considered as a defined region in which neurones of the next order are interpolated in a given nerve pathway or system of neurone chains. Fasciculi in the spinal cord which bear impulses to the cerebrum have their nuclei of termination in the medulla oblongata, and the sensory or afferent axones of the cranial nerves find their nuclei of termination upon entering the central system.

A nucleus of origin is an accumulation of cell-bodies of neurones which give origin to the axones going to form a given nerve-root or a fasciculus. Strictly speaking, a nucleus of termination for one nerve-tract is the nucleus of origin for another, the next link in the neurone chain. However, the term is commonly used to distinguish a group of cell-bodies giving rise to a motor nerve tract. Thus each motor cranial nerve has its nucleus of origin within the central system. The central gray substance of the spinal cord is in the form of a column continuous throughout the length of the cord and so the cell-bodies in the ventral horns of this column which give rise to the motor or efferent roots of the spinal nerves are not considered as grouped into nuclei of origin, one for each of the motor roots.

The **dorsal root** of each spinal nerve is afferent or sensory in function and its axones arise as processes of cell-bodies comprising the spinal ganglion of the nerve. The afferent or sensory fibers of the cranial nerves arise as processes of cell-bodies comprising the ganglia of the cranial nerves, which ganglia are, in development and character, with the exception of the optic, exactly homologous to the spinal ganglia.

The **ventral root** of each spinal nerve is efferent or motor in function and its fibers arise as processes of cell-bodies situated in the ventral horn of the gray substance of the spinal cord. The efferent or motor fibers of the cranial nerves arise as processes of cell-bodies accumulated as nuclei of origin in the gray substance of the encephalon, and homologous with those cell-bodies of the ventral horns of the spinal cord which give origin to the ventral-root fibers.

The general relation of the cerebrum (which includes the mesencephalon) to the remainder of the nervous system is a *crossed relation.* Neurone-chains from the general body to the cerebrum, via the spinal nerves and cord and via the cranial nerves and medulla oblongata and pons of one side, cross the mid-line to terminate in the opposite side of the cerebrum. Axones and neurone chains, arising in response in one side of the cerebrum, likewise usually decussate in descending to terminate in the respective regions of the opposite side.

Many of the names given nervous structures, prior to 1850 especially, instead of suggesting something of their functional or anatomical significance, indicate nothing more than active imaginations for accidental resemblances between the various structures of the nervous system and objects in ordinary domestic environment. Also, quite often the name given a structure is merely the name of some anatomist associated with it. The much needed elimination of these old non-descriptive names is proving a very slow process. Attempts have often increased the difficulty by making necessary the use of several names for a given structure instead of one. The most recent and concerted attempt, the nomenclature known as the BNA (anatomical names chosen by a commission appointed for the purpose which convened in Basle in 1895), has been adopted by modern text-books. It is here used in the form of the English equivalents of the Latin terms, except in cases of those Latin terms which have become so commonly used as to be considered words incorporated into the English language. The BNA has retained many of the old names and, since a name should indicate something of the locality and significance of the structure to which it is applied, it is not yet wholly satisfactory throughout. In applying the names of a few fasciculi, the BNA in the following pages is slightly modified by so compounding the name that the first word in the compound indicates the locality of origin of the faciculus and the second, the locality of its termination. Thus, '*Dorsal spinocerebellar fasciculus*' indicates the more dorsally coursing of the fasciculi which arise from cell-bodies in the spinal cord and terminate in the cerebellum. This principle applies to many of the BNA names without change, as '***lateral cerebrospinal fasciculus.***

THE CENTRAL NERVOUS SYSTEM

The central nervous system [systema nervorum centrale] or organ is an aggregation of nuclei, fasciculi and commissures—a large axis of gray and white substance—situated in the dorsal midline of the body, and the bundles of fibers connecting it with the tissues of other systems and with the peripheral ganglia are of necessity correspondingly large. So numerous are the axones connecting it and so intimately are its neurones associated that a disturbance affecting any one part of the system may extend by way of its neurone chains to influence all other parts. The enlarged cephalic extremity of this central axis, the brain or **encephalon**, is a special aggregation of nuclei and masses of gray substance, many of which are much larger than any found in the periphery.

In the study of the central nervous system its enveloping membranes or meninges are met with first, and logically should be considered first, but since a comprehensive description of these membranes involves a foreknowledge of the various structures with which they are related, it is more expedient to consider them after making a closer study of the entire system they envelop.

For convenience of study, the central nervous system is separated into the gross divisions, spinal cord and brain (encephalon) as illustrated in figure 645. Each of these divisions will be subdivided and considered with especial reference to its anatomical and functional relations to the other divisions and the interrelations of its component parts.

1. THE SPINAL CORD

The spinal cord [medulla spinalis] is the lower (caudal) and most attenuated portion of the central nervous system. It is approximately cylindrical in form and terminates conically. Its average length in the adult is 45 cm. (18 in.) in the male and 42 cm. in the female. It weighs from 26 to 28 grams or about 2 per cent. of the entire central nervous system.

After birth it grows more rapidly and for a longer period than the encephalon, increasing in weight more than sevenfold, while the brain increases less than half that amount. Its specific gravity is given as 1.038.

The line of division between the spinal cord and the medulla oblongata is arbitrary. The outer border of the foramen magnum is commonly given, or, better, a transverse line just below the decussation of the pyramids. Lying in the vertebral canal, the adult cord usually extends to the upper border of the body of the second lumbar vertebra. However, cases may be found among taller individuals in which it extends no farther than the last thoracic vertebra. With increase in stature, its actual length increases, but the extent to which it may descend the vertebral canal decreases. Up to the third month of intrauterine life it occupies the entire length of the vertebral canal, but owing to the fact that the vertebral column lengthens more rapidly and for a longer period than does the spinal cord, the latter, being attached to the brain above, soon ceases to occupy the entire canal. At birth its average extent is to the body of the third lumbar vertebra.

External Morphology of the Spinal Cord

In position in the body, the spinal cord conforms to the curvatures of the vertebral canal (fig. 645). In addition to the bony wall of the vertebral canal, it is enveloped and protected by its three membranes or meninges, which are continuous with the like membranes of the encephalon: first, the **pia mater**, which closely invests the cord and sends ingrowths into its substance, contributing to its support; second, the **arachnoid**, a loosely constructed, thin membrane, separated from the pia mater by a considerable **subarachnoid space**; third, the **dura mater**, the outermost and thickest of the membranes, separated from the arachnoid by merely a slit-like space, the **subdural space**.

The intimate association of the central system with all the peripheral organs is attained chiefly through the spinal cord, and this is accomplished by means of thirty-one pairs of spinal nerves, which are attached along its lateral aspects. The nerves of each pair are attached opposite each other at more or less equal intervals along its entire length, and in passing to the periphery they penetrate the meninges, which contribute to and are continuous with the connective tissue sheaths investing them. Each nerve is attached by two roots, an afferent or **dorsal root**, which enters the cord along its posterolateral sulcus, and an efferent or **ventral root**, which makes its exit along the ventrolateral aspect.

With its inequalities in thickness and its conical termination the spinal cord is subdivided into four parts or regions:—(1) The **cervical portion,** with eight pairs of cervical nerves; (2) the **thoracic portion,** with twelve pairs of thoracic nerves; (3) the **lumbar portion,** with five pairs of lumbar nerves; and (4) the **conus medullaris,** or sacral portion, with five pairs of sacral and one pair of coccygeal nerves. From the termination of the conus medullaris, the pia mater continues below in the subarachnoid space into the portion of the vertebral canal not occupied by the spinal cord, and forms the non-nervous, slender, thread-like terminus, the *filum terminale.* This becomes continuous with the dura mater at the lower extremity of the filum.

In the early fetus the spinal nerves pass from their attachment to the spinal cord outward through the intervertebral foramina at right angles to the long axis of the cord, but, owing to the fact that the vertebral column increases considerably in length after the spinal cord has practically ceased growing, the nerve-roots become drawn caudad from their points of attachment, and, as is necessarily the case, their respective foramina are displaced progressively downward as the termination of the cord is approached, until finally the roots of the lumbar and sacral nerves extend downward as a brush of parallel bundles considerably below the levels at which they are attached. This brush of nerve-roots is the **cauda equina.** The dura mater, being more closely related to the bony wall of the canal than to the spinal cord, extends with the vertebral column and thus envelops the cauda equina, undergoing a slightly bulbous, conical dilation which decreases rapidly and terminates in the attenuated canal of the coccyx as the coccygeal ligament [filum duræ matris spinalis].

The enlargements.—Wherever there is a greater mass of tissue to be innervated, the region of the nervous system supplying such must of necessity contain a greater number of neurones. Therefore, the regions of the spinal cord associated with the skin and musculature of the regions of the superior and inferior limbs are thicker than the regions from which the neck or trunk alone are innervated. Thus in the lower cervical region the spinal cord becomes broadened into the *cervical enlargement,* and likewise in the lumbar region occurs the *lumbar enlargement.* The spinal nerves attached to these regions are of greater size than in other regions.

The **cervical enlargement** [intumescentia cervicalis] begins with the third cervical vertebra, acquires its greatest breadth (12 to 14 mm.) opposite the lower part of the fifth cervical vertebra (attachment of the sixth cervical nerves), and extends to opposite the second thoracic vertebra. Unlike the lumbar enlargement, its lateral is noticeably greater than its dorsoventral diameter.

The **lumbar enlargement** [intumescentia lumbalis] begins gradually with the ninth or tenth thoracic vertebra, is most marked at the twelfth thoracic vertebra (attachment of the fourth lumbar nerves), and rapidly diminishes into the conus medullaris.

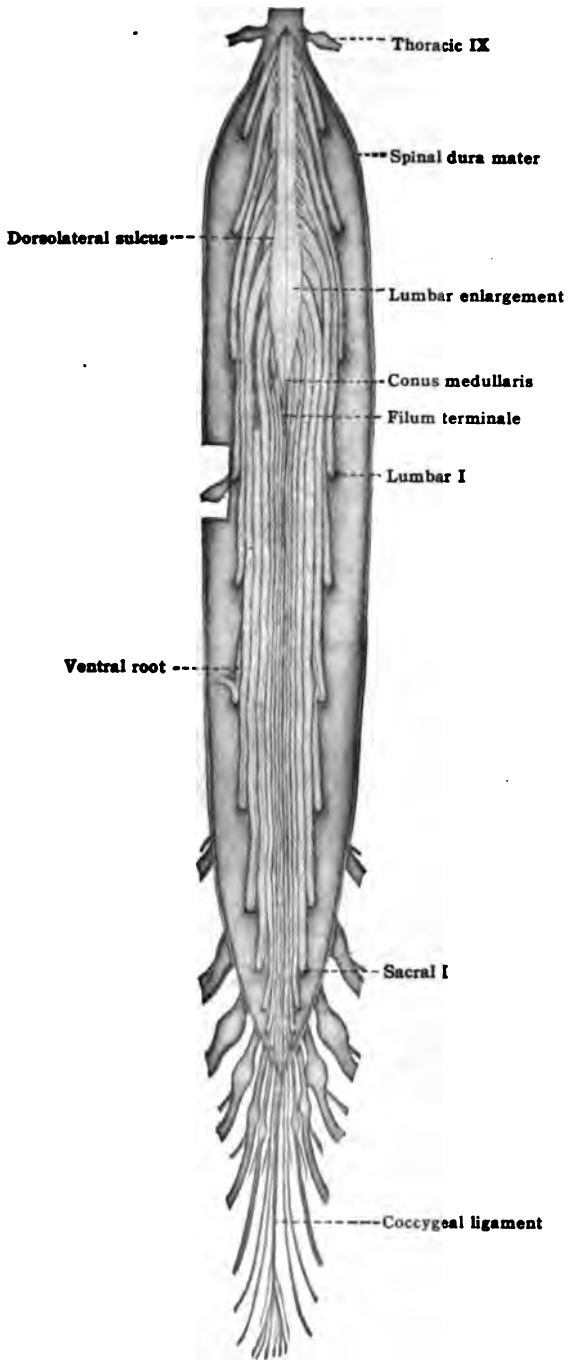
Both the lumbar and thoracic regions are practically circular in transverse section. Neither diameter of the lumbar is ever so great as the lateral diameter of the cervical enlargement. The thoracic part attains its smallest diameter opposite the fifth and sixth thoracic vertebræ (attachment of the seventh and eighth thoracic nerves).

The enlargements occur with the development of the upper and lower limbs. In the embryo they are not evident until the limbs are formed. In the orang-utan and gorilla the cervical enlargement is greatly developed; the ostrich and emu have practically none at all.

Surface of the spinal cord.—The cord is separated into nearly symmetrical right and left halves by the broad **anterior median fissure** into which the pia mater is duplicated, and opposite this, on the dorsal surface, by the **posterior median sulcus.** Along the lower two-thirds of the cord this sulcus is shallowed to little more than a line which marks the position of the posterior median septum; in the medulla oblongata it opens up and attains the character of a fissure. Each of the two lateral halves of the cord is marked off into posterior, lateral, and anterior divisions by two other longitudinal sulci. Of these, the **posterolateral sulcus** occurs as a slight groove 2 to 3½ mm. lateral from the posterior median sulcus, and is the groove in which the root filaments of the dorsal roots enter the cord in regular linear series. The ventral division is separated from the lateral by the **anterolateral sulcus.** This is an irregular, linear area rather than a sulcus. It is from 1 to 2 mm. broad, and represents the area along which the *efferent* fibers make their exit from the cord to be assembled into the respective

. This area varies in width according to the size of the nerve-roots, posterolateral sulcus, its distance from the midline varies according being greatest on the enlargements of the cord. In the cervical

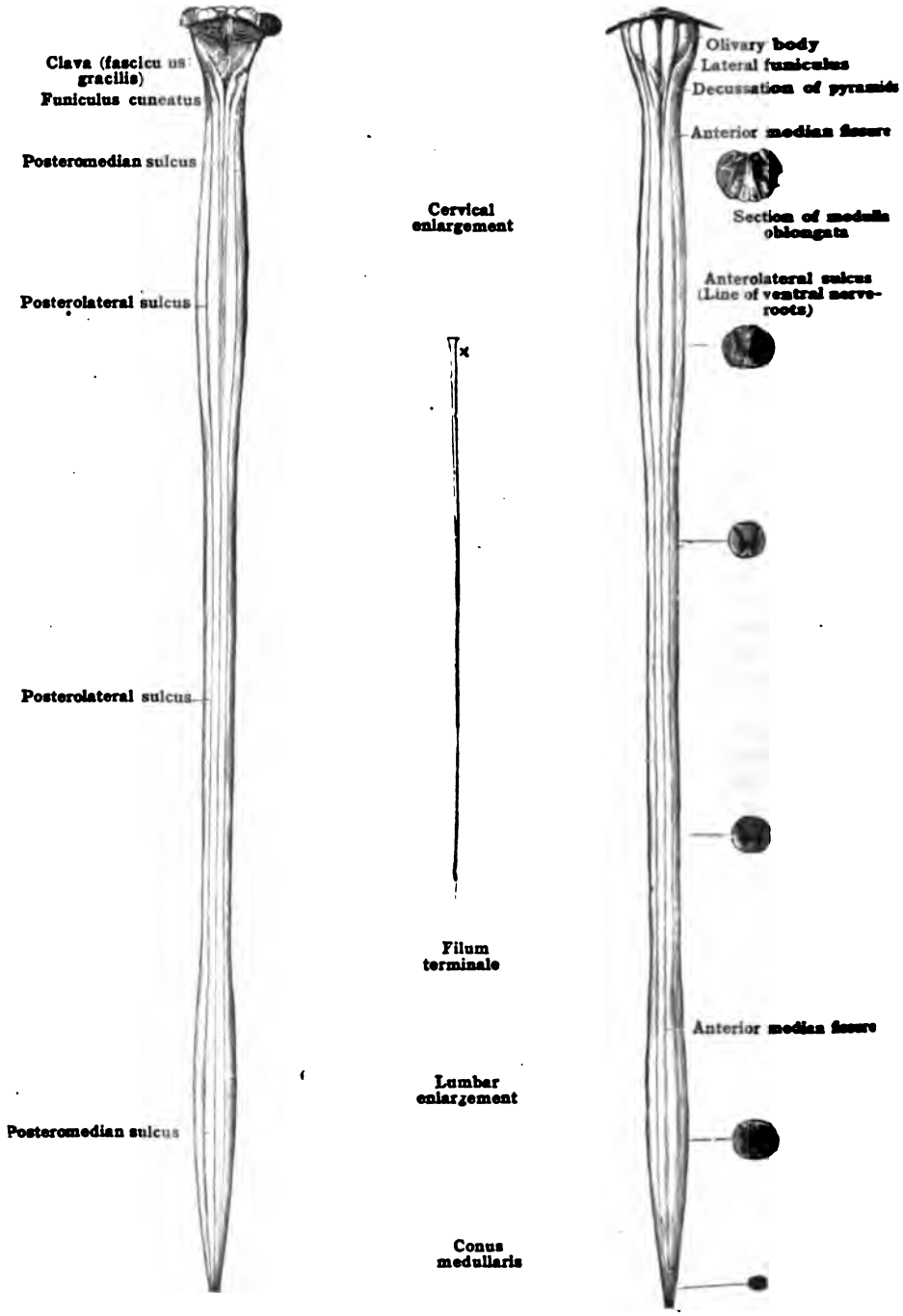
AWING FROM SPECIMEN SHOWING CAUDA EQUINA, THE ROOTS OF CERTAIN OF THE VES WHICH FORM IT, AND ITS ACCOMPANYING DURA MATER. (Dorsal aspect.)



long the cephalic part of the thoracic, the posterior division is sub-delicate longitudinal groove, the **posterointermediate sulcus,** which e evident toward the medulla oblongata and represents the line of between the fasciculus gracilis and the fasciculus cuneatus. Occa-

sionally in the upper cervical region a similar line may be seen along the ventral aspect close to the anterior median fissure. This is the **anterointermediate sulcus**, forming the lateral boundary of the ventral cerebrospinal fasciculus.

FIG. 656.—POSTERIOR AND ANTERIOR VIEWS OF THE SPINAL CORD. (Modified from Quain



Collectively, the entire space between the posterior median sulcus and the line of attachment of the dorsal roots is occupied by the **posterior funiculus**; the lateral space between the line of attachment of the dorsal and that of the ventral roots, by the **lateral funiculus**; and the space between the ventral roots and the

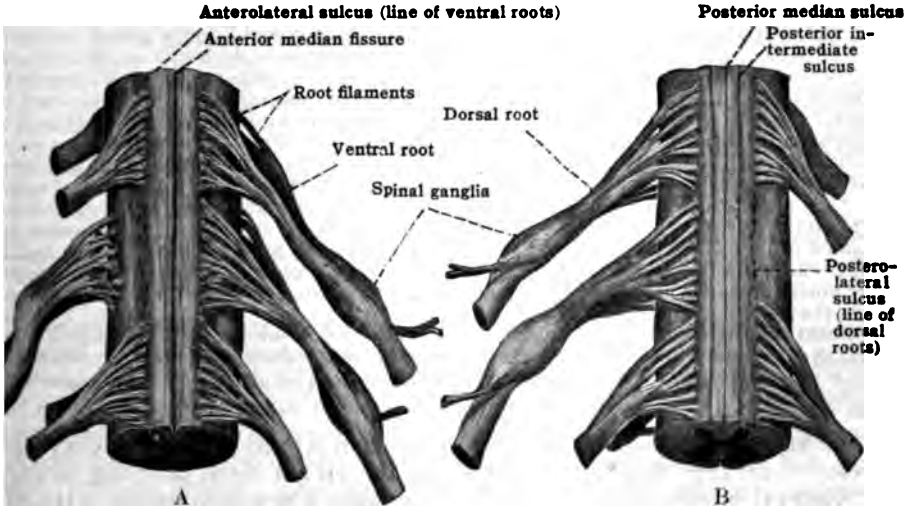
ior median fissure, by the **anterior funiculus.** Each of these funiculi is vided within into its component fasciculi.

he dorsal and ventral nerve-roots are not attached to the cord as such, but rst frayed out into numerous thread-like bundles of axones which are dis-ted along their lines of entrance and exit. These bundles are the **root-fila-s** [fila radicularia] of the respective roots. The fila of the larger spinal es are fanned out to the extent of forming almost continuous lines of attach-, while in the thoracic nerves there are small intervals between the root-ents belonging to adjacent roots. Throughout, the intervals are less be-n the fila of the ventral than between those of the dorsal roots.

Internal Structure of the Spinal Cord (Fig. 658)

y reflected light masses of medullated axones appear white when fresh, and masses are known as **white substance.** The spinal cord consists of a con-us, centrally placed column of gray substance surrounded by a variously ened tunic of white substance. The closely investing pia mater sends

657.—A, Ventral, and B, Dorsal, Views of Portion of Spinal Cord Showing Modes of Attachment of Dorsal and Ventral Roots.



erous ingrowths into the cord, bearing blood-vessels and contributing to its nal supporting tissue. The volume of white and of gray substance varies absolutely and relatively at different levels of the cord. The absolute nt of gray substance increases with the enlargements. The absolute nt of white substance also increases with the enlargements coincident with reater amount of gray substance in those regions. The relative amount of substance increases in passing from the conus medullaris to the medulla gata as explained later.

he gray substance.—All the nerve-cells of the gray substance are derived from ells forming the neural tube in the embryo, and in the adult the column of substance, though greatly modified in shape, still retains its position about entral canal. In transverse section the column appears as a gray figure of aterally developed halves, connected across the mid-line by a more attenu-portion, the whole roughly resembling the letter H. The cross-bar of the H own as the **gray commissure.** Naturally, it contains the **central canal,** is quite small and is either rounded or laterally or ventrally oval in section, ding to the level of the cord in which it is examined. The canal continues rd, and in the medulla oblongata opens out into the fourth ventricle. Down-in the extremity of the conus medullaris, it widens slightly and forms the boidal sinus or **terminal ventricle,** then is suddenly constricted into an ex-ly small canal extending a short distance into the filum terminale, and ends blindly. The gray commissure always lies somewhat nearer the ven-

tral than the dorsal surface of the cord, and itself contains a few medullate axones which vary in amount in the different regions of the cord. The medullate axones crossing the midline on the ventral side of the central canal form th ventral or **anterior white commissure**; those, usually much fewer in numb crossing on the dorsal side of the central canal, form the dorsal or **posterior wh commissure.** These two commissures comprise fibers crossing in the gray s stance as distinguished from others which cross in the white substance dor and ventral to them, namely, the dorsal cornucommissural tract and the vent commissural bundle. The axones of these four commissures serve in function associating the two lateral halves of the gray column.

Each lateral half of the gray column presents a somewhat crescentic or com shaped appearance in transverse section, which also varies at the different le of the cord. At all levels each half presents two vertical, well-defined ho themselves spoken of as columns of gray substance. **The dorsal horn** [colu posterior] extends posteriorly and somewhat laterally toward the surface of cord along the line of the posterolateral sulcus. It is composed of an **apex a neck** [cervix columnæ posterioris].

In structure the apex is peculiar. The greater portion of it consists of a mass of nerve-cells and neuroglia tissue, among which a gelatinous substance of questionable predominates, giving the horn a semi-translucent appearance. This is termed the gelat **substance of Rolando,** to distinguish it from a similar appearance immediately about the c canal, **the central gelatinous substance.** The apex of the dorsal horn is widest in the r of the enlargements, especially the lumbar, and the gelatinous substance of Rolando is marked in the cervical region. In these regions the cervix consists of a slight constrict the dorsal horn between the apex and the line of the gray commissure. In the thoracic r however, the base of the cervix is the thickest part of the dorsal horn. This thickness is the presence there of the **nucleus dorsalis,** or Clarke's column—**a column of gray sub** containing numerous nerve-cells of larger size than elsewhere in the dorsal horn, and exte between the seventh cervical and third lumbar segments of the cord. Tapering finely ends, this nucleus attains its height in the lower thoracic or first lumbar segment. Abo ventrolateral periphery of the nucleus dorsalis are scattered nerve-cells of the same t contained in it. These cells are sometimes distinguished as **Stilling's nucleus,** though C column was also described by Stilling. They are more numerous about the lower ext of the nucleus dorsalis, and they continue still more numerous in line with it below its te tion in the lumbar region.

It must be noted that the dorsal horn throughout contains numerous cell-bodies of ne mostly of small size. These are especially numerous in the margins of the horn where t referred to as the *stratum zonale*. Their significance will be given below in connectio the nerve-tracts with which they are concerned.

The **ventral horn** [columna anterior] of each lateral half of the gray fi directed ventrally toward the surface of the spinal cord, pointing towa anterolateral sulcus. It contains the cell-bodies which give origin to the e or ventral root axones, and these axones make their emergence from the cord along the anterolateral sulcus. The ventral horns vary markedly in in the different regions. In certain segments each ventral horn is thickene ally and thus presents its two component columns of gray substance: the **horn** [columna lateralis], a triangular projection of gray substance into t rounding white substance, in line with or a little ventral to the line of th commissure; and the **ventral horn proper** [columna anterior], projecting ve In the midthoracic region the lateral horn is absent except in its dorsal pa the ventral horn is quite slender; in the cervical and lumbar enlargement horns are considerably enlarged.

The gray substance is not sharply demarcated from the white. blending of the two there are often small fasciculi of white substance em in the gray, and likewise the gray substance sends fine processes among the composing the white substance. Such processes or gray trabeculæ ar marked along the lateral aspects of the gray figure and present there the ance known as the **reticular formation.** The reticular formation of the cord is most evident in the cervical region (fig. 658).

Minute structure.—The large cell-bodies of the ventral horn as a whole are divis four groups, only three of which are to be distinguished in the midthoracic region of th cord:—(1) A *ventral group* of cells, sometimes separated into a ventrolateral and a medial portion (see figs. 658, 661), occupies the ventral horn proper, is constant thr the entire length of the cord, and contributes axones to the ventral root, most of which supply the muscles adjacent to the vertebral column; (2) a ***dorsomedial group*** of cells, *in the medial* part of the ventral horn, just below the level of the central canal, gives

zones some of which go to the ventral root of the same side, some of which cross the mid- line viâ the anterior white commissure, either to pass out in the ventral root of the opposite side or (mostly) to enter the white substance of that side and course upward or downward, associating with other levels of the cord. Some if its axones terminate among the cells of the ventral horn in the same level of the opposite side; (3) a *lateral group* of cells, which is sepa- rated into a dorsolateral and a ventrolateral portion, occupies the lateral column or horn, and is best differentiated in the cervical and lumbar enlargements. Most of the axones arising from the larger cells are contributed to the ventral root of the same side, and such axones probably supply the muscles of the extremities. Some of those from its ventral portion are distributed to the muscles of the body-wall. The dorsolateral portion is that part of the lateral column which persists throughout the cord, and is considered as supplying the visceral efferent ('autonomic') fibers in the ventral roots. It is usually referred to as the dorsolateral (or intermediolateral) cell group, the only lateral group in the midthoracic region. (4) An *intermediate group*, occupying the middorsal portion of the ventral horn. Axones arising from its cells are in part contributed to the ventral root as visceral efferent fibers, but most of them course wholly within the central nervous system. Some pass to the opposite side of the cord, chiefly viâ the anterior and possibly the posterior white commissure, to terminate either in the same or different levels of the gray column. Others of longer course pass to the periphery of the cord, join one of the spinocerebel- lar fasciculi, and pass upward to the cerebellum.

Furthermore, there are scattered throughout the gray substance many small cell-bodies of neurones. These give rise to axones of shorter course, either **commissural** or **associational proper**. Of such axones many are quite short, coursing practically in the same level as that in which their cells of origin are located, and serve to associate the different parts of the gray sub- stance of that level. Others course varrying distances upward and downward for the association of different levels of the gray column.

It is evident from the above that in addition to the various nerve-cells it contains, there is also to be found a felt-work of axones in the gray substance. Many of these axones are medul- lated, though not in sufficient abundance to destroy the gray character of the substance. The felt-work is composed of four general varieties of fibers:—(1) Axones arising from the cells of the spinal ganglia which enter the cord as dorsal root-fibers and form synapses with the cell-bodies of the gray substance; (2) The terminal branches of axones entering from the fasciculi of the white substance and forming end-brushes (synapses) about the various cell-bodies in the gray substance (partly medullated); (3) axones given off from the cells of the gray substance and which pass into the surrounding white substance either to enter the ventral roots or to join the ascending and descending fasciculi within the spinal cord (partly medullated); (4) axones of Golgi neurones of type II, which do not pass outside the confines of the gray substance (non- medullated). Some axones of any of these varieties may cross the midline and thus become commissural. In general all fibers of long course acquire medullary sheaths a short distance from their cells of origin, and lose them again just before termination.

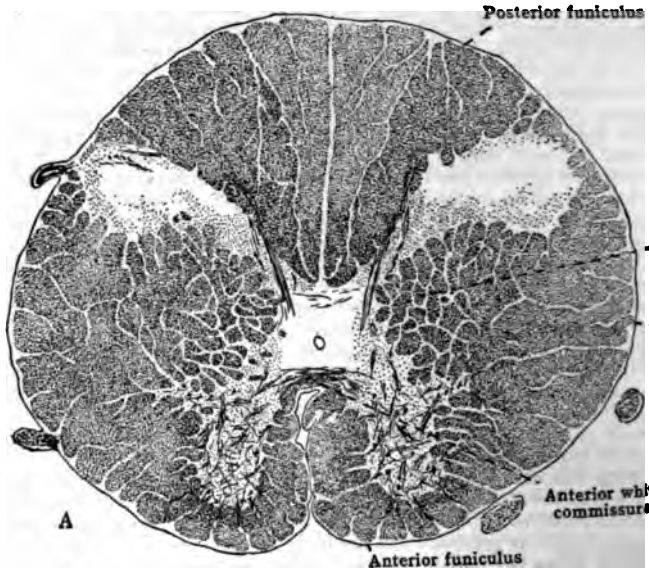
The white substance of the spinal cord.—The great mass of the axones of the spinal cord course longitudinally and form the thick mantle surrounding the column of gray substance. This mantle is divided into right and left homo- lateral halves by the anterior median fissure along its ventral aspect, and along its dorsal aspect by the posterior median septum, which is for the most part a connective tissue partition derived from the pia mater along the line of the posterior median sulcus. The mantle is supported internally by interwoven neuroglia and white fibrous connective tissue, the latter, derived from the meso- derm viâ the pia mater, closely investing it without.

The axones of the white substance belong to three general neurone systems:—(1) The *spinal association* and *commissural system* of axones which serve to cor- relate the different levels and the two sides of the spinal cord and which are proper to the spinal cord, i.e., they do not pass outside its confines. (2) The *spinocerebral and cerebrospinal system*, which consists of axones of long course, one set ascending and another descending, forming links in the neurone chains between the cerebrum and the peripheral organs. The ascending axones of this system collect the general bodily sensations which are conveyed to the cerebrum, the cells of which in response contribute axones which descend the cord, con- veying efferent or motor impulses. (3) The *spinocerebellar and cerebellospinal system* consists of conduction paths, one set ascending and another descending, which are connections between cerebellar structures and the gray substance of the spinal cord. To this might be added a fourth system of neurones (spinobul- bar) connecting and correlating the spinal cord and the medulla oblongata.

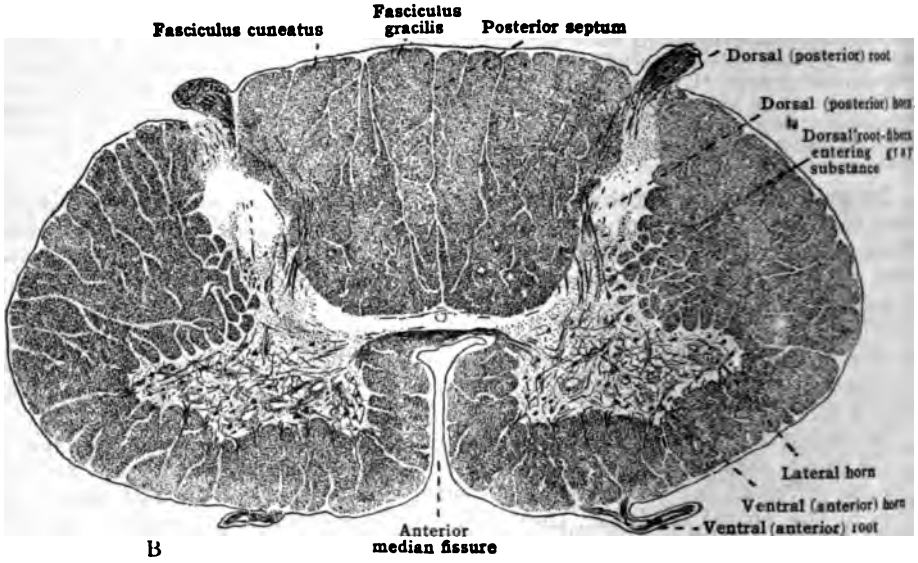
The second and third (and fourth) systems increase in bulk as the cord is ascended. The ascending axones of each system are contributed to the white substance of the cord along its length, and therefore accumulate upward; the axones descending from the encephalon are distributed to the different levels of the cord along its length, and therefore diminish downward.

The mass of the first system of axones varies according to locality (figs. 658, 664). Wherever there is a greater mass of neurones to be associated, as there is

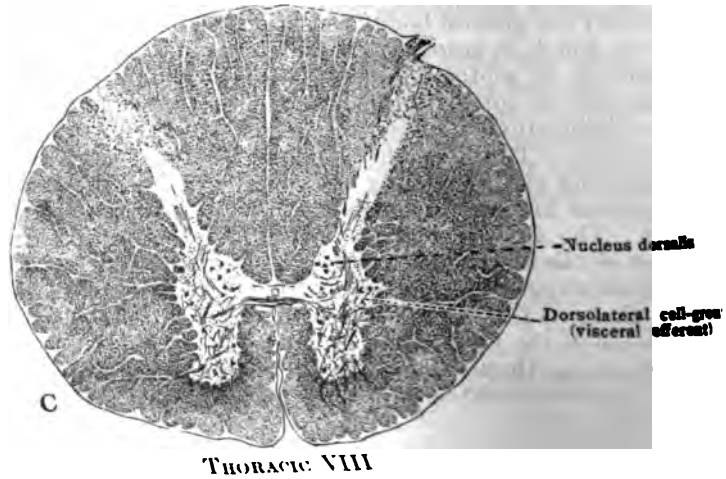
FIG. 658—TRANSVERSE SECTIONS FROM DIFFERENT SEGMENTS OF THE SPINAL CORD, SHOWING SHAPE AND RELATIVE PROPORTIONS OF GRAY AND WHITE SUBSTANCE IN THE VARIOUS REGIONS.



CERVICAL I



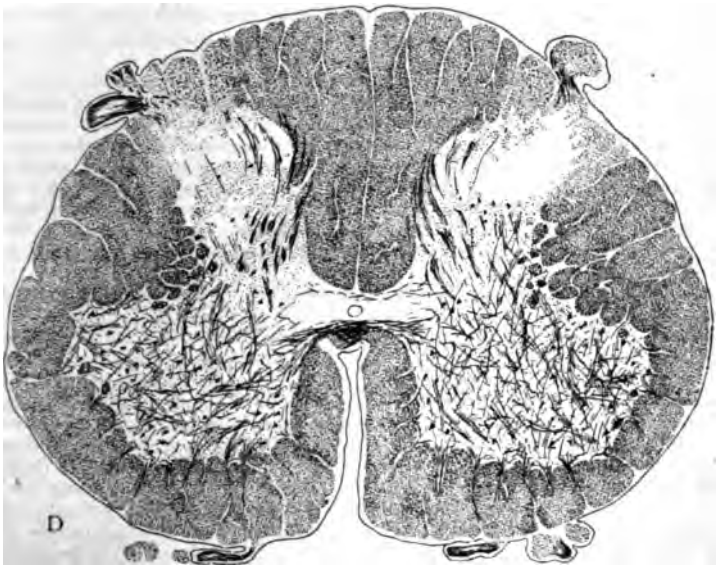
CERVICAL VI



THORACIC VIII

enlargements of the cord, a greater number of these axones is required. cells of origin, being in the gray substance of the cord, contribute to its nd thus both the cells and the axones of this system serve to make the ements more marked. In the lumbar and sacral regions the greater mass entire white substance consists of axones belonging to this system. It a dense felt-work about the gray column throughout the cord. Neces- this system contains axones of various lengths. Some merely associate

FIG. 658.—*Continued.*



LUMBAR III

SACRAL IV

COCCYGEAL

nt levels within a single segment of the cord; others associate the different nts with each other. Many of these axones cross the mid-line both in the nd in the white substance to associate the neurones of the two sides. For ses of distinction, such as cross the midline are called **commissural fibers,** those which course upward and downward on the same side are **association**

Coursing in longitudinal bundles about the gray substance, the latter com- he **fasciculi proprii** or 'ground bundles' of the spinal cord.

METHODS BY WHICH THE CONDUCTION PATHS HAVE BEEN DETERMINED

A purely anatomical examination of a normal adult cord, prepared by whatever means, gives no indication of the fact that the mass of longitudinally coursing fibers of the white substance is composed of more or less definite bundles or fasciculi, each having a definite origin, course and termination and, forming links (conduction paths) in a definite system of neurone chains. Present information as to the size, position, and connections of the various fasciculi is based upon evidence obtained by three different lines of investigation:—

(1) **Physiological investigation.**—(*a*) Direct stimulation of definite bundles or areas in section and carefully noting the resulting reactions which indicate the function and course of the axones stimulated. (*b*) 'Wallerian degeneration' and the application of such methods as that of Marchi. When an axone is severed, that portion of it which is separated from its parent cell-body degenerates. Likewise a bundle of axones severed from their cells of origin, whether by accident or design, will degenerate from the point of the lesion on to the locality of their termination in whichever direction this may be. This phenomenon was noted by Waller in 1852 and is known as **Wallerian degeneration.** By the application of a staining technique which is differential for these degenerating axones and a study of serial sections containing the axones in question, their course and distribution may be determined. The locality of their cells of origin, if unknown, may be determined by repeated experiment till a point of lesion is found not followed by degeneration of the axones under investigation. (*c*) The axonic reaction or 'reaction from a distance.' Cell-bodies whose axones have been severed undergo chemical change and stain differently from those whose axones are intact. Thus cell-bodies giving origin to a bundle of severed axones may be located in correctly stained sections of the region containing them.

(2) **Embryological evidence.**—In the first stages of their development axones of the cerebrospinal nervous system are non-medullated. They acquire their sheaths of myelin later. Axone pathways forming different chains become medullated at different periods. Based upon this fact a method of investigation originated by Flechsig is employed, by which the position and course of various pathways may be determined. A staining method differential for medullated axones alone is applied to the nervous systems of fetuses of different ages, and pathways medullated at given stages may be followed from the locality of their origin to their termination. In the later stages, when most of the pathways are medullated and therefore stain alike, the less precocious pathways may be followed by their absence of medullation.

(3) **Direct anatomical evidence.**—(*a*) Stains differential for axones alone are applied to a given locality to determine the fact that the axones of a given bundle actually arise from the cell-bodies there, or that axones traced to a given locality actually terminate about the cell-bodies of that locality. For example, it may be proved anatomically that the axones of a dorsal root arise from the cells of the corresponding spinal ganglion, and then these axones may be traced into the spinal cord and the terminations noted either of their collateral or terminal twigs or the fasciculus they join in their cephalic course may be determined. (*b*) The staining properties and the size and distribution of the tigroid masses in the cell-bodies of sensory neurones differ from those in the motor neurones, and recently Malone has claimed that, in the central system, the cell-bodies in the nuclei of sensory neurone-chains, those chains ascending toward the cerebral cortex, may be distinguished from the cell-bodies of the motor or descending chains by the arrangement and size of their tigroid masses. He claims further that in the same way, the cell-bodies of the somatic efferent neurones may be distinguished from those of the visceral efferent neurones. In this way the locality of origin of certain physiologically known paths may be determined.

(4) The so-called **pathologic-anatomical method** is based upon the same general principles as is the physiological (or experimental) method. A pathological lesion, a local infection or a tumor for example, may destroy a nucleus of cell-bodies or sever a bundle of axones, and the resulting degeneration, of the axones may be followed through serial sections suitably prepared. The locality of the lesion known, the path may be followed to determine the locality of its termination; its locality of termination known from the symptoms resulting, the path may be followed to its cells of origin, or to determine whatever be the locality of the lesion.

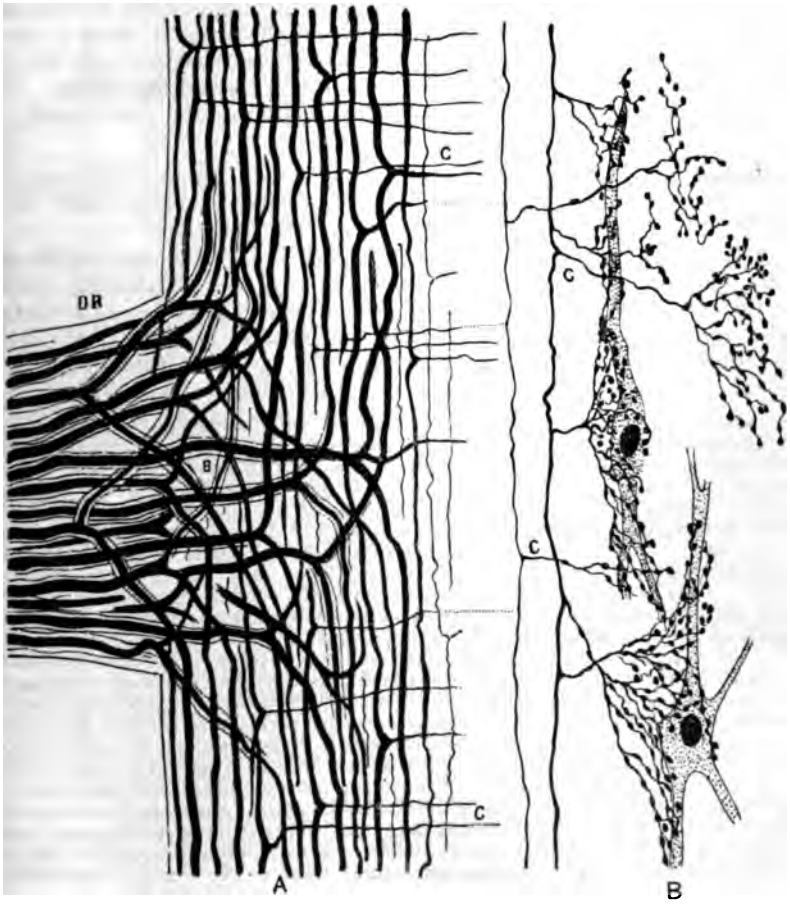
Funiculi.—In order that the various fasciculi may be referred to with greater ease, the white substance of the spinal cord in transverse section is divided into three areas known as funiculi or columns and which correspond to the funiculi already mentioned as evident upon the surface of the cord when intact. The funiculi are outlined wholly upon the basis of their position in the cord and with reference to the median line and the contour of the column of gray substance; their component fasciculi are defined upon the basis of function. (1) The *posterior funiculus* or column is bounded by the posterior median septum and the line of the dorsal horn; (2) the *lateral funiculus* or column is bounded by the lateral concavity of the gray column and the lines of entrance and exit of the dorsal and ventral roots; (3) the *ventral funiculus* or column is bounded by the line of exit of the ventral roots, and by the anterior median fissure. (See figs. 658, 661

The posterior funiculus or column [funiculus posterior].—This funiculus is composed of two general varieties of axones arranged in five fasciculi. First, an constituting the predominant type in all the higher segments of the cord, are the afferent or general sensory axones, which arise in the spinal ganglia, enter the cor

e dorsal roots, assume their distribution to the neurones of the cord, and then e of them) take their ascending course toward the encephalon. The axone e spinal ganglion neurone undergoes a T-shaped division a short distance the cell-body, one limb of this division terminating in the peripheral organs the other going to form the dorsal root. Upon entering the cord the dorsal axones undergo a Y-shaped bifurcation in the neighborhood of the dorsal , one branch ascending and the other descending (fig. 659). The longest of ascending branches form the **fasciculus gracilis** (Goll's column) and the culus cuneatus (Burdach's column). These fasciculi are the largest ascending nsory spinocerebral connections, the direct sensory path to the brain. Their ones represent the first links in the neurone chains between the periphery of ody and the cerebral or cerebellar cortex.

659.—Showing Disposition of the Dorsal Root Fibers Upon Entering the Spinal Cord. (From Edinger after Cajal.)

ws dorsal root axones DR, entering the spinal cord, bifurcating at B, and giving off ollaterals C to the neurones of the cord. B shows the telodendria of these axones or of their ollaterals forming synapses with cell-bodies of the gray substance of the cord.



threading their way toward the brain, these sensory axones of long course tend to work d the midline. Therefore those of longest course are to be found nearer the posterior n, in the upper segments of the cord, than those axones which enter the cord by the dorsal of the upper segments. Thus it is that the fasciculus gracilis, the medial of the two fas- contains the axones which arise in the spinal ganglia of the sacral, lumbar and lower ic segments (S., L. and T. 12 to 6). In other words, it is the fasciculus bearing sensory es from the lower limbs to the brain, while the fasciculus cuneatus, the lateral of the two, corresponding pathway for the higher levels (T. 6 to 1 and C.). Naturally, there is no ulus cuneatus as such in the lower segments of the spinal cord. The axones being much ed at first, it is only in the upper thoracic and cervical region that there is any anatomical reation between the two fasciculi. In this region the two become so distinct that there

is in some cases an apparent connective tissue septum between them, continuing inward to the posterointermediate sulcus—the surface indication of the line of their junction (fig. 6

Upon reaching the medulla oblongata the fibers of the fasciculus gracilis and the fasciculus cuneatus terminate about cells grouped to form the nuclei of termination of these fasciculi. The nucleus of termination of the fasciculus gracilis is situated medially and begins just below the point at which the central canal opens into the fourth ventricle; that of the fasciculus cuneatus is placed laterally and extends somewhat higher than the other nucleus. The neurones whose cell-bodies compose these nuclei constitute the second links in the neurone chains conveying sensory impulses from the periphery to the cerebral and cerebellar cortex.

The descending or *caudal branches* of the dorsal root-axones are concerned wholly with the neurones of the spinal cord. They descend varying distances, some of them as much as four segments of the cord, and give off numerous collaterals on their way to the cells of the gray column. Those terminating about cell-bodies of the ventral horn, which give rise to the ventral or motor root-fibers, are responsible for certain of the so-called *'reflex activities'* and thus contribute to the simplest of the **reflex arcs.** In descending they serve to associate different levels of the gray substance of the cord with impulses entering by way of a single dorsal root. Some of their collaterals cross the midline in the posterior white commissure, and thus transfer impulses to neurones of the opposite side. The caudal branches of longer course are scattered throughout the ventral portion of the fasciculus cuneatus (*middle root zone*), and the longest show a tendency to collect along the border-line between the fasciculus cuneatus and the fasciculus gracilis, and thus contribute largely to the **comma-shaped fasciculus.** Also a few of the longest of them in the lower levels course in the *oval bundle* or septomarginal root zone.

The ascending branches of the dorsal-root axones also give off some collaterals to the gray substance of the cord, thus extending the area of distribution of a given dorsal nerve-root to levels of the cord above the region at which the root enters.

The greater number of the terminations of dorsal root-axones within the spinal cord form synapses with neurones other than those contributing ventral root-fibers. The greater mass of the neurones concerned are those of the Golgi type II and those contributing the **fasciculi proprii** or **ground bundles** of the spinal cord, or the second variety of axones composing the posterior funiculus. The latter fasciculi arise from the smaller cells of the gray column (fig. 660).

These axones pass from the gray substance to enter the surrounding white substance, bifurcate into ascending and descending branches, which in their turn give off numerous collaterals to the cells of the gray substance of the levels through which they pass. The cell-bodies giving origin to such axones are so numerous that the entire column of gray substance is surrounded by a continuous felt-work of fasciculi proprii.

The **dorsal fasciculus proprius** (anterior root zone of posterior column) arises chiefly from cells situated in the dorsal horn (*stratum zonale*). Coincident with the ingrowth and arrangement of the fasciculi gracilis and cuneatus many of the longer fibers of the dorsal fasciculus proprius go to form both the oval bundle and the comma-shaped fasciculus. Thus these two bundles are mixed, being fasciculus proprius which contain caudal branches of dorsal root-axones. The association fibers in the oval bundle are the longest of any belonging to the dorsal fasciculus proprius. The cephalic and caudal branches combined of some are said to extend more than half the length of the cord and it has been claimed that some even associate the conus medullaris with the cervical region. Based upon this claim, Obersteiner has called the oval bundle the 'dorsomedial sacral field' and Edinger has referred to the most dorsal part of it as the *'tractus cervicolumbalis dorsalis.'* A better name for it is *lumbocervical tract*, since, to become so isolated from the gray substance, it probably arises in the lumbar region of the cord. The *'medial triangle'*, is formed by the continuation of the dorsal fasciculi proprii with the oval or septomarginal fasciculus. Some of the axones of the dorsal fasciculus proprius cross the midline to distribute impulses to the neurones of the opposite side. These commissural axones, together with certain collaterals of the dorsal root-axones, which cross the midline outside the dorsal white commissure, compose the so-called **cornucommissural tract** at the ventral edge of the posterior septum.

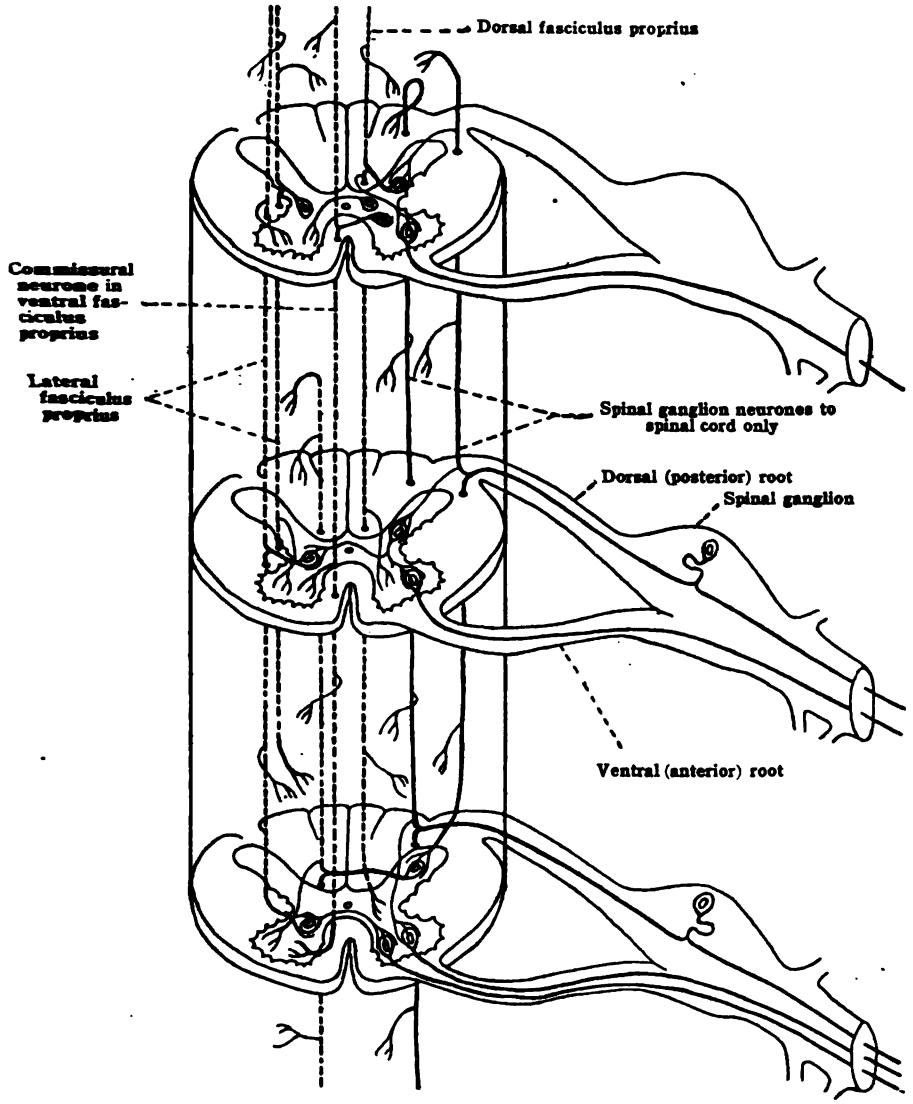
Only a minor proportion of the axones of the posterior or dorsal nerve-roots extend to the encephalon. Estimation shows that the sum of all the dorsal roots is greatly in excess of the sum contained in the fasciculi cuneatus and gracilis just before these enter their nuclei of termination. Therefore most of the ascending branches are concerned with spinal cord relations wholly.

The lateral and ventral funiculi or columns.—The region of the passage of the ventral root-fibers from the ventral horn is considered the line of demarcation between the lateral and ventral funiculi. In that it is much less definite than the demarcation between the lateral and dorsal funiculi and because it is so broad as to involve in it certain of the tracts to be considered, some extending through the line, the fasciculi comprising the two funiculi will be considered together.

The marginal zone of Lissauer, situated along the lateral margin of the posterolateral sulcus, is composed largely of dorsal root-axones which bifurcate lateral instead of medial to their line of entrance. Many of these finally work across the line of entrance into the posterior funiculus. Many of the dorsal root-fibers which do not reach the brain occur in Lissauer's zone. Lissauer's zone also contains some fibers arising from the small cells of the dorsal horn, and to this extent corresponds to a fasciculus proprius. Ranson has found that large numbers of the non-medullated dorsal root-axones which enter the cord are contributed to Lissauer's zone.

FIG. 660.—DIAGRAM ILLUSTRATING THE FORMATION OF THE FASCICULI PROPRII (ASSOCIATION FASCICULI) AND THE COMMISSURAL FIBERS OF THE SPINAL CORD, AND THE GENERAL ARCHITECTURE OF THE CORD AS A MECHANISM FOR REFLEX ACTIVITIES.

The ventral fasciculus proprius is omitted and the lateral is shown on one side only. The lower spinal ganglion neurone shown illustrates the type whose ascending branch is of much longer extent than that of the upper one. Reflex arcs involving the sympathetic are not included.



The lateral and ventral fasciculi proprii (ground or basis-bundles).—The lateral fasciculus proprius is situated in the lateral concavity of the gray column and is continuous with the other fasciculi proprii both dorsal and ventral. Beyond that it probably contains fewer commissural axones, it is of the same general significance as the others. It is the largest of the three and is frequently divided into small bundles by the reticular formation (see fig. 658).

The ventral fasciculus proprius is continuous unbrokenly around the ventral horn with the lateral, is bounded medially by the ventral median fissure and is continuous under the floor of this fissure with its fellow of the opposite side. More commissural fibers traverse it than traverse either of the other two. The neurones represented in it serve especially to associate

the different levels of the ventral horn, and it is known to contain some association-fibers extra long course—extending between the brain and cord.

The lateral cerebrospinal fasciculus (crossed pyramidal tract).—In contrast to the sensory fibers passing through the spinal cord conveying impulses destined to reach the cerebral cortex, axones are given off from the pyramidal cells of the cortex, which descend to terminate about the cells of the gray substance of the spinal cord, chiefly the cells which give origin to the ventral root-fibers.

Upon reaching the medulla oblongata in their descent, these axones are accumulated in two well-defined, ventrally placed bundles, the **pyramids**, one from each cerebral hemisphere. In passing through the brain stem the pyramids contribute many fibers which cross the midline to terminate in the motor nuclei of the cranial nerves of the opposite side, and thus decrease appreciably in bulk. According to the estimate of Thompson, only about 160,000 of the pyramidal fibers are destined to enter the spinal cord.

Upon reaching the lower part of the medulla, the greater mass of the fibers of each pyramid, which are destined to enter the cord, suddenly cross the midline in the 'decussation of the pyramids.' The remainder retain their ventral position in their descent decussating gradually in the cord itself. The pyramidal fibers which cross in the medulla course in the lateral column ventral to Lissauer's zone, and lateral to the lateral fasciculus proprius, and form the *lateral cerebrospinal fasciculus* (crossed pyramidal tract). It is a large fasciculus, oval-shaped in transection, and since its axones terminate in the gray column of the cord all along its length, it decreases in bulk as the cord is descended.

The **ventral cerebrospinal fasciculus** (anterior or direct pyramidal tract), as stated above, is the uncrossed portion of the descending cerebrospinal system of neurones. It is a small, oblong bundle, situated mesially in the anterior funiculus, parallel with the anterior median fissure. Like the lateral cerebrospinal fasciculus (crossed pyramidal tract), its axones arise from the large pyramidal cells of the motor area of the cerebral cortex, and transmit their impulses to the neurones of the ventral horns of the gray substance of the spinal cord, and almost entirely to those neurones which give origin to the ventral or motor root-fibers.

It represents merely a delayed decussation of the pyramidal fibers, for instead of crossing to the opposite side in the lower portion of the medulla oblongata, as do the fibers of the lateral fasciculus, its fibers decussate all along its course, crossing in the ventral white commissure and in the *commissural bundle* of the cord to terminate about the ventral horn cells of the opposite side. Hoche, employing Marchi's method, found that a few of its fibers terminate in the ventral horn of the same side. This conforms to the pathological and experimental evidence that there may be a few homolateral or uncrossed fibers in the crossed pyramidal tracts also. Like the crossed tract, the ventral pyramidal tract diminishes rapidly in volume as it descends the cord. Its loss is greatest in the cervical enlargement, and it is entirely exhausted in the upper half of the thoracic cord. With the exception of the anthropoid apes and certain monkeys, none of the mammalia below man, which have been investigated, possess this ventral pyramidal tract.

In addition to the dispositions of the dorsal root-axones given above, certain of them, either by collaterals or terminal twigs, form synapses with the cells of the dorsal nucleus (Clarke's column), which nucleus, tapering in its two ends, extends from about the seventh cervical to the third lumbar segment of the cord. The axones given off by these cells pass to the dorsolateral periphery of the lateral funiculus and there collect to form the **dorsal spinocerebellar fasciculus** (direct cerebellar tract of Flechsig). As such they ascend without interruption, and in the upper level of the medulla oblongata pass into the cerebellum by way of the inferior cerebellar peduncle or restiform body. Necessarily, this fasciculus is not evident in levels below the extent of the nucleus dorsalis.

Also situated superficially in the lateral funiculus is another ascending conduction path, and, like the dorsal spinocerebellar fasciculus, to which it is adjacent, it is also in great part at least a cerebellar connection. Its position suggests its name, **superficial ventrolateral spinocerebellar fasciculus (Gowers' tract)**.

This tract at present does not include as great an area in transverse section as when originally described. The more internal portion of the original Gowers' tract is now given a separate significance, and will be considered separately. While the exact location in the gray column of all the cell-bodies giving origin to the superficial ventrolateral spinocerebellar fasciculus is uncertain, it is known that certain ventral horn cells contribute their axones to it. Many of its cells of origin are scattered in the area immediately ventral to the nucleus dorsalis, others in the intermediate group and mesial portion of the lateral group of ventral horn cells. In the lumbar region these cells increase in line with the position of the nucleus dorsalis above and are quite numerous; therefore, the fasciculus arises for the most part at a lower level in the spinal cord than does the direct cerebellar tract. In degenerations it becomes visible in the upper segments of the lumbar region, and has been proved to increase notably in volume as the cord is ascended. Its

nes arise for the most part directly from cell-bodies of the same side of the cord, though it has n shown by several investigators that many of its axones come from the gray substance of the osite side by way of the ventral white commissure. Terminal twigs and collaterals of the al root-fibers, mostly of the same side, but occasionally from the opposite side, transfer sory impulses to its cells of origin. At one time Gowers' tract was considered an entity, now, even in the more limited area it occupies, it must be considered a mixture of axones of eral terminal destinations or distinct neurone systems. The destination of some of its nes has not been determined with certainty. The spinocerebellar fibers proper go to cerebellum, and there have been traced to the cortex of the superior vermis. Most of these ch the cerebellum not by way of the restiform body, as does the dorsal spinocerebellar tract, pass on in the brain-stem to the level of the inferior corpora quadrigemina, and there turn k to join the brachium conjunctivum or superior cerebellar peduncle. Only a few of its nes leave the fasciculus lower down in the medulla, to enter the cerebellum by way of the iform body, in company with the dorsal spinocerebellar tract. (Rossolimo, Tschermak.) other portion of its axones are thought to reach the cerebrum, probably the nucleus lenti-mis, though it has not been positively traced further than the superior corpora quadrigemina. ny axones in Gowers' tract of the cord correspond to those of the fasciculi proprii, and merely n varying distances in the cord, to turn again into its gray substance. Schaeffer followed some these from the lumbar region up to the level of the second cervical nerve.

In the ventromesial border of Gowers' tract and immediately upon the eriphery, near the anterolateral sulcus (exit of ventral nerve-roots), there is und in the higher segments of the cord a small oval bundle, the **spino-olivary** sciculus or **Helweg's** (Bechterew's) **bundle.** The functional direction of its bers has not been settled.

The bundle was at first thought to arise wholly within the olive in the medulla oblongata nd to terminate in the cord. More recent claims assert that it arises from cell-bodies in the ord and thus is spino-olivary. By some observers it has been traced as far down as the mid-horacic region; by others, however, only as far as the third cervical segment. Goldstein ggests that spino-olivary fibers arise from the entire length of the cord. Others hold that the sciculus contains both spino-olivary and olivospinal fibers, the latter having the shorter rtent. The olives being nuclei largely concerned with cerebellar connections, Helweg's sciculus is probably an indirect cerebellar association with the cervical spinal cord neurones. is composed of axones of relatively very small diameter, and it is one of the last fasciculi of e spinal cord to become medullated.

Considering Helweg's bundle as spinocerebellar, it may be noted that there are three spino-rebellar fasciculi, one for the cervical region, one for the thoracic and one for the lumbosacral gion of the cord, the origin of each considerably overlapping that of the succeeding.

Situated between the lateral and ventral fasciculi proprii and the super-ially placed fasciculi is an area which, in transverse sections, may be, by po-ition, referred to collectively as the **intermediate zone.** So intermingled are the ones comprising it that it has been called the **mixed zone.** It extends through oth the lateral and ventral funiculi and it contains fibers of the following func-onal varieties:

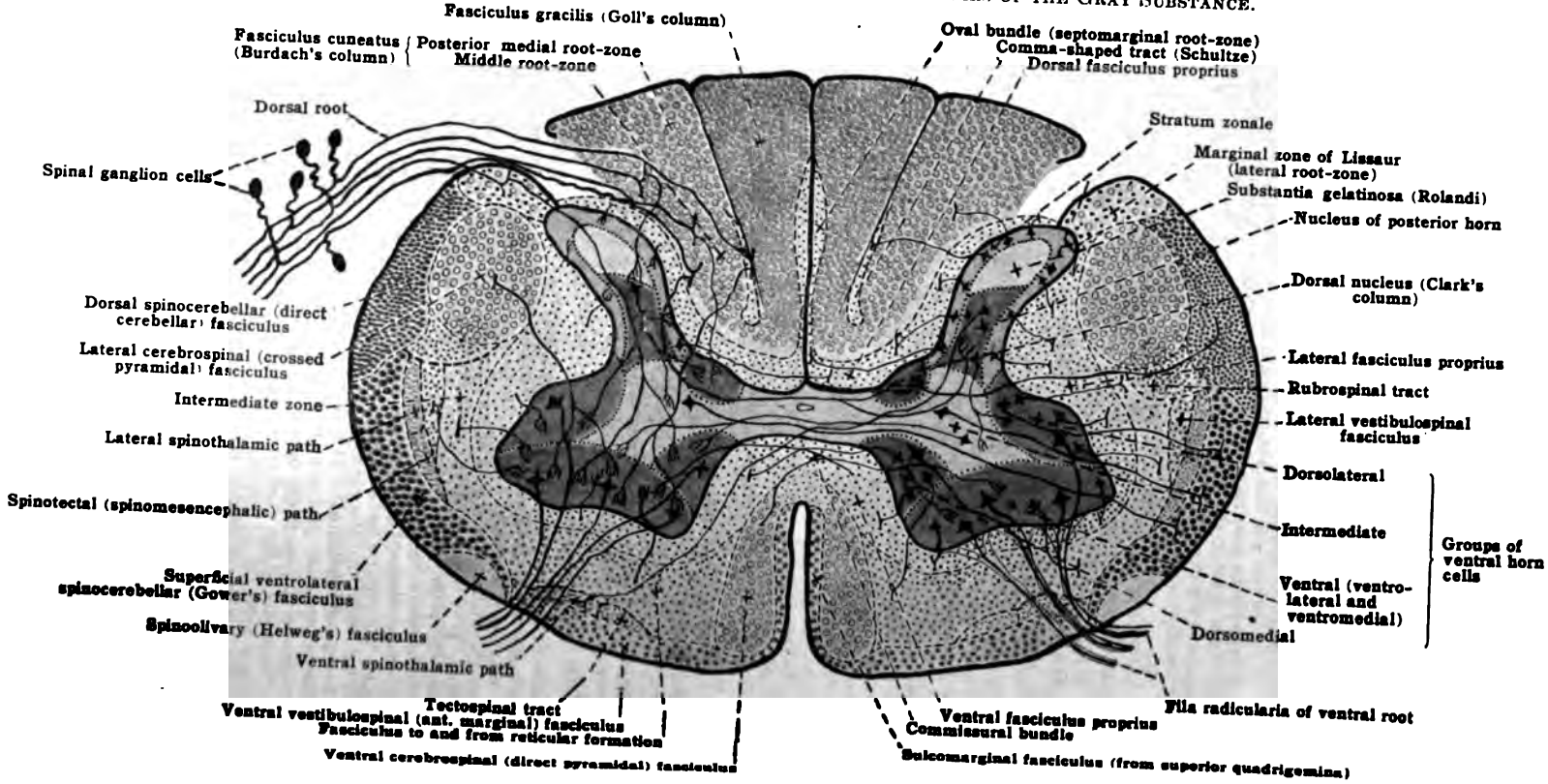
1. Fibers ascending and descending, belonging to the lateral and ventral fasciculus proprius hich are of longer extent gradually course farther away from the gray substance of the cord d such mix into the intermediate zone. It is said to contain fibers descending from the cere-llum to associate with the neurones of spinal cord, probably directly with the ventral root or otor neurones. It is doubtful that there are present in the cord any fibers arising directly om cell-bodies situated in the cerebellum. None are indicated by anatomical evidence rough degenerations. Some may occur as a downward continuation of the *tractus cere-llotegmentalis bulbi* claimed by some authors. It is thought that the cortical cerebrospinal yramidal) and rubrospinal fasciculi serve for responses to the several paths conveying sensory mpulses from the body into the cerebellum.

2. **The rubrospinal fasciculus.**—This arises from cell-bodies in the red nucleus of the tegmen-m (in the mesencephalon) and is a crossed fasciculus. Axones arising from the red nucleus one side across the midline in the mesencephalon (ventral tegmental decussation) and descend the lateral funiculus of the cord to terminate gradually about cell-bodies of the ventral horn, oth those which give rise of ventral root fibers and those which contribute to the fasciculi oprii. Its fibers are more thickly bundled in a crescentic area fitting onto the ventral side of e lateral cerebrospinal fasciculus, and some are said to mix into the area of this latter.

3. **The lateral vestibulospinal fasciculus** is a much smaller tract than one of similar signifi-nce in the ventral funiculus of the cord. It arises from some of the cell-bodies comprising eiter's nucleus, the lateral nucleus of termination of the vestibular nerve, and from some of ose of the spinal nucleus (nucleus of the descending root) of this nerve, all of which is in the edulla. It descends the cord, uncrossed, to terminate gradually about ventral horn cells, thus mprising a part of the apparatus for the equilibration of the body. Its fibers are thought be more closely collected in the area immediately ventral to the rubrospinal fasciculus, ut of course commingle with the latter.

4. *The corpora-quadrigemina-thalamus paths.* In the lateral, ventrolateral and medial por-ons of the intermediate zone are small tracts, both ascending and descending, which connect e spinal cord with the thalamus (diencephalon) and the quadrigeminate bodies of the mesence-halon. These are crossed paths. The ascending fibers arise from cell-bodies situated in the

FIG. 661.—SCHEMATIC REPRESENTATION OF THE SHAPE AND POSITION OF THE VARIOUS FASCICULI OR CONDUCTION PATHS OF THE SPINAL CORD AND THE GROUPING AND SIGNIFICANCE OF THE CELL-BODIES OF THE GRAY SUBSTANCE.



al horns and carry sensory impulses received by direct synapses made by collaterals and inal twigs of the dorsal root-fibers invading the dorsal horns. Of the descending com-nts, fibers arising in the quadrigeminate bodies are best established. For description, omponents of the paths are named as follows:

a). **The spinal lemniscus** is a name used to represent collectively the sensory or ascending ponents of the corpora-quadrigemina-thalamus paths, not because of any 'band-like' shape med by the tracts but because, like the well-known lemniscus in the rhomboencephalon, they y sensory impulses from the general body, received from spinal ganglion neurones, to the brum. They are described as ascending in three paths:

The spinotectal (spinomesencephalic) path arises from cell-bodies in the dorsal horn of one , crosses in the commissures of the cord (chiefly the ventral), turns cephalad and accumulates a bundle in the lateral part of the intermediate zone, medial to Gowers' tract. It termin-s in the gray substance of the quadrigeminate bodies or tectum of the mesencephalon. se bodies likewise receive visual and auditory impulses for transmission to the nuclei of in of the oculomotor and trochlear nerves. Therefore, by this path, general body-sensa-ns may induce eye movements.

The lateral and ventral spinothalamic paths both arise from cell-bodies in the dorsal horn of side and both cross in the ventral commissures of the cord to ascend in the intermediate e of the opposite side. The lateral ascends medial to Gowers' tract in dorsal company with spinotectal tract. The ventral one ascends in the ventral funciulus of the cord, medial to spino-olivary tract and in the dorsolateral extension of the ventral vestibulospinal fascic-s. Both terminate in the inferior and lateral nuclei of the thalamus, which nuclei in their n give fibers which terminate in the cerebral cortex.

(b). The *descending* components of the corpora-quadrigemina-thalamus paths are as follows:

The tectospinal tract (of Löwenthal) which arises from the corpora quadrigemina or tectum the mesencephalon, decussates there in the 'fountain decussation' and descends the medulla longata and the spinal cord in company with the ascending fibers of the ventral spinothalamic ct. It probably distributes its impulses to the ventral horn neurones throughout the cord. nce the superior and inferior pairs of the quadrigeminate bodies receive impulses of sight and aring respectively, it may be assumed that this tract correlates these sensations with bodily ovements.

The sulcomarginal fasciculus, as its name implies, descends in the margin of the ventral edian fissure of the cord, medial to the ventral cerebrospinal fasciculus where this is present. is continuous into the cord with the median longitudinal fasciculus, one of the long associa-on-tracts of the brain, but it contains fibers which arise from the cell-bodies of the superior uadrigeminate body and which form part of the 'optic-acoustic-reflex path' of the mesen-ephalon, cross the midline in the fountain decussation and descend to distribute impulses to the entral horn of the opposite side of the cord, supposedly along its entire length. The superior uadrigemina having to do with sight, the sulcomarginal fasciculus forms the chief path by hich general bodily movements may be induced in response to visual impulses. It is a entromedial tectospinal tract.

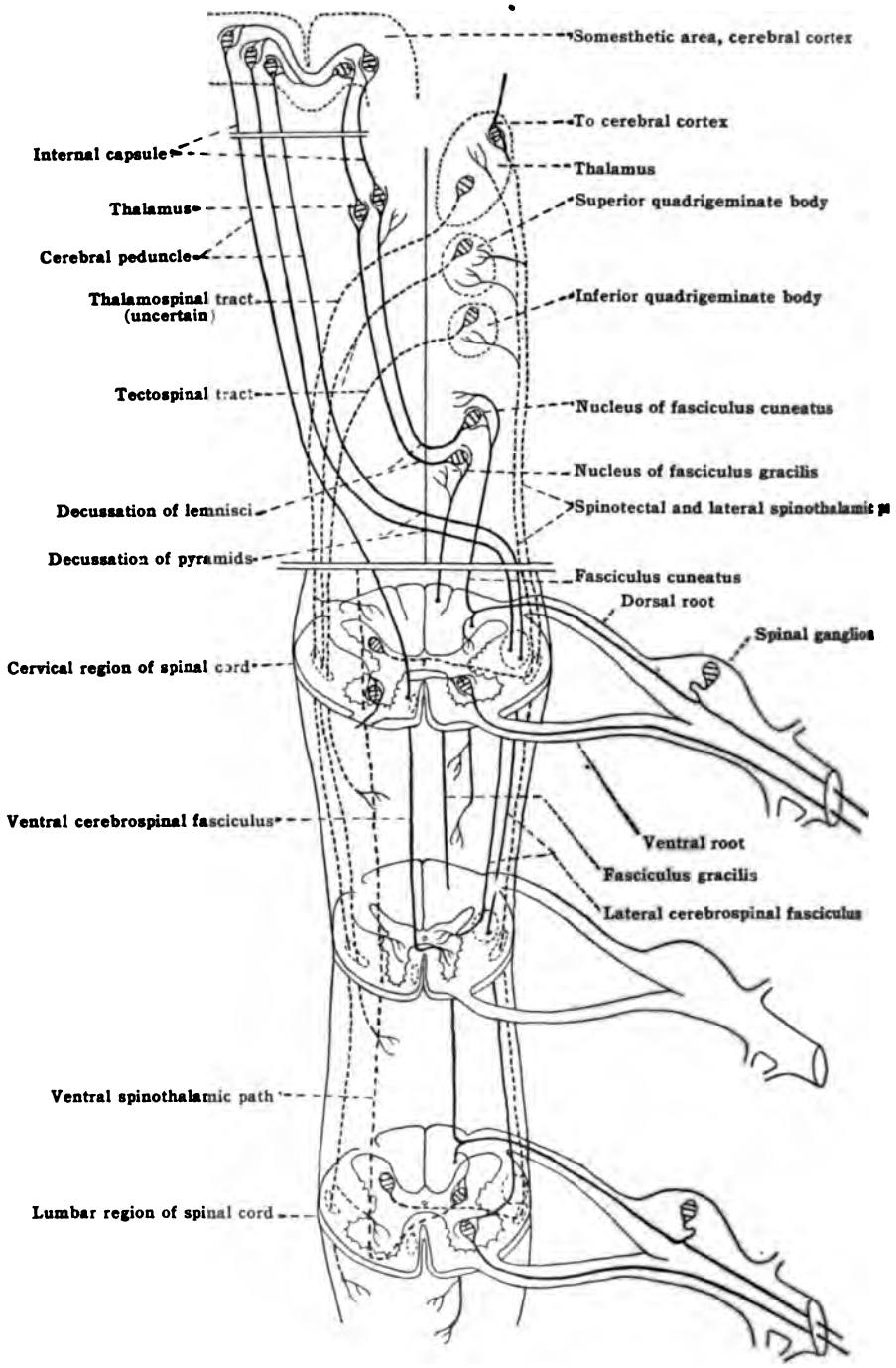
In addition to the above components of the intermediate zone, the studies of Flechsig, von echterew and others suggest that the medial portion of the zone also contains fibers both ascend-g and descending, probably uncrossed, which associate the gray substance of the spinal cord ith the reticular formation of the medulla oblongata. Among the regions to which it is claimed ey have been traced are :the nuclei of origin of the facial and eye-moving nerves and om the nuclei of termination of the vagus, glossopharyngeal, auditory and trigeminal nerves. l of the intermediate zone grades into the lateral and ventral fasciculi proprii. The fasciculi oprii proper, the axones nearest the gray substance, serve for the intersegmental association the cord itself, while the intermediate zone may be considered as carrying axones which ve to associate more distant levels of the nerve axis, i.e., the gray substance of the cord with at of its upward continuation into the medulla, pons, mesencephalon and thalami. In gen-al terms, the relation of the cord to the cerebrum is a crossed relation, while its relation to e medulla, cerebellum and pons is uncrossed.

The anterior marginal fasciculus or ventral vestibulospinal tract forms the perficial boundary of the medial portion of the intermediate zone. It is a arrow band, on the surface of the cord, and extends medially from the medial tremity of Gowers' tract (from Helweg's bundle) to the beginning of the terior median fissure.

The axones belonging to it proper are descending from the recipient nuclei of the vestib-ar nerve. Of these nuclei it has been held by some investigators that only Deiters' nucleus e lateral nucleus of termination in the upper extremity of the medulla oblongata) gives gin to the axones of the anterior marginal fasciculus. Others agree with Tschermak that superior and more laterally situated Bechterew's nucleus of the vestibular nerve also tributes axones to it, and quite probably the nucleus of the spinal root of the vestibular ds further axones. Still other investigations have suggested that a part at least of the fas-ulus comes from the nucleus fastigius (roof nucleus) of the cerebellum. Since many axones m both Deiters' and Bechterew's nucleus terminate in the nucleus fastigius, the ventral tibulospinal fasciculus is, in any case, a conduction path from the nerve for equilibration to gray substance of the spinal cord. The fasciculus is said to extend as far as the sacral re-n of the cord, its axones terminating about the cells of the ventral horns. The term 'ven-l' is added to its name to distinguish it from the vestibulospinal tract described above as rsing in the lateral funiculus. It is considered an uncrossed pathway.

The **commissural bundle** is situated about the floor of the anterior me fissure, and is the most dorsal tract of the anterior funiculus. It contains d sating or commissural axones of four varieties.

FIG. 662.—DIAGRAM OF SPINAL CORD ILLUSTRATING THE TWO CHIEF VARIETIES OF S CEREBRAL AND CEREBROSPINAL NEURONE CHAINS. The ventral tectospinal (t marginal) fasciculus, fibers descending from the superior quadrigeminate bodies, i filled in.



(1) It contains the decussating axones of the ventral **cerebrospinal fasciculus throu** the extent of that fasciculus; (2) it is chiefly composed of the **axones of the ventral fasc** proprius which arise in the gray substance (ventral horn) of **one side, cross the midline a** missural fibers, and course both upward and downward to be **distributed to the neuro**

nt levels of the gray substance of the opposite side; (3) it contains decussating axones which rom cell-bodies in the gray substance of one side and cross the midline to terminate cell-bodies in practically the same level of the opposite side. The latter are merely s belonging to the ventral white commissure which course without the confines of the grey . (4) It carries most of the decussating fibers of the spinothalamic and spinotectal tracts. ommissural bundle is present throughout the length of the spinal cord, and is largest in largements, i. e., where the association and commissural neurones occur in greater number ally.

SUMMARY OF THE SPINAL CORD

he spinal cord contains two general classes of axones arranged into three ral systems. It contains axones which—(a) enter it from cell-bodies situated ide its boundaries, i. e., in the spinal ganglia and in the encephalon, and (b) es which arise from cell-bodies situated within its own gray substance, some hich axones pass outside its boundaries both to the periphery and into the phalon; some of which remain wholly within it. Its axones comprise—(1) stem for the intersegmental association of its gray substance, both ascending descending, association proper and commissural; (2) a spinocerebral and brospinal system, ascending and descending; and (3) a spinorhombencephalic nocerebellar and spinobulbar) and a rhombencephalospinal system, ascending descending.

For these relations the gray substance of the cord contains three general classes erve-cells: those which give rise to the peripheral efferent or motor axones he ventral roots; those which give rise to central axones of long course, going he encephalon; and those which supply its central axones of short course, association and commissural systems.

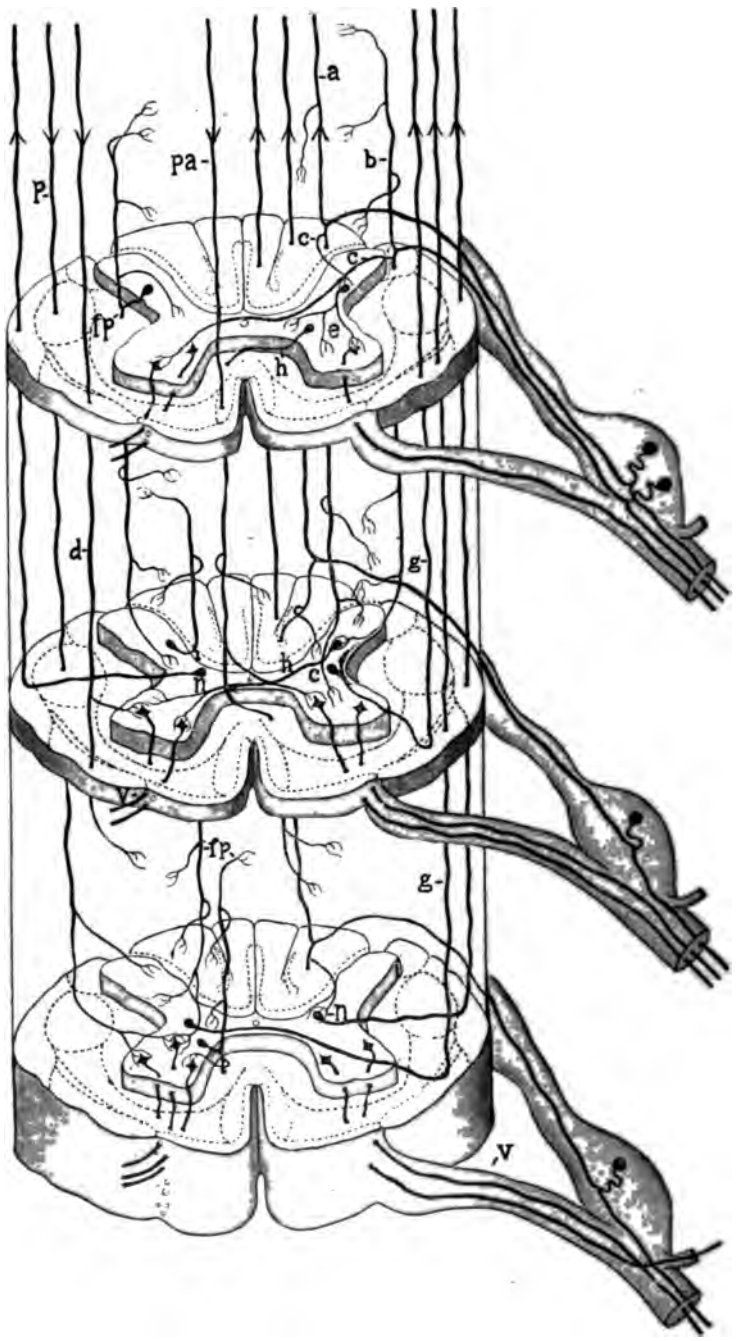
The three systems: (1) Association and commissural.—Axones of spinal ganglion (afferent) ones bifurcate within the cord into cephalic and caudal branches which extend varying nces upward and downward and terminate, (*a*) about cell-bodies whose axones are short terminate within the gray substance of the same side and in the same level as their cell-ies (*Golgi neurones of type II*); (*b*) about cell-bodies whose axones pass without the gray sub-ce, bifurcate into cephalic and caudal branches to terminate in the gray substance of the e side but in various levels above and below (association fibers in the *dorsal*, *lateral* and *ven-fasciculi proprii*); (*c*) about cell-bodies whose axones cross the midline to terminate either he same level of the gray substance of the opposite side, or bifurcate and the cephalic and al branches pass in the fasciculi proprii to terminate in various levels of the gray substance e opposite side. The longer cephalic branches of (*b*) and (*c*) may terminate in the medulla ngata. All, associated with ventral root (efferent) neurones, belong to the neurone-chains he so-called *reflex activities*.

2) **The cerebral system.**—(*a*) The cephalic branches of certain spinal ganglion neurones ed beyond the bounds of the spinal cord to terminate within the medulla. Those ascend-rom the spinal ganglia of lower thoracic and lumbosacral segments accumulate medially rm the *fasciculus gracilis* which terminates in the nucleus of this fasciculus; those arising the upper thoracic and cervical segments accumulate more laterally in the posterior fun-s to form the *fasciculus cuneatus* which terminates in the nucleus of the fasciculus cuneatus. he impulses transferred to the neurones of these nuclei are borne across the midline and ly reach the sensory-motor area of the cerebral cortex, and cell-bodies here give rise to es which *descend*, some decussating in the medulla to form the *lateral cerebrospinal fascicu-*others form the uncrossed *ventral cerebrospinal fasciculus* which crosses the midline as it de-ds the cord, practically all crossing in the cervical region. Both of these fasciculi transfer r impulses either directly to efferent ventral horn neurones, or to association neurones and e to the efferent neurones. (*c*) The cephalic and caudal branches of spinal ganglion neu-s terminate about cell-bodies in the dorsal horns of the cord whose axones cross the mid- and *ascend* laterally to terminate either in the quadrigeminate bodies (*spinotectal tract*), n the thalamus (*spinothalamic paths*). (*d*) Cell-bodies in the superior quadrigeminate es (receiving optic impulses) and in the inferior quadrigeminate bodies (probably mediating tory impulses), give axones which cross the midline in the mesencephalon and *descend*, ing the *tectospinal tracts*, to terminate in contact with the efferent neurones of the cord. es from both sources descend in the lateral funiculus, while from the superior quadrigemi-body, a separate bundle descends in the ventral funiculus as the *sulcomarginal* (*ventral pinal*) *fasciculus*. (*e*) The *rubrospinal tract* arises from cell-bodies in the red nucleus (in nesencephalon), crosses the midline in the ventral tegmental decussation and descends in ateral funiculus to transfer (probably cerebellar) impulses to the efferent neurones of the l cord.

3) **The rhombencephalic system.**—(*a*) The cephalic and caudal branches of spinal ganglion ones give telodendria about the cell-bodies forming the *dorsal nucleus* of the cord (Clarke's nn) and about cell-bodies situated in grey substances ventral to the dorsal nucleus and in with it in the lumbar and sacral regions. Axones arising from the cells of the dorsal nucleus laterally to form the *dorsal spinocerebellar fasciculus* which *ascends* into the cerebellum by of its inferior peduncle of the same side and terminates about cell-bodies of its cortex. es arising from near and in line with the dorsal nucleus, of both the *same* and opposite

FIG. 663.—SCHEMATIC REPRESENTATION OF THE MORE IMPORTANT ARCHITECTURAL REL OF NEURONES IN THE SPINAL CORD, OMITTING THOSE INVOLVING THE MESENCEPH AND THALAMUS.

a, afferent (spinal ganglion) axone of spinocerebral chain with bifurcation and caudal b, afferent axone coursing in Lissauer's zone, and distributed wholly within th c, collaterals of a and b disposed in three ways; p, pyramidal axone in lateral (c cerebrospinal fasciculus distributed to levels of grey substance; pa, axone in ventral c spinal fasciculus decussating before termination; v, ventral root or motor neuro nucleus dorsalis giving axone to dorsal spinocerebellar fasciculus; g, ascending n of Gowers' tract; d, descending axone from cerebellum (probable); fp, neurones of f proprii, association proper; h, commissural neurones; c, Golgi cell of type II.



of the cord, accumulate to form the *superficial ventrolateral spinocerebellar fasciculus*, h *ascends* to enter the cerebellum by way of its superior peduncle and terminate about the of the cerebellar cortex. (*b*) A few axones arising in the roof nucleus of the cerebellum ably *descend* in the *anterior marginal fasciculus* in company with the *ventral vestibulospinal* to terminate upon the efferent neurones of the cord. (*c*) The inferior olivary nucleus, in the lla, is a cerebellar relay and its cell-bodies are associated with the neurones of the upper ion of the same side of the spinal cord. Whether the axones arise in the olivary nucleus or e gray substance of the cord is uncertain, but the more usual supposition favors the cord thus the name *spino-olivary fasciculus* is given them. (*d*) Among its other functions, cerebellum is concerned with muscular tone and equilibration. The vestibular nerve is the rent nerve of equilibration and a large mass of the axones arising from its nuclei of termina- terminate in the cerebellum, in the roof nuclei especially. Axones arising from cell-bodies Deiters' nucleus (its lateral nucleus of termination) and in the nucleus of its descending root end the cord in the lateral funiculus to form the (lateral) *vestibulospinal tract*, and also in the rior *marginal fasciculus* to form *ventral vestibulospinal tract*. Impulses borne by these axones ch the efferent or motor root neurones. The rubrospinal fasciculus, mentioned above, also y be possibly considered as belonging to the cerebellar system. (*e*) The fasciculi proprii tain ascending and descending association-fibers between the spinal cord and the medulla ongatæ.

Sympathetic relations.—The cell-bodies of the efferent neurones in the ventral horns are two general varieties: (*a*) those whose axones terminate upon skeletal muscle (somatic erent), and (*b*) those whose axones terminate in contact with cell-bodies of sympathetic urones, *preganglionic* or *visceral efferent neurones*. The axones of the sympathetic neurones, their turn, terminate upon cardiac and smooth muscle (motor) and in glands (secretory). e the somatic, the visceral efferent neurones receive impulses within the ventral horns from the cephalic and caudal branches of spinal ganglion neurones, (*b*) the descending cere- spinal fasciculi, and (*c*) from either, by way of the fasciculi proprii and Golgi neurones of pe II. Their cell-bodies are situated for the most part in the dorsal rn (dorsolateral or intermediolateral group of cells), which is the only portion of the lateral rn present in the thoracic region of the cord. Many of the visceral efferent fibers leave the inal nerves distal to the spinal gangila and make the white communicating rami, thus going the nearest sympathetic ganglia; others pass on in the sympathetic nerves or in the trunk of e spinal nerve and its branches to terminate in more distant sympathetic ganglia. Some tones arising in symphatic ganglia enter the spinal cord by either the dorsal or ventral roots the spinal nerves or by separate roots (meningeal rami) to supply the muscle of the blood essels of the cord.

Functionally, the peripheral afferent (spinal ganglion) neurones have been referred to as *ceptors* and the efferent or peripheral motor neurones as *effectors*. According to the tissues nd organs innervated, they are grouped into (1) somatic receptors and effectors and (2) visceral ceptors and effectors. The somatic tissues are the skin, including its appendages and the pithelium of the organs of special sense, the subcutaneous fascia, membranes of joints, tendons nd skeletal muscle; the visceral tissues are all glands and glandular epithelium, cardiac uscle and all smooth muscle, including that of blood-vessels and hair-follicles. A somatic ferent neurone may give some of its branches in the cord for synapsis with visceral efferent urones.

Sherrington, Head and others who hold specific or separate afferent neurones for the differ- t sensations experienced suggest three groups of receptor neurones:

1. *An exteroceptive group*, comprising those spinal ganglion neurones whose peripheral ocesses collect impulses from the skin and its appendages especially (impulses aroused by muli outside the body), but doubtless from any or all the somatic tissues and even the visceral sues also, and which, in the cord, transfer these impulses to those cell-bodies in the dorsal rn whose axones cross the midline to form the two spinothalamic tracts of the opposite side. ie lateral of these tracts is claimed to carry sensations of pain and heat and cold, while to the ntral are given sensations of touch and pressure. These tracts terminate in the ventral and teral nuclei of the thalamus. In passing, each may give collaterals which form synapses with ie nuclei of origin of the motor cranial nerves. The inferior and lateral nuclei of the thalamus nd axones to the cerebral cortex and the corticospinal impulses aroused in response descend ie cord by way of the cerebrospinal fasciculi. The functions of the neurone chains of this oup are classed within 'conscious phenomena.' The neurones of the eye and cochlea are in- uded among the exteroceptive neurones of the cranial nerves.

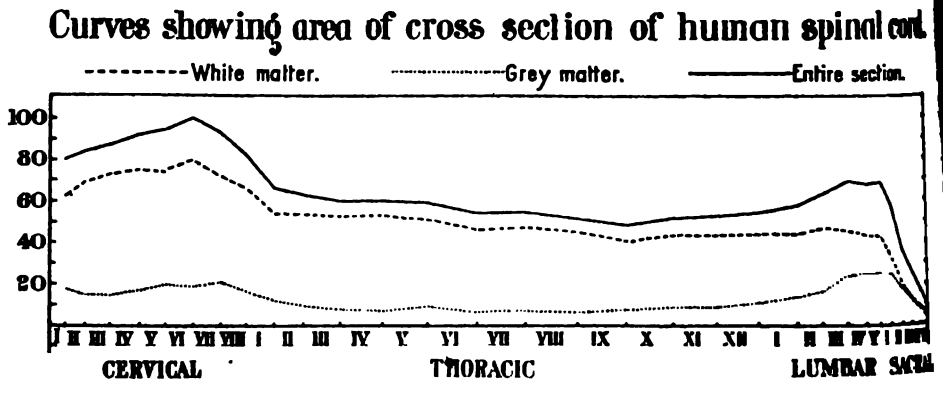
(2) *A proprioceptive group*. This group is subdivided into two classes: (*a*) spinal ganglion urones which collect impulses from the somatic tissues (skin, tendons, joints, skeletal muscle, c.) and whose cephalic branches within the cord form the fasciculus gracilis and fasciculus neatus. The nuclei of termination of these fasciculi in the medulla give rise to the medial nniscus of the opposite side and this transfers the impulses to the ventral thalamic gray sub- ance, whose cell-bodies in turn send axones to the cerebral cortex. Corticospinal impulses, scending in response, are distributed to the cord by the cerebrospinal fasciculi. The neurone ains included are claimed to mediate tactile sensations of position and spatial relations and to ake possible motor control, aiding also in regulating reactions mediated through the extero- ptive group. Most of the functions of this class are likewise within consciousness. (*b*) inal ganglion neurones which collect impulses from the somatic tissues, especially from ten- ns, joints, skeletal muscle and muscle-fasciæ, and which in the spinal cord give collaterals d terminal twigs to the cell-bodies giving origin to the dorsolateral and superficial ventro- eral spinocerebellar fasciculi. The chief functions of the cerebellum are coördination of uscular contractions and maintenance of muscular tone. Impulses from it are distributed the cord by way of the rubrospinal and cerebrospinal fasciculi. The functions of the neu- nes of this class are considered unconscious. The neurones of the vestibular nerve (auditory brinth, exclusive of cochlea) are considered *proprioceptive*.

3. *An interoceptive group* (visceral receptors), comprising those spinal ganglion neu... which collect impulses from the visceral tissues (the epithelium of the digestive canal, incl... the infoldings of the skin continuous with it, from all glands, from the epithelium lining ... cavities of the body, from blood-vessels and probably from smooth and cardiac muscle), ... which in the cord give collaterals and terminal twigs for synapses with the dorsolateral (v... efferent) cell-group of the grey column. These cell-bodies give rise to ventral root (pre... glionic) axones which form synapses in the sympathetic ganglia, the cells of which in turn gi... sympathetic or postganglionic axones for the secretory and motor innervation of glands ... smooth muscle (visceral effectors). The afferent or visceral receptors also give branches w... form synapses with the neurones of the fasciculi proprii of the cord, the longer of which ... transfer impulses to visceral efferent or preganglionic neurones in the cranial nerves. Cer... of the cranial nerves, the vagus especially, are very rich in both visceral receptors and v... effectors. The central control of the muscle of the heart and of many of the blood-vessels ... the body, of the lungs, esophagus, stomach and intestine, is largely mediated by the vagus.

It must be remembered that the above three general groups of neurones functionally ... anatomically overlap each other. An afferent neurone of either the exteroceptive or proprio... ceptive group may, in the cord, give some of its many terminals to form synapses with visce... efferent neurones, and a visceral receptor may give a branch in the cord whose synapsis w... make it a chain from the peripheral structures to the cerebral cortex, bringing sensations arou...

FIG. 664.—GRAPHIC REPRESENTATION OF THE VARYING AMOUNTS OF GRAY AND WHITE SUBSTANCE AND OF THE VARIATIONS IN AREA OF ENTIRE SECTIONS OF THE DIFFERENT SEGMENTS OF THE SPINAL CORD. (From Donaldson and Davis.)

(Based upon measurements from several adult human spinal cords.)



in the visceral organs into the domain of consciousness, as sensations of pain, pressure, temperature, etc. Also, the contention for a specific afferent neurone for conveying each of the many varieties of sensation, verbally indicated by man, is not satisfactorily supported. There are peculiar anatomical differentiations of peripheral tissue-elements (sense organs) of such character and arrangement as to be especially acted upon, specifically irritated, each by a certain form of stimuli. It is probable that, terminating in any tissue, impulses may be aroused in any spinal ganglion neurone by any form of stimulus. These impulses reaching the cerebral cortex or entering 'consciousness', are analyzed and designated there according to the character, quality and intensity of the stimulus applied and according to the locality of its application. Certain tracts in the cord carry impulses destined for certain areas of the cerebral cortex especially devoted to the analysis of certain forms of stimuli.

In transverse sections of the spinal cord (figs. 658, 664), the relative area of white substance as compared with that of gray increases as the cord is ascended. The absolute area of each varies with the locality, both being greatest in the enlargements. The gray substance predominates in the conus medullaris and lower lumbar segments. The white substance begins to predominate in the upper lumbar segments, not because of the increased presence of ascending and descending cerebral and cerebellar axones, but because of the increased volume of the fasciculi proprii coincident with the greater mass of gray substance to be intersegmentally associated in this region. In the thoracic region the greatly predominating white substance is composed mostly of the axones of long course. The greatly increased absolute amount of white substance in the cervical region is due both to the greater accumulation of cerebral and cerebellar axones in this region and to the increased volume of the fasciculi proprii necessary for the increased amount of gray substance of the cervical enlargement.

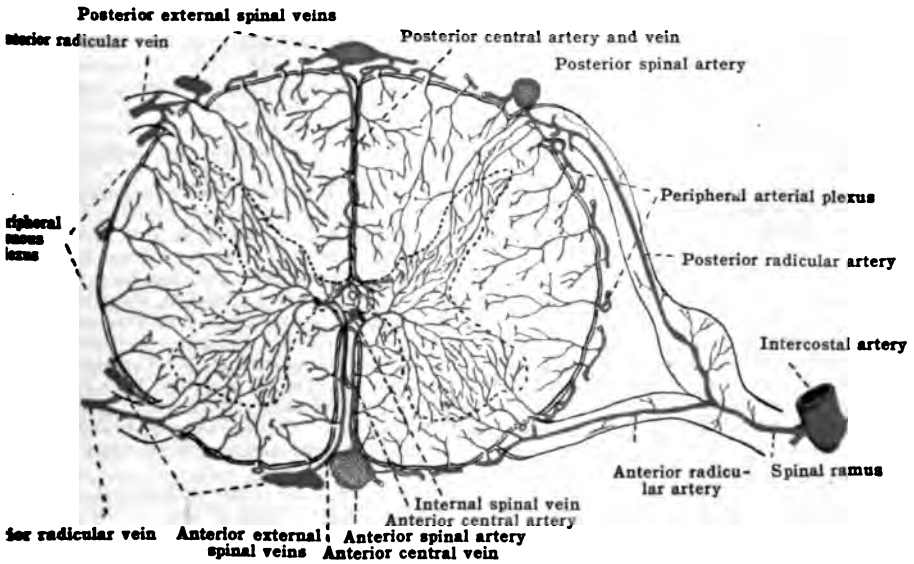
ER OF MEDULLATION OF THE FASCICULI OF THE CORD

he axones of the spinal cord begin to acquire their myelin sheaths during the fifth month of terine life and myelinization is not fully completed till between the fifteenth and twentieth . In general, axones which have the same origin and the same locality of termination—e function—acquire their sheaths at the same time. While it has been proved that the ary sheath does not necessarily precede the functioning of an axone, it may be said that sciculi which first attain complete and definite functional ability are the first to become ated. At birth all the fasciculi of the spinal cord are medullated except the spino-olivary us, and occasionally the lateral and ventral cerebrospinal tracts. The latter tracts vary erably and in general may be said to become medullated between the ninth month (before and the second year. As indicated by their medullation, those axones by which the cord bled to function as an organ *per se*, that is, the axones making possible the simpler reflex ies, complete their development before those axones which involve the brain with the ties of the cord.

ecording to Flechsig and van Gehuchten, and investigators succeeding them, the following order in which the axones of the cord become medullated:

1.) The afferent and efferent nerve-roots and commissural fibers of the gray substance.
2) The fasciculi proprii, first the ventral, then the lateral, and last the dorsal, fasciculus rius.
3) The fasciculus cuneatus (Burdach's column) and Lissauer's zone—the area of those ding spinocerebral fibers which run the shorter course and which convey impulses from pper limbs, thorax and neck.
(4) Fasciculus gracilis (Goll's column).
(5) The dorsal spinocerebellar fasciculus (direct cerebellar tract).
(6) The superficial anterolateral spinocerebellar fasciculus (Gowers' tract).
(7) The lateral cerebrospinal fasciculus (crossed pyramidal) and the ventral cerebrospina sculus (direct pyramidal tract).
(8) The spino-olivary fasciculus.
he remaining fasciciul are so mixed with other axones that it is difficult to determine the nce of their medullation. The fasciculi containing them also contain axones of the variety he fasciculi proprii and so show medullation early.

G. 665.—Semi-diagrammatic Representation of the Blood-supply of the Spinal Cord.



Blood-supply of the Spinal Cord

he spinal rami of the sacral, lumbar, intercostal, or vertebral arteries, as the case may be, npany the spinal nerves through the intervertebral foramina, traverse the dura mater rachnoid, and each divides into a dorsal and a ventral radicular artery. These accompany erve-roots to the surface of the cord, and there break up into an anastomosing plexus in ia mater. From this plexus are derived three tortuously coursing longitudinal arteries numerous independent central branches, which latter penetrate the cord direct. Of the tudinal arteries, the **anterior spinal artery** zigzags along the anterior median fissure and off the anterior central branches, which pass into the fissure and penetrate the cord. These hes give off a few twigs to the white substance in passing, but their most partial distribus to the ventral portion of the gray substance. The two **posterior spinal arteries,** one on side, course near the lines of entrance of the dorsal root-fibers. They each branch and omose, so that often two or more posterior arteries may appear in section upon either side

of the dorsal root. These give off transverse or central twigs to the white substance, but cially to the gray substance of the dorsal horns. Of the remaining central branches many the cord along the efferent fibers of the ventral roots, and are distributed chiefly to the substance; others from the peripheral plexus throughout penetrate the cord and break u capillaries within the white substance. Some of the terminal twigs of these also enter the substance. The-blood supply of the gray substance is so much more abundant than th the white substance that in injected preparations the outline of the gray figure may be distinguished by its abundance of capillaries alone. The central branches are of the ter variety. In the white substance the capillaries run for the most part longitudinally, or pa with the axones. The radicular arteries in passing give twigs supplying the spinal gangli the nerve-roots.

The *venous system* is quite similar to the arterial. The blood of the central arteries lected into corresponding central venous branches which converge into a superficial v plexus in which are six main longitudinal channels, one along the posterior median sulcu along the anterior median fissure, and one along each of the four lines of the nerve These comprise the **posterior** and **anterior external spinal veins** (fig. 665).

The **internal spinal veins** course along the ventral surface of the gray commissure, an from the convergence of certain of the twigs flowing into the *anterior central veins*. The po *central vein* courses along the posterior median septum in company with the posterior c artery, and empties into the *median dorsal vein*. The venous system communicates wi coarser extradural or internal vertebral plexus chiefly by way of the **radicular veins**.

II. THE BRAIN OR ENCEPHALON

The brain is that greatly modified and enlarged portion of the central ne system which is enclosed within the cranial cavity. It is surrounded an ported by the same three membranes (meninges) that envelop the spinal While there is a considerable subarachnoid space, the brain more nearly f cavity than does the spinal cord.

The average length of the brain is about 165 mm. and its greatest transverse d about 140 mm. It averages longer in the male than in the female. Exclusive of its dur the normal brain weighs from 1100 to 1700 gm. (40–60 oz.), varying in weight with the of the individual or with the bulk of the tissues to be innervated. Its average weight gm. (48 oz.) in males and 1250 gm. (44 oz.) in females. It averages about fifty times than the spinal cord, or about 98 per cent. of the entire central nervous system. In its pr growth it is at birth relatively much larger than at maturity. At birth it comprises a per cent. of the total body-weight, while at maturity it averages only about 2 per the weight of the body. Its specific gravity averages 1.036. In proportion to the bod the brain-weight averages somewhat higher in smaller men and women. Some ve dogs and monkeys and some mice have brains heavier in proportion to body-weig does man.

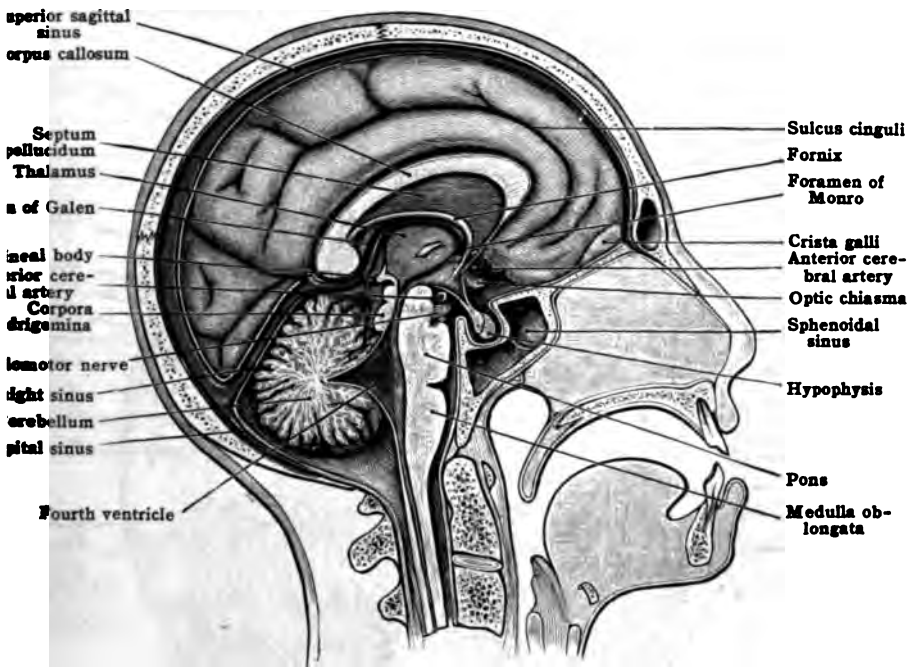
The minimal weight of the adult brain compatible with human intelligence may b at from 950 to 1000 grams. Above the minimal, there is only a general relation bet degree of intelligence and the weight of the brain, owing to the fact that several factor coincident with large brains. It may be said in general, however, that the average brai of eminent men is above the general average. Some men judged eminent have ha weighing less than the general average. Of the records generally accepted, the greate weight for eminent men is 2012 grams, recorded for the poet and novelist, Ivan Tourgeni trustworthiness of this weighing is doubted by some authorities. From the undispute the following may be taken: Cuvier, 1830 grams; John Abercrombie, 1786 grams; T 1658 grams; Kant, 1600 grams; Spurzheim, 1559 grams; Daniel Webster, 1518 gra Agassiz, 1495 grams; Dante, 1420 grams; Helmholtz, 1440 grams; Goltz, 1395 grams 1352 grams; Walt Whitman, 1282 grams; Gall, 1198 grams. In the average brain-w the races that for the Caucasian stands highest, the Chinese standing next, then th followed by the Negro, with the Australian lowest.

The differences between the meninges of the brain and those of the spinal cord occ in the dura mater. The *dura mater* is about double the thickness of that of the spi and consists of two closely adhering layers, the outermost of which is the internal pe of the cranial bones, while that of the cord is entirely separate from the periosteum vertebral canal. The inner layer is duplicated in places into strong partitions whi between the great natural divisions of the encephalon. Of these, the sickle-shaped f extends between the hemispheres of the cerebrum, the crescentic *tentorium cerebell* between the cerebellum and the overlapping posterior portion of the cerebrum, and th *falx cerebelli* occupies the notch between the hemispheres of the cerebellum. Contain these partitions of the dura mater are the great collecting venous sinuses of the brai will be considered in the more detailed description of the cranial meninges.

General topography.—In its superior aspect or **convex surface** the enc is oval in contour, with its **frontal pole** usually narrower than its occipi Viewed from above, the **cerebrum** comprises almost the entire dorsal asp occipital lobes overlapping the **cerebellum** to such an extent that only th and lower margins of the cerebellar hemispheres are visible. The great dinal fissure of the cerebrum separates the cerebral hemispheres.

aterally the **temporal lobes,** with their rounded anterior extremities, the **tem-** l **poles,** are each separated from the frontal and **parietal lobes** above by the **al cerebral fissure** (fissure of Sylvius). In the depths of this fissure and over- **ed** by the temporal lobe is situated the **insula,** or **island of Reil** (central lobe). The surface of each cerebral hemisphere is thrown into numerous folds or **ed** elevations, the **gyri cerebri** or convolutions, which are separated from each **r** by slit-like fissures, the **sulci cerebri.** The gyri (and sulci) vary greatly in **th,** in depth, and in their degrees of curvature. The larger and deeper of them similar in the two hemispheres; most of them are individually variable, but **i** gyrus of one hemisphere is homologous with that of the like region of the **r** hemisphere. By gently pressing open the great longitudinal fissure, the **us callosum,** the chief commissural pathway between the cerebral hemi-

FIG. 666.—MEDIAL SECTION OF THE HEAD OF A FEMALE THIRTY-FIVE YEARS OLD.



res, may be seen. The occipital margin of this large transverse band of white **tance** is rounded and thickened into the **splenium** of the corpus callosum, **e** its frontal margin is curved downward into its **genu** and rostrum.

The base of the encephalon (fig. 667) is more irregular than the convex surface, consists of a greater variety of structures. In the midline between the frontal **s** appears the anterior and inferior extension of the great longitudinal fissure. **en** the margins of this are separated, the outer aspect of the **rostrum** of the ***us callosum,*** the downward continuation of the curve of the genu, is exposed. The inferior surface of each frontal lobe is concave, due to its compression upon superior wall of the orbit. The *orbital gyri* with their respective *orbital sulci* **ipy** this concave area.

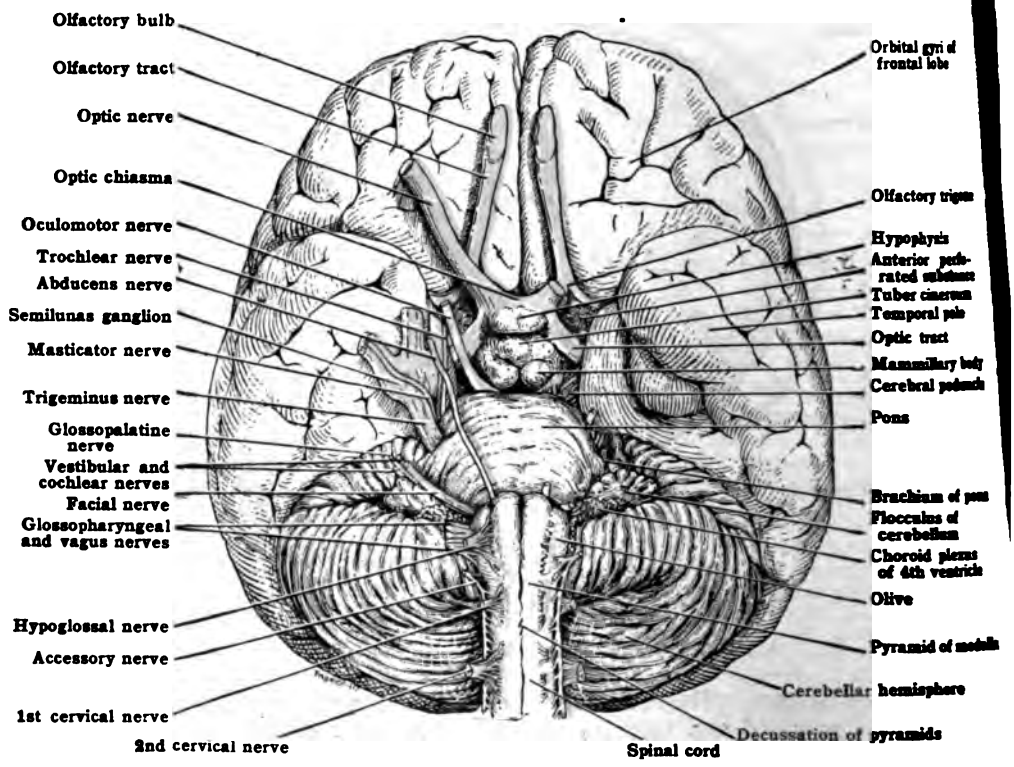
The cranial nerves [nervi cerebrales].—Along the mesial border of each orbital **l,** and parallel with the great longitudinal fissure, lie the **olfactory bulbs** con- **ed** into the **olfactory tracts.** Each olfactory bulb is the first central connec- **. or** the 'nucleus of termination' of the **olfactory nerve,** the first of the cranial **res.** A few fine filaments of this nerve may often be discerned penetrating the **tral** surface of the bulb. The olfactory bulb and tract lie in the *olfactory* ***us,*** which forms the lateral boundary of the *gyrus rectus,* the most medial **as** of the inferior surface of the frontal lobe. Upon reaching the parolfactory **a of Broca,** or the region about the posterior extremity of the gyrus rectus, each **ctory tract** undergoes a slight expansion, the **olfactory tubercle,** and then

divides into three roots or **olfactory striæ**—a medial, an intermediate, and a lateral, which comprise the **olfactory trigone.** The striæ begin their respective courses upon the **anterior perforated substance,** an area which contains numerous small foramina through which the anterolateral group of central cerebral arteries enters the brain. This region forms the anterior boundary of that area of the base of the encephalon in which the substance of the brain becomes continuous across the midline.

At the posterior boundary of the anterior perforated substance the **optic nerves** come together and fuse to form the **optic chiasma.** Thence the **optic tracts** disappear under the poles of the temporal lobes in their backward course to the *thalami,* the geniculate bodies and superior quadrigeminate bodies.

Immediately behind the optic chiasma occurs that diverticulum from the floor of the third ventricle known as the **tuber cinereum.** It is connected by its tubular

FIG. 667.—VIEW OF THE BASE OF THE BRAIN. (Spalteholz's Atlas.)



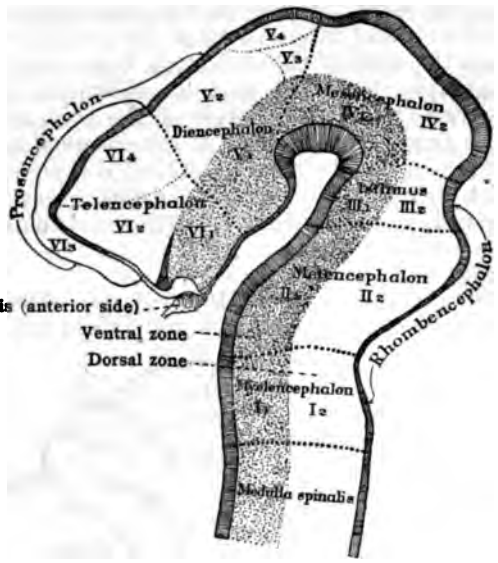
stalk, the **infundibulum,** with the **hypophysis** or pituitary body, which occupies its special depression (sella turcica) in the floor of the cranium and is usually torn from the encephalon in the process of its removal. Behind the tuber cinereum are the two **mammillary bodies** (corpora albicantia), each of which is connected with the fornix, one of the larger association fasciculi of the cerebrum. The **peduncles of the cerebrum** (crura cerebri) are the two great funiculi which associate the cerebral hemispheres with all the structures below them. They diverge from the anterior border of the **pons** (Varoli) and, one for each hemisphere, disappear under the poles of the temporal lobes. The pons (brachium pontis or middle cerebellar peduncle) is chiefly a bridge of white substance or a commissure between the cerebellar hemispheres.

The **oculomotor** or third pair of cranial nerves make their exit from the posterior perforated substance in the interpeduncular fossa just behind the corpora mammillaria.

The **trochlear nerves** emerge around the lateral aspects of the cerebral peduncles along the anterior border of the pons. The trochlear is the smallest of the cranial nerves, and the only pair arising from the dorsal aspect of the brain.

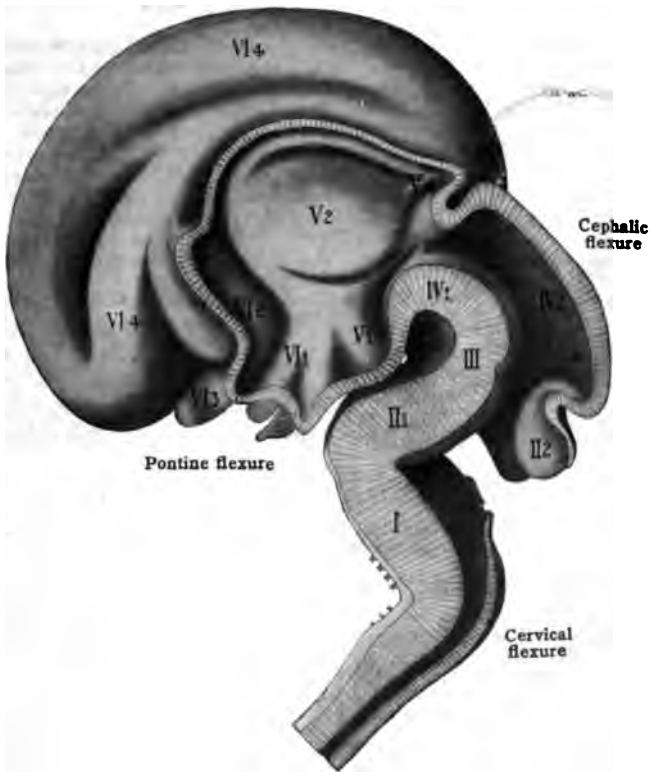
668.—MEDIAN SAGITTAL SECTION THROUGH EMBRYONIC HUMAN BRAIN AT END OF FIRST MONTH. (After His.)

ring the localities of origin of the derivatives of the vesicles named in outline on p. 834.)



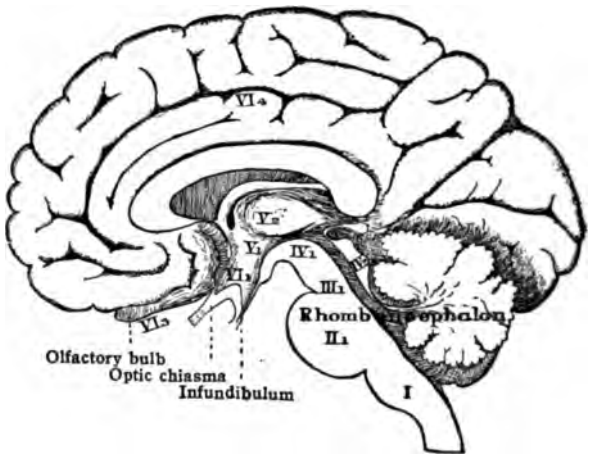
69.—SAGITTAL SECTION OF BRAIN OF HUMAN EMBRYO OF THE THIRD MONTH. (After His.)

rence numerals correspond with those of fig. 668 and those after names of parts in outline on p. 834.)



In its general conformation four natural divisions of the brain are apparent; the two most enlarged portions—(1) the cerebral hemispheres and (2) the cerebellum; (3) the midbrain (mesencephalon) between the cerebral hemispheres and the cerebellum, and (4) the medulla oblongata, the portion below the pons and above the spinal cord (fig. 645). However, the most logical and advantageous arrangement of the divisions and subdivisions of the encephalon is on the basis of their development from the walls of the embryonic brain vesicles. (See fig. 641.) On this basis, for example, both the medulla oblongata and the cerebellum with its pons are derived from the posterior of the primary vesicles, and are, therefore, included in a single gross division of the encephalon, viz., the *rhombencephalon*. In the outline on p. 834 the anatomical components of the encephalon are arranged with reference to the three primary vesicles from the walls of which they are derived, and the primary flexures and thickenings of the walls of which they are elaborations.

FIG. 670.—MEDIAN SAGITTAL SECTION OF ADULT HUMAN BRAIN. (Drawing of model by His.) (Reference numerals same as in figs. 668 and 669.)



During the early growth of the neural tube its basal or ventral portion and the lateral portions acquire a greater thickness than the roof of the tube, and thus the tube is longitudinally divided into a ventral zone and an alar or dorsal zone. This is especially marked in the brain. Thickenings arising from the dorsal zone begin as localized thickenings of the roof. For example, in the rhombencephalon the greater part of the medulla oblongata and of the pons region is derived from the ventral zone, while the cerebellum is derived from the superior part of the dorsal zone of the posterior vesicle. The first of the flexures occurs in the region of the future mesencephalon, and is known as the **cephalic flexure**; next occurs the **cervical flexure**, at the junction with the spinal cord; third, the **pontine flexure**, in the region of the future fourth ventricle. Both the cervical and pontine flexures, while having a significance in the growth processes, are almost entirely obliterated in the later growth of the encephalon.

The location of the development of the various parts of the encephalon may be determined, and their elaboration and changes in shape and position may be traced by comparing the accompanying figs. 668, 669, 670. The reference numbers in the last three figures correspond with the like numerals after the names of the parts on p. 834 in the outline of the divisions of the encephalon. The more detailed subdivisions of the parts will be met with in their individual descriptions.

THE RHOMBENCEPHALON

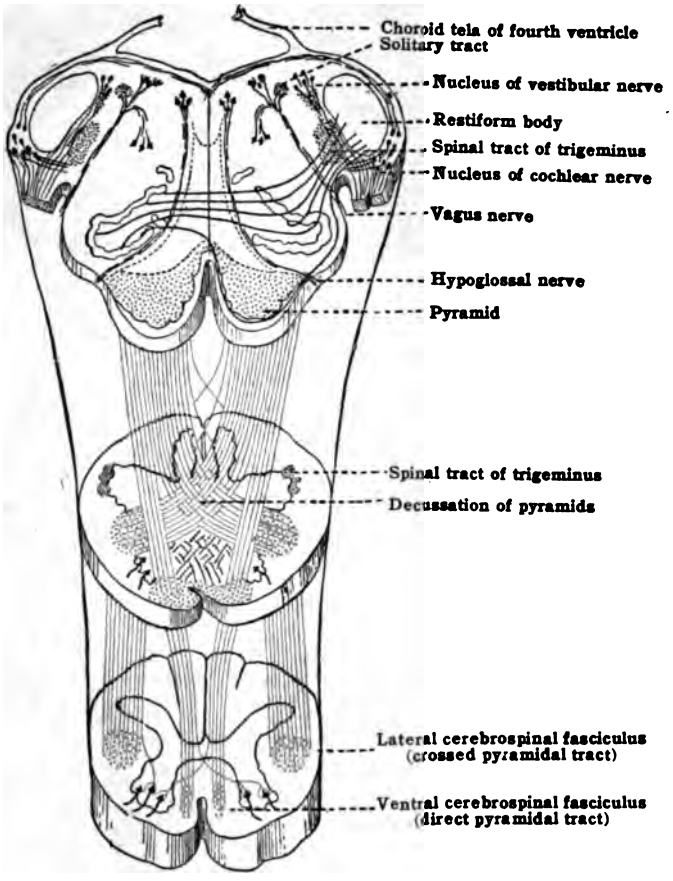
1. THE MEDULLA OBLONGATA

The **medulla oblongata** [myelencephalon] is the upward continuation of the spinal cord. It is only about 25 mm. long, extending from just above the first cervical nerve (beginning of the first cervical segment of the spinal cord) to the inferior border of the pons. It lies almost wholly within the cranial cavity, resting upon the superior surface of the basal portion of the occipital bone, with its lower extremity in the foramen magnum. Its weight is from 6 to 7 gm. or about one-half of 1 per cent. of the central nervous system. It is a continuation of the

[redacted]inal cord, and more. It contains structures continuous with and homologous [redacted]o the structures of the spinal cord, and in addition it contains structures which [redacted]ve no homologues in the spinal cord. Due in part to these additional struc[redacted]res, the medulla, as it approaches the pons, rapidly expands in its dorsoventral [redacted]nd especially in its lateral diameter. With it are associated nine of the pairs of [redacted]ranial nerves.

On its **ventral aspect** (figs. 667, 709) the anterior median fissure of the spinal [redacted]ord becomes broader and deeper because of the great height attained by the [redacted]yramids. At the level at which the pyramids emerge from the pons, the region in [redacted]which they are largest, the fissure terminates in a triangular recess so deep as to

FIG. 671.—DIAGRAM SHOWING THE DECUSSATION OF THE PYRAMIDS.
The uppermost level represented is near the inferior border of the pons.

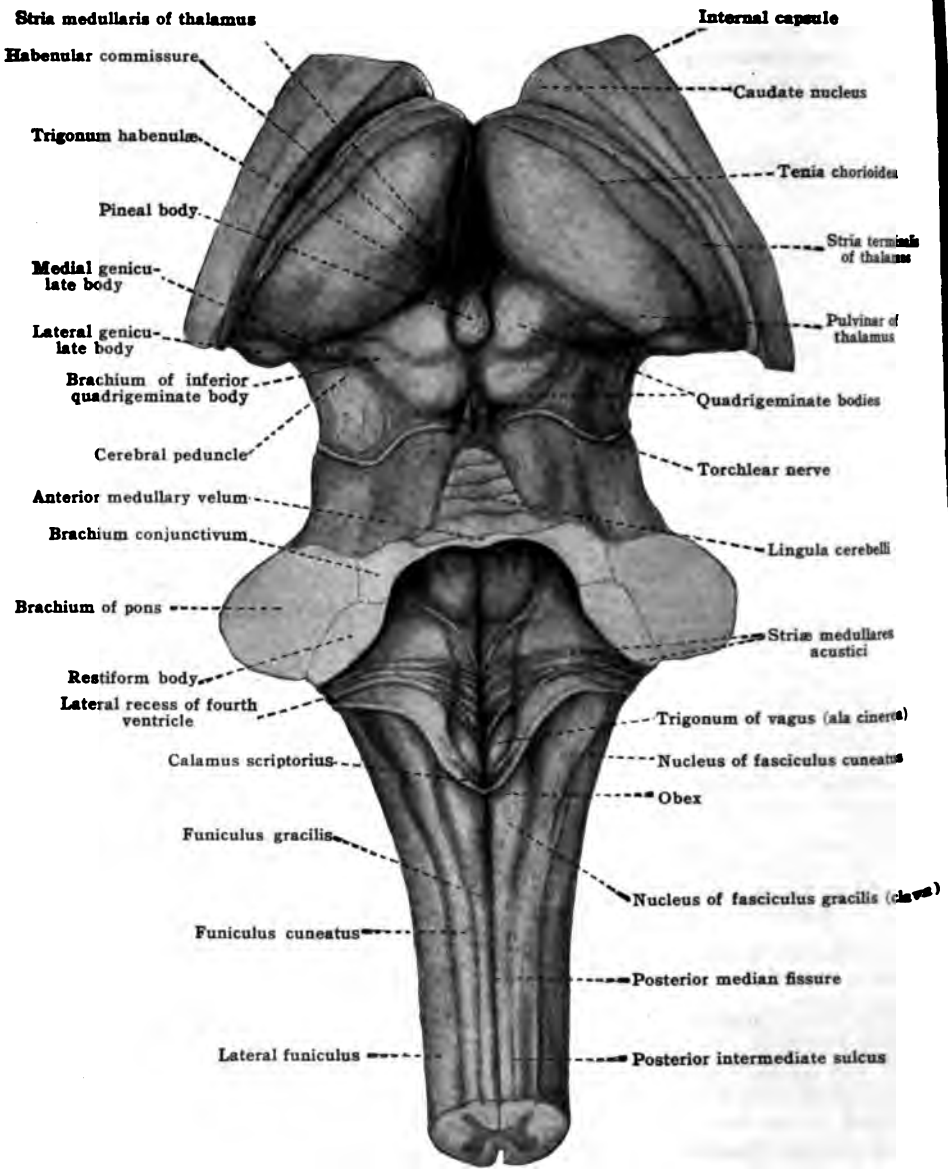


merit the name **foramen cecum.** The pyramids are the great descending cerebral or motor funiculi. In the medulla oblongata they decrease in bulk in passing toward the spinal cord, for the reason that many of the pyramidal axones are contributed to structures of the medulla, chiefly after crossing the midline. At the lower end of the medulla occurs the **decussation of the pyramids,** by which the anterior median fissure is almost obliterated for about 6 mm., and which, upon removal of the pia mater, may be easily observed as bundles of fibers interdigitating obliquely across the midline.

Not all the pyramidal fibers cross to the opposite side at this level in man, but a portion of those coursing in the lateral portion of the pyramid maintain their ventromedial position and continue directly into the spinal cord, to form there the ventral cerebrospinal fasciculus or direct pyramidal tract. However, most of such fibers finally cross the midline during their course in the cervical region of the spinal cord. The exact proportion of the direct fibers is variable, but always the greater mass of each pyramid crosses to the opposite side at the level of the decussation of the pyramids, and descends the cord as the lateral cerebrospinal fasciculus or crossed pyramidal tract. Both of these pyramidal tracts are described in the discussion of the fasciculi of the cord.

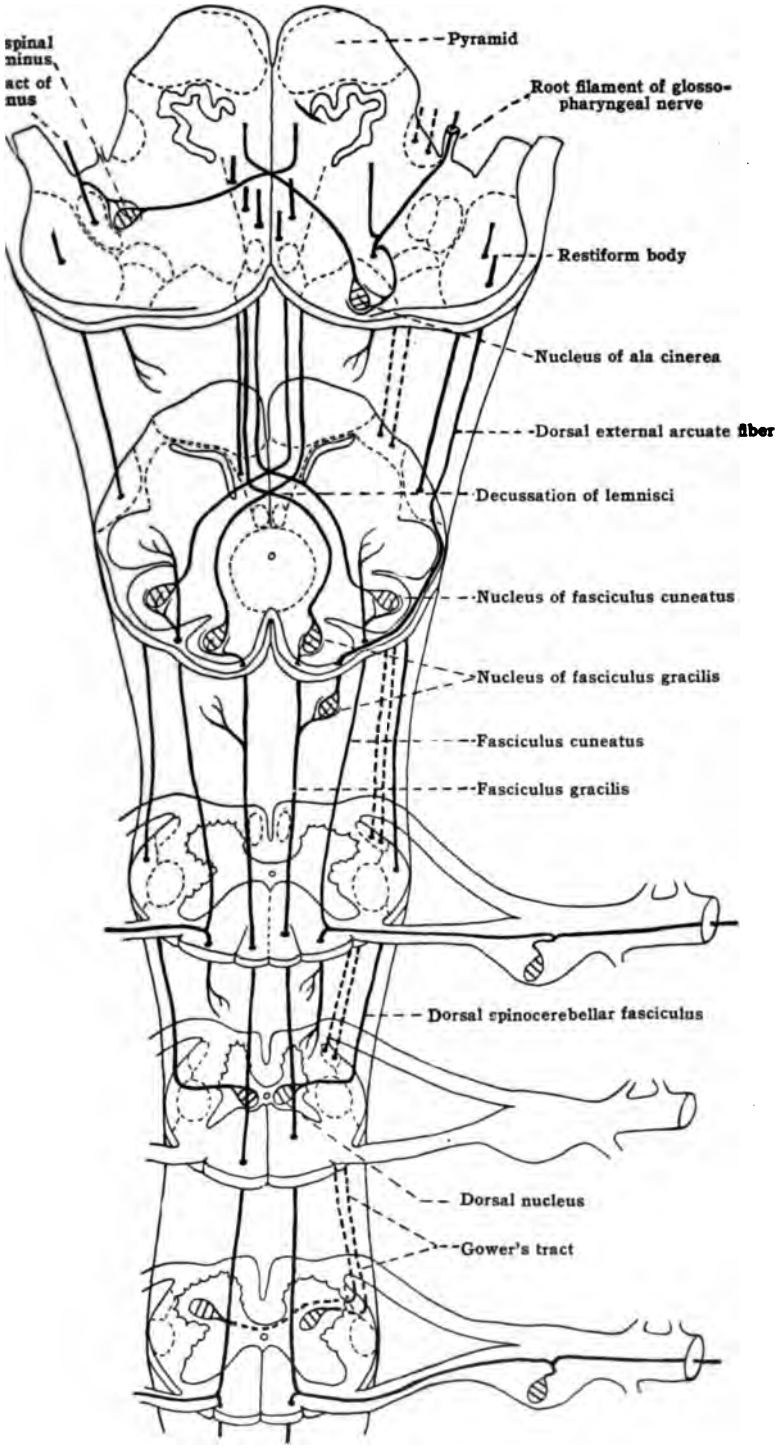
Each pyramid is bounded laterally by the **anterolateral sulcus,** also continuous with that of the same name in the spinal cord. Toward the pons this sulcus separates the pyramid from the **olive** [oliva] (inferior olivary nucleus), and in the region of the olive there emerge along this sulcus the root-filaments of the hypoglossal nerve. The olives, as their name implies, are oblong oval eminences about 1.2 cm. in length. They extend to the border of the pons, and are somewhat

FIG. 672.—DORSAL ASPECT OF MEDULLA OBLONGATA AND MESENCEPHALON, SHOWING THE FLOOR OF THE FOURTH VENTRICLE (RHOMBOID FOSSA). (Modified from Spalteholz.)



thicker at their upper ends. Their surfaces are usually smooth, **except at their** lower ends, where they frequently appear ribbed, owing to **bundles of the external arcuate fibers** passing across them to and from the *restiform* **body, which occupies** the extreme lateral portion of the medulla. Along the line **between the restiform** body and the olive are attached the root-filaments of the *vagus, glossopharyngeal,* and *spinal accessory nerves.* Both the *abducens* and the *facial* **nerve emerge along** the inferior border of the pons, the facial in line with **the glossopharyngeal, but** the abducens in line with the hypoglossus.

DIAGRAM OF THE SPINOCEREBELLAR FASCICULI AND THE ORIGIN AND DECUSSATION OF THE MEDIAL LEMNISCI.



Dorsal aspect.—The increased lateral diameter of the medulla oblongata is contributed to a great extent by the **restiform bodies.** These are the inferior cerebellar peduncles and contain the majority of the ascending fibers, which associate the cerebellum with the structures below it.

In toto, the restiform bodies are much larger than could be formed by the combined cerebellar fasciculi of the spinal cord, their great size being due to their receiving numerous axons coursing in both directions, which connect the cerebellum with structures contained in the medulla oblongata alone, so that in the medulla they increase as they approach the cerebellum. Their mesial borders form the lateral boundaries of the fourth ventricle. Their name (*restiform*, meaning rope-like) was suggested from the appearance frequently given them by the fibers of the cochlear nerve, which course around their lateral periphery to become the *striæ medullares* in the floor of the fourth ventricle.

Upon removal of the cerebellum it may be seen that below the *calamus scriptorius* (inferior terminus of the fourth ventricle) the structures manifest in the dorsal surface of the medulla are directly continuous with those of the spinal cord. The fasciculus gracilis (Goll's column) of the spinal cord acquires a greater height and volume and becomes the **funiculus gracilis** of the medulla, and because of this increased height the posterior median sulcus of the cord becomes deepened into the **posterior median fissure.** The posterior intermediate sulcus is also accentuated by the fasciculus cuneatus (Burdach's column) likewise now enlarged into the **funiculus cuneatus** of the medulla. The lateral funiculus of the medulla, of course, does not contain the lateral or crossed pyramidal tract present in the spinal cord.

At the border of the calamus scriptorius the funiculus gracilis terminates in a slight elevation, the **clava,** which is the superficial indication of the (terminal) **nucleus of the fasciculus gracilis.** Beginning somewhat more anteriorly, and having a somewhat greater length, is a similar enlargement of the funiculus cuneatus, the **tuberculum cuneatum** or **nucleus of the fasciculus cuneatus.**

These nuclei are the groups of nerve cell-bodies about which the ascending or sensory axones of the respective fasciculi terminate or where the sensory impulses are transferred to a second neurone in their course to the structures of the encephalon. These cell-bodies in their turn give off axones which immediately cross the midline and assume a more ventral position, contributing largely to the *lemniscus* or fillet of the opposite side. Thus such axones are the encephalic continuation of the central sensory ('proprioceptive')pathway conveying impulses from the periphery of one side of the body to the opposite side of the cerebrum. The crossing of these axones is known as the *decussation of the lemnisci.*

With the termination of the dorsal funiculi and the ventral course of the fibers of the lemnisci in their decussation, the central canal of the spinal cord loses its roof of nervous tissue in the medulla and comes to the surface as the fourth ventricle. The floor of the fourth ventricle, which corresponds to the floor of the central canal, is considerably widened into two **lateral recesses** opposite the junction of the inferior and middle cerebellar peduncles of either side, and, being pointed at both its superior and inferior extremities, it is rhomboidal in shape and thus is the **rhomboid fossa.** The pia mater of the spinal cord is maintained across the tip of the calamus scriptorius to form the **obex,** a small, semilunar lamina roofing over the immediate opening of the central canal. The obex carries a few medullated commissural fibers.

2. THE PONS

The **pons (Varoli)** is, for the most part, a great commissure or 'bridge' of white substance coursing across the ventral aspect of the brain-stem, and connecting the cerebellar hemisphere of one side with that of the other. In addition it contains considerable gray substance and fibers passing both to and from the structures of the brain-stem and the gray substance of the cerebellum, and fibers descending from the cerebral cortex. Each of its lateral halves forms the middle of the three cerebellar peduncles, the *brachium pontis* of either side.

In size it naturally varies directly with the development of the cerebellum, both in a given animal and relatively throughout the animal series. In man it attains its greatest relative size, and possesses a median or **basilar sulcus** in which lies the basilar artery. Its sagittal dimension varies from 25 to 30 mm., while its transverse dimension (parallel with the course of its fibers) is somewhat greater. It is a rounded white prominence interposed between the visible portion of the

cerebral peduncles (crura) above and the medulla oblongata below. Its *inferior margin* is rounded to form the **inferior pontine sulcus,** which, between the points of the emergence of the pyramids, is continuous with and transverse to the foramen cecum. Its *superior margin* is thicker and is rounded to form the **superior pontine sulcus,** which, between the cerebral peduncles, is continuous with and transverse to the interpeduncular fossa (figs. 667, 709). It is bilaterally symmetrical. The ventrolateral bulgings of its sides (and, therefore, the basilar sulcus) are produced by the passage through it of the fibers of the cerebral peduncles from above, to reappear as the pyramids below. Its ventral surface rests upon the basilar process of the occipital bone and the dorsum sellæ of the sphenoid, while its lateral surfaces are adjacent to the posterior parts of the petrous portions of the temporal bones.

The fibers of the thicker superior portion of the pons (*fasciculus superior pontis*) course obliquely downward to their entrance into the brachium of the pons and the cerebellar hemisphere; those of the lower and midportions (*fasciculus medius pontis*) course more transversely, naturally converging upon approaching the cerebellum. Certain fibers of the upper midportion course at first transversely and then turn abruptly downward across the fibers above them, to join the inferior portion of the brachium pontis. This bundle is termed the **oblique fasciculus** (fig. 709). The *trigeminus* or fifth cranial nerve penetrates the superior lateral portion of each brachium pontis near the point of the downward turn of the oblique fasciculus; its large afferent root and the masticator nerve (its small efferent root)accompany each other quite closely. On either side of the basal surface of the pons usually may be seen a small bundle of fibers which begins in the interpeduncular fossa, near or in the sulcus of the oculomotor nerve. It passes laterally along or under the superior border of the pons, loses some of its fibers in the lateral sulcus of the mesencephalon, then runs inferiorly between the superior cerebellar peduncle and the brachium of the pons to disappear in the junction of these. Being sometimes double, it is known as the **lateral filaments of the pons** (*fila lateralia pontis* or *tenia pontis*). The location of the cell-bodies giving origin to it is uncertain.

That portion of the rhombencephalon overlying the pons and forming the floor of the fourth ventricle is not really a part of the pons at all. It is merely a continuation of the brain-stem from the medulla below to the structures above. Therefore on the *dorsal surface* there is no line of demarcation between the pons and medulla below or between the pons and isthmus above. The fibers of the trigeminus and masticator nerve pass through the pontine fibers to and from their nuclei in the brain-stem.

3. THE CEREBELLUM

The **cerebellum** or *hindbrain* is the largest portion of the rhombencephalon. It lies in the posterior or cerebellar fossa of the cranium, and dorsal to the pons and medulla oblongata, overhanging the latter. It fits under the occipital lobes of the cerebral hemispheres, from which it is separated by a strong duplication of the inner layer of the dura mater, the *tentorium cerebelli.*

Its greatest diameter lies transversely, and its average weight, exclusive of the dura mater, is about 140 gm., or about 10 per cent. of the entire encephalon. It varies in development with the cerebrum, and, like it, averages larger in the male. It is relatively larger in adults than in children. Its development begins as a thickening of the anterolateral portion of the roof (dorsal zone) of the posterior of the three primary brain-vesicles. Resting upon the brain-stem, it roofs over the fourth ventricle and is connected with the structures anterior, below, and posterior to it by its three pairs of peduncles.

The surface of the cerebellum is thrown into numerous narrow folia or **gyri,** which in the given localities run more or less parallel with each other. They are separated by narrow but relatively deep **sulci.** Unlike the spinal cord and medulla, in which the gray substance is centrally placed and surrounded by a mantle of white substance, the surface of the cerebellum is itself a cortex of gray substance [substantia corticalis], enclosing a core of white substance, the *medullary body* [corpus medullare]. However, within this central core of white substance are situated definite gray masses, the *nuclei* of the cerebellum.

The **gross divisions** of the cerebellum are three: the two larger lateral portions, the **hemispheres,** and between these the smaller central portion, the **vermis.** The demarcation between these gross divisions is not very evident from the dorsal surface, because the hemispheres in their extraordinary development in man encroach upon the vermis, and, being pressed under the overlapping occipital ends of the cerebral hemispheres, they become partially fused upon the vermis along the dorsal midline.

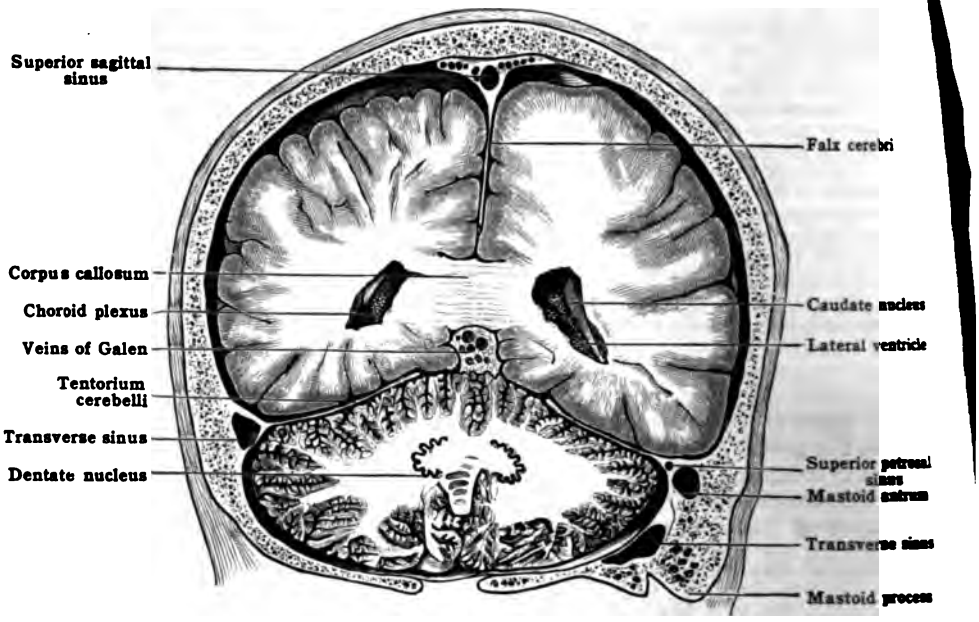
Though differentiated simultaneously with the cerebellar hemispheres in the human fetus, in most of the mammalia the vermis is the largest and most evident of the parts, and it is practically the only part which exists in the fishes, reptiles, and birds. In man, owing to the fact

that the vermis does not keep pace in development with the hemispheres, there results a very decided notch between the two hemispheres along the line of the entire ventral and inferior aspect of the cerebellum, the floor of this notch being the surface of the vermis.

The inferior portion of the notch between the hemispheres is the **posterior cerebellar notch** (incisura marsupialis); its prolongation above is wider than below, and is termed the **superior cerebellar notch.** It is occupied by a fold of the dura mater, the falx cerebelli. With the variations in contour of the cerebellum, certain of its sulci are broader and deeper, and merit the name **fissures.** These are more or less definitely placed, and subdivide the hemispheres into **lobes** and the vermis (the median lobe) into **lobules.**

Superior surface.—The superior surface is bounded from the inferior surface by the **horizontal fissure** (fig. 676) which extends anterolaterally, to the entrance of the brachium of the pons. Between this and the extreme anterior border of

FIG. 674.—SECTION OF HEAD PASSING THROUGH THE MASTOID PROCESSES AND BEHIND THE MEDULLA OBLONGATA, SHOWING THE POSITION OF THE CEREBELLUM.
(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)



the dorsal surface are two other fissures, the **posterior** and **anterior semilunar fissures.** These, like the horizontal fissure, may be traced, with slight interruptions, across the midline, and consequently mark off not only the two hemispheres but also the vermis into corresponding divisions.

The **superior semilunar lobe** [lobulus semilunaris superior] (posterosuperior lobe) of each hemisphere lies between the horizontal and the posterior semilunar fissures. It largely composes the outer border of the cerebellum, and, therefore, is the longest of the lobes.

The adjacent surface of the hemispheres anterior to the superior semilunar lobe, because of the frequently less complete development of the anterior semilunar fissure, is sometimes referred to as the **quadrangular lobe, with its** *posterior* and its *anterior portions.* On the other hand, especially when the anterior semilunar fissure is well marked, this area may be divided into—(1) the *posterior semilunar lobule*, between the posterior and anterior semilunar fissures, and (2) the *anterior semilunar lobule*, anterior to the anterior semilunar fissure (fig. 676).

Anterior to the quadrangular lobe on each hemisphere is the **ala of the central lobule** bounded by the postcentral and the precentral sulci. Anterior to this, on the anterior margin of the hemisphere, is the **vinculum lingulæ,** a slender process continuous with the lingula of the cerebellum (fig. 700).

The superior aspect of the vermis, the **superior vermis,** because of the fusion of the hemispheres, is, for the most part, a slight ridge, the **monticulus** (fig. 676).

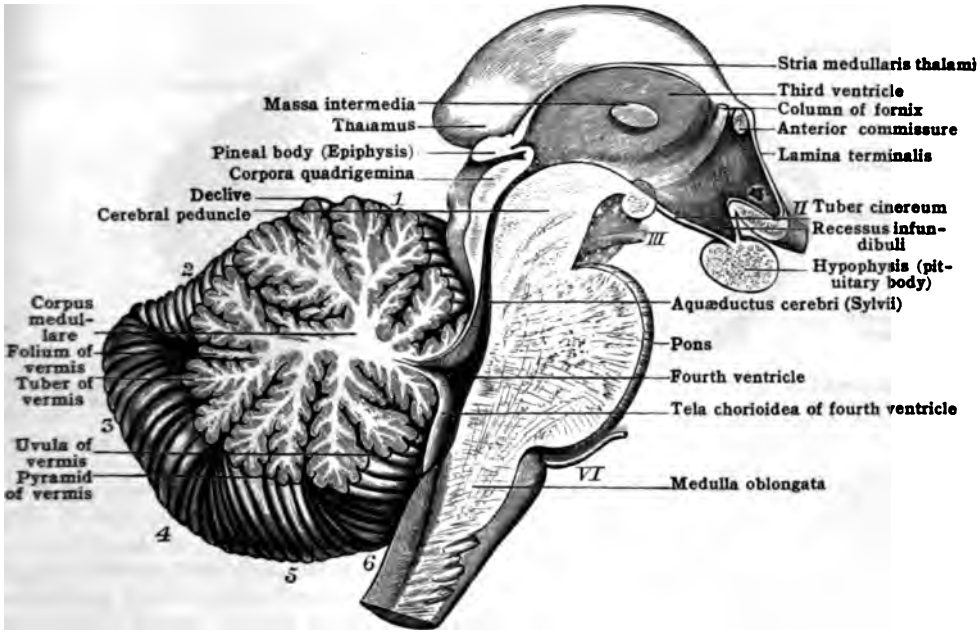
[illegible]ead of a depression. However, in the posterior portion of the superior sur[illegible]e the depression of the posterior notch begins, and here the horizontal and the [illegible]sterior semilunar fissures approach each other so closely that the correspond[illegible] subdivision of the vermis is seldom more than a single folium, the **folium ver[illegible]** (*cacuminis*).

The monticulus proper is divided into an inferior lobule, the **declive,** and a [illegible]perior lobule, the **culmen.** These appear as continuations across the midline [illegible] the posterior and anterior semilunar lobes of the hemispheres, and are sepa[illegible]ted by the corresponding fissures (fig. 676).

At the extreme anterior part of the superior surface and in the bottom of the [illegible]nterior cerebellar notch lies a more definitely defined portion of the vermis. This is the **central lobule** (fig. 676). It is broadened laterally into two pointed wings, the *alæ* of the central lobule, the folia of which, if present, are parallel with those of the anterior semilunar lobes and separated from them by the **post-central sulcus.**

FIG. 675.—MEDIAN SECTION THROUGH CEREBELLUM AND BRAIN-STEM. (Allen Thompson, after Reichert.)

1. Culmen monticuli; 2, superior semilunar lobe; 3, inferior semilunar lobe; 4, slender lobe; 5, biventral lobe; 6, tonsil.



If the anterior margin of the central lobule be lifted, the **lingula cerebell** (*lingula vermis*) will appear separated from the central lobule by the **precentra sulcus.** It is a thin, tongue-like anterior projection of the cortical substance comprising four to eight folia adhering upon the *anterior medullary velum,* the roof of the superior portion of tne fourth ventricle (figs. 675, 700).

Inferior surface.—The three cerebellar peduncles of each side join to form a single mass of white substance, and enter the ventral aspect of each hemisphere medially and ventrally in the extremity of the horizontal fissure. The inferior surface of the cerebellum is less convex than the superior surface. The hemispheres are decidedly separated by a continuation of the posterior cerebellar notch, which becomes broader, the **vallecula of the cerebellum,** which contains the inferior portion of the vermis, **vermis inferior,** and whose margins embrace the medulla oblongata. The inferior surfaces of the hemispheres are each divided by the intervening fissures into four lobes (fig. 677).

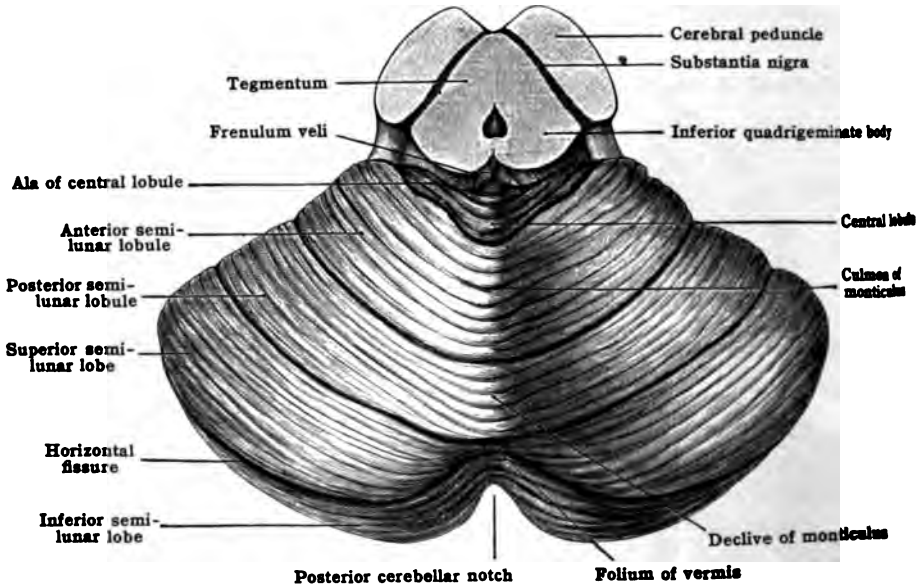
Below, the **inferior semilunar lobe** (posteroinferior lobe) is separated from the superior semilunar lobe of the superior surface by the horizontal fissure. It is the largest of the inferior lobes, and is broader at its medial extremity. Frequently

two and sometimes three of its curved sulci appear deeper than others, and separate it into two or three **slender lobules** [lobuli graciles]. More commonly there are two of these, the *lobulus gracilis posterior* and *lobulus gracilis anterior*, separated by the *posteroinferior sulcus*.

The **biventral lobe** is smaller and more curved than the inferior semilunar lobe, from the anterior margin of which it is separated by the curved **anteroinferior sulcus.** Its medial extremity is pointed and does not extend to the vermis; its lateral extremity is broader and curves anteriorly to the extremity of the horizontal fissure—the line of outer termination of the inferior semilunar lobe.

The **tonsil** [tonsilla cerebelli] (*amygdala*) is a rounded, triangular mass, placed medially within the inner curvature of the biventral lobe, and separated from it by the **retrotonsillar fissure.** Its inferior medial border slightly overlaps the vermis.

FIG. 676.—DIAGRAM OF THE SUPERIOR SURFACE OF THE CEREBELLUM. (The anterior and posterior semilunar lobes form the quadrangular lobe.)



The smallest of the lobes is the **flocculus.** It lies adjacent to the inferior and lateral surface of the mass of white substance produced by the confluence of the three cerebellar peduncles, and extends into the medial extremity of the horizontal fissure. It is so flattened that its short folia give it the appearance suggesting its name. Occasionally there is added a second, less perfectly formed portion, the *secondary flocculus*. From each floccular lobe there passes toward the midline a thin band of white substance, the **peduncle of the flocculus.** From the flocculi of the two sides the peduncles extend to meet each other at the most anterior portion of the inferior vermis, and thus form the narrow **posterior medullary velum.**

The **inferior vermis** (figs. 675, 677) is more definitely demarcated than the superior. Lying in the floor of the vallecula cerebelli, it is separated on each side from the adjacent lobes of the hemispheres by a well-marked sulcus about it, the *nidus avis*. By contour and by deeper transverse fissures (sulci) occurring at intervals across it, four divisions or lobules of the inferior vermis are recognized. These lobules, like those of the superior vermis, are each in intimate relation with the pair of lobes of the hemispheres adjacent to it on either side.

1. The **tuber vermis** is adjacent to the folium vermis of the superior aspect. It is a short, somewhat pyramidal-shaped division, whose four or five transversely arranged folia are continuous with the folia of the inferior semilunar lobes on either side.

2. The **pyramid** is separated from the tuber vermis by the *postpyramidal sulcus*. Its several folia cross the vallecula cerebelli and curve to connect with the biventral lobes on either side.

3. The **uvula** is separated from the pyramid by the *prepyramidal sulcus.* It is triangular in shape. Its base or broader superior portion appears as two laterally projecting ridges of gray substance, the **furrowed bands** or *alæ uvulæ*, which extend across the floor of the nidus avis and under the medial margins of the tonsils on either side. In these bands its folia curve and become continuous with the tonsils. The uvula and the two tonsils are sometimes referred to collectively as the *uvular lobe.*

4. The **nodule** is the smallest and most anterior division of the inferior vermis. It is separated from the uvula by the **postnodular sulcus,** and is closely associated anteriorly with the posterior medullary velum, the transverse continuation of the peduncles of the floccular lobes.

SUMMARY OF EXTERNAL FEATURES OF CEREBELLUM

Superior Surface

HEMISPHERE	VERMIS
Anterior border—Anterior medullary velum—Anterior border	
Vinculum of Lingula	*Lingula*
Precentral sulcus	
Ala of central lobule	*Central lobule*
Postcentral sulcus	
Quadrangular lobe: *Anterior semilunar lobule*	*Culmen* } *Monticulus*
Anterior semilunar fissure	
Posterior semilunar lobule	*Declive* } *Monticulus*
Posterior semilunar fissure	
Superior semilunar lobe	*Folium*
Horizontal Fissure	

Inferior Surface

Horizontal Fissure	
Inferior semilunar lobe: *Posterior slender lobule*	} *Tuber*
Posteroinferior sulcus	} *Tuber*
Anterior slender lobule	} *Tuber*
Anteroinferior sulcus	Postpyramidal sulcus
Biventral lobe	*Pyramid*
Retrotonsillar fissure	Prepyramidal sulcus
Tonsil	*Uvula*
Horizontal Fissure	Postnodular sulcus
Flocculus	*Nodule*
Posterior medullary velum	

Internal structure of the cerebellum (figs. 675, 678).—The white substance of the cerebellum is continuous with its peduncles and forms a compact central mass [corpus medullare]. Over the surface of this the gray substance or cortex is spread in a thin but uniform and much folded layer. Upon section of the cerebellum certain of the sulci as well as the fissures are shown to be much deeper than is apparent from the surface. The deeper sulci separate the lobes into divisions, the **medullary laminæ,** each of which is composed of a number of folia and each of which has its own core of white substance. The folia of the laminæ line the sulci (and fissures), and also comprise their surface aspect, and are separated by the shallow, *secondary sulci.* The larger laminæ are subdivided into from two to four secondary laminæ of varying size. Such subdivision is especially marked in the vermis. Here each lamina comprises a lobule and is, therefore, separated by a fissure, and each lobule is usually subdivided with the exception of the nodule, the folium, and the lingula. In sagittal sections, or sections transverse to the general direction of the sulci, this arrangement of the laminæ gives a foliate appearance, which, especially in sagittal sections of the vermis, is termed **the arbor vitæ** (fig. 675).

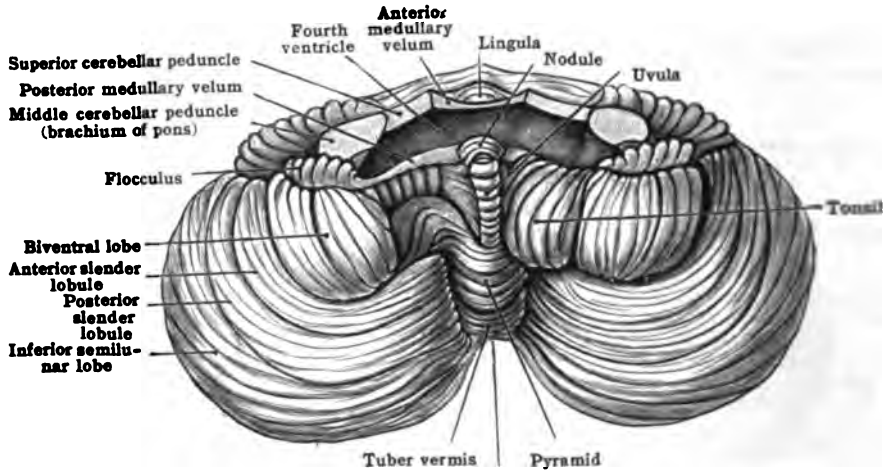
The cerebellar cortex consists of three layers and contains four general types of cell-bodies of neurones, all of which possess features peculiar to the cerebellum.

The outermost or **molecular layer** contains small **stellate cells,** 'basket cells,' with relatively long dendrites. These serve to associate the different portions of a given folium. The axones of the largest of them give off branches which form pericellular baskets about the bodies of the *cells of Purkinje,* each axone contributing to several baskets. The **layer of Purkinje cells,** or the middle layer, is quite thin. The bodies of the cells of Purkinje are arranged in a single layer, and their elaborate systems of dendrites extend throughout and largely compose the molecular layer. The dendrites of these, the most essential cells of the cortex, are displayed in the form of arborescent fans (see fig. 647), arranged parallel with each other and transverse to the long axis of the folium containing them. Their axones are given off from the base of the cell-body and acquire their medullary sheaths quite close to the cell-body, and, after giving off several collaterals in the inner layer, pass into the general white substance and thence to other

laminæ or lobes. Certain of them go to structures outside the cerebellum. The inner layer is the **granular layer.** It contains numerous small nerve-cells or 'granule-cells' which possess from two to five radiating dendrites, unbranched except at their termination, which occur suddenly in the form of three to six claw-like twigs. Their axones are given off either from the cell-body direct or more often from the base of one of the dendrites, and pass outward into the molecular layer, where they bifurcate and course in both directions parallel to the long axis of the folium, to become associated with the dendrites of the cells of Purkinje. In the layer of the cells of Purkinje there is situated at intervals a neurone of the Golgi type II (see fig. 647). The short, elaborately branched axone of this neurone is distributed among the cells of the granular layer. Axones conveying impulses to the cerebellar cortex terminate upon the granule cells in the granular layer as *'moss fibers,'* or directly upon the cells of Purkinje as *'climbing fibers,'* and probably upon the 'basket' cells and the cells of the Golgi type II.

FIG. 677.—DIAGRAM OF THE INFERIOR SURFACE OF THE CEREBELLUM AFTER THE REMOVAL OF THE MEDULLA OBLONGATA, PONS, AND MESENCEPHALON.

The tonsil of the right side is omitted in order to display the connection of the pyramid with the biventral lobe, the furrowed band of the uvula, and more fully the posterior medullary velum. The anterior notch is less evident than in the actual specimen.



Thus the neurones which receive impulses coming to the cortex are the cells of Purkinje, probably the Golgi cells of type II, the basket-cells and the granule-cells; those which distribute these impulses to other neurones of the folium are the Golgi cells of type II, the granule-cells, and the basket-cells (association neurones), and the collaterals of the cells of Purkinje. Impulses are conveyed from the cortex of a folium to that of other folia, lamina, lobules or lobes, or to the nuclei of the cerebellum, or to structures outside the cerebellum by the axones of the cells of Purkinje.

The **nuclei of the cerebellum** (figs. 678, 692) are in its central core [*corpus medullare*] of white substance. They are four in number, and all are paired, those of each pair being situated opposite each other on either side of the midline. They include (1) the dentate nucleus, (2) nucleus emboliformis, (3) nucleus globosus, and (4) roof-nucleus.

1. The largest of the cerebellar nuclei is the **dentate nucleus.** This is an isolated mass of gray substance situated in the core of white substance of each hemisphere. It is in the form of a folded or corrugated cup-shaped lamina, with the opening of the cup (*hilus*) directed anteriorly and obliquely toward the mid-line. It contains a mass of white substance and possesses a capsule. Its cell-bodies give rise to most of the fibers forming the superior cerebellar peduncles. It receives its impulses from axones of Purkinje cells and some direct from the axones of the spinocerebellar fasciculi.

2. The **nucleus emboliformis** is an oblong and much smaller mass of gray substance, which lies immediately medial to the hilus of the dentate nucleus. It is probably of the same significance as the dentate nucleus, being merely a portion separated from it.

3. The **nucleus globosus,** the smallest of the cerebellar nuclei, is an irregular horizontal mass of gray substance with its larger end placed in front. It lies close to the medial side of the nucleus emboliformis, and often appears separated into two or more rounded or globular masses.

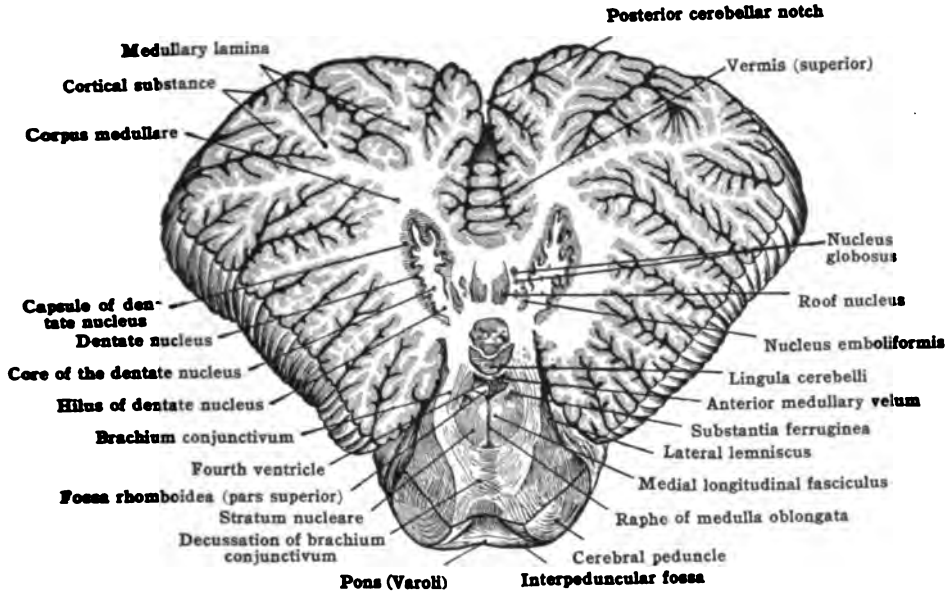
4. The **roof-nucleus** [nucleus fastigii] is the second largest of the cerebellar nuclei, and is the most mesially placed. The pair is situated in the roof of the fourth ventricle, and so near the midline that both nuclei are in the white substance of the vermis. They are ovoid in shape, and the nucleus of one side receives axones from the nucleus of the vestibular nerve chiefly of the opposite side, the decussation of these axones taking place in the vermis. Its cells are larger than those of the two first-mentioned nuclei.

The peduncles of the cerebellum.—The peduncles consist of three pairs—the **inferior**, middle, and superior. The three peduncles of each side come together at **the level** of the lower border of the pons, and the entering and emerging fibers of **which** they are composed become continuous with the central core of white substance of the cerebellar hemispheres (figs. 672, 678, 679, 680.)

The restiform body (fig. 680) of the medulla oblongata is the inferior peduncle. **It forms** the lateral boundary of the inferior portion of the fourth ventricle, and **upon reaching** the level of the pons turns sharply backward into the cerebellum. **In the** region of the turn it is encircled externally by fibers of the cochlear nerve. **It contains** fibers, both ascending and descending, between the cerebellar cortex **and the** structures below the cerebellum.

Its fibers include: (1) fibers from the spinal cord including the dorsal spinocerebellar fasciculus (direct cerebellar tract) and probably a small proportion of the ascending fibers of the superficial ventrolateral spinocerebellar fasciculus (Gowers' tract); (2) fibers from the olive of the same but chiefly from that of the opposite side of the medulla oblongata; (3) fibers

FIG. 678.—SECTION OF CEREBELLUM AND BRAIN-STEM PASSING OBLIQUELY THROUGH INFERIOR PORTION OF CEREBELLUM TO SUPERIOR MARGIN OF PONS. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York).



from the nuclei of the funiculus gracilis and cuneatus of the same and opposite sides (dorsal and ventral external arcuate fibers); (4) fibers to the olive of the opposite side; (5) fibers to the nuclei of the motor cranial nerves; (6) fibers descending to the ventral horn cells of the spinal cord. The ascending or afferent fibers of the spinocerebellar and cerebello-olivary fasciculi are the principal components of the inferior peduncle; the existence of fibers (5) and (6) is not well established. The fibers of the direct cerebellar tract terminate in the cortex of the superior vermis of both sides of the midline, but, for the most part, in that of the same side. The olivary fibers end in the cortex of both the superior vermis and the adjacent cortex of the hemispheres, and some of them terminate in the nucleus dentatus.

The brachium pontis or the middle peduncle (figs. 680, 698) is the largest of the three cerebellar peduncles. In it the pons fibers pass into the cerebellar hemisphere, between the lips of the anterior part of the horizontal fissure, entering lateral to the inferior peduncle.

It consists of the transverse fibers of the pons, and within the cerebellum its fibers are distributed in two main groups—the upper transverse fibers of the pons apparently pass downward to radiate in the lower portion of the hemisphere, while the lower transverse fibers pass upward and medialward to radiate in the superior part of the hemisphere and vermis. For the most part the fibers of the middle peduncle may be considered as commissural fibers, passing from one side of the cerebellum to the other. Each peduncle contains fibers coursing in opposite directions. Many of these fibers are interrupted in their course to the opposite side by cells scattered throughout the pons, *nuclei pontis*, and, therefore, in each brachium pontis some of the fibers are processes of the cells of the cerebellum and course toward the opposite side, while others are processes of the cells of the pontine nuclei, which receive impulses from cerebel-

laminæ or lobes. Certain of them go to structures outside the cerebellum. The inner la is the **granular layer.** It contains numerous small nerve-cells or 'granule-cells' which p sess from two to five radiating dendrites, unbranched except at their termination, which cou suddenly in the form of three to six claw-like twigs. Their axones are given off either from cell-body direct or more often from the base of one of the dendrites, and pass outward i the molecular layer, where they bifurcate and course in both directions parallel to the long a of the folium, to become associated with the dendrites of the cells of Purkinje. In the la of the cells of Purkinje there is situated at intervals a neurone of the Golgi type II (see 647). The short, elaborately branched axone of this neurone is distributed among the c of the granular layer. Axones conveying impulses to the cerebellar cortex terminate upon granule cells in the granular layer as *'moss fibers,'* or directly upon the cells of Purkinje *'climbing fibers,'* and probably upon the 'basket' cells and the cells of the Golgi type II.

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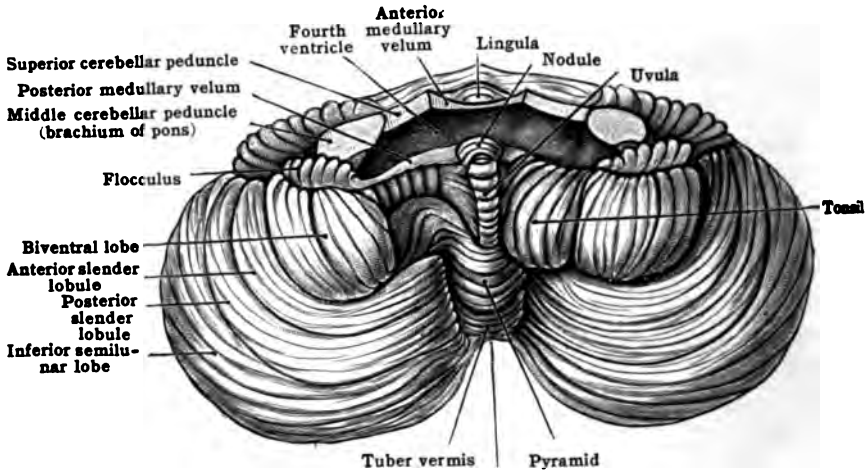

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3. The **nucleus globosus,** the smallest of the cerebellar nuclei, is an irregular ho mass of gray substance with its larger end placed in front. It lies close to the medial sid nucleus emboliformis, and often appears separated into two or more rounded or masses.

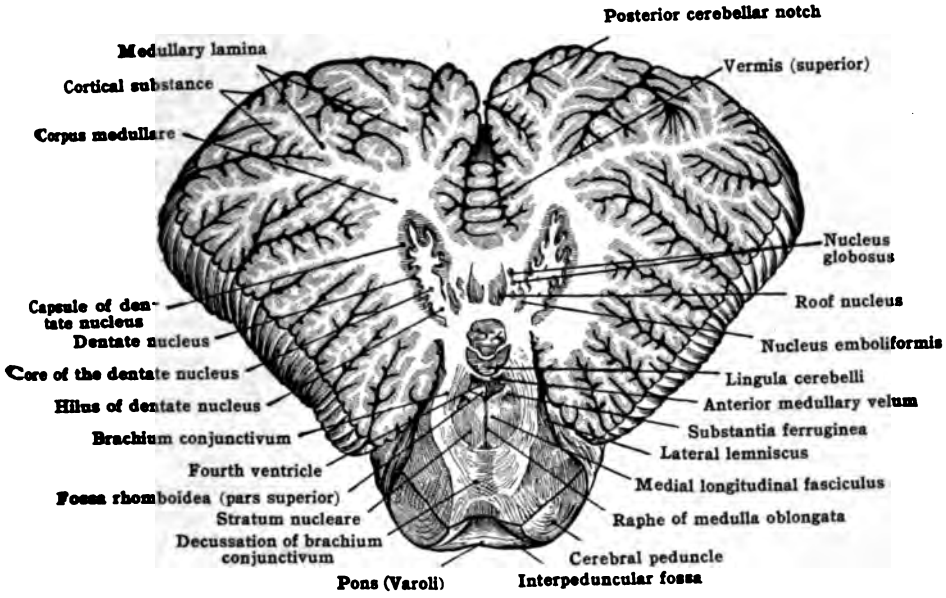
4. The **roof-nucleus** [nucleus fastigii] is the second largest of the cerebellar nuclei, an most mesially placed. The pair is situated in the roof of the fourth ventricle, and so n midline that both nuclei are in the white substance of the vermis. They are ovoid in and the nucleus of one side receives axones from the nucleus of the vestibular nerve cl the opposite side, the decussation of these axones taking place in the vermis. Its c larger than those of the two first-mentioned nuclei.

The peduncles of the cerebellum.—The peduncles consist of three pairs—the inferior, middle, and superior. The three peduncles of each side come together at the level of the lower border of the pons, and the entering and emerging fibers of which they are composed become continuous with the central core of white substance of the cerebellar hemispheres (figs. 672, 678, 679, 680.)

The restiform body (fig. 680) of the medulla oblongata is the inferior peduncle. It forms the lateral boundary of the inferior portion of the fourth ventricle, and upon reaching the level of the pons turns sharply backward into the cerebellum. In the region of the turn it is encircled externally by fibers of the cochlear nerve. It contains fibers, both ascending and descending, between the cerebellar cortex and the structures below the cerebellum.

Its fibers include: (1) fibers from the spinal cord including the dorsal spinocerebellar fasciculus (direct cerebellar tract) and probably a small proportion of the ascending fibers of the superficial ventrolateral spinocerebellar fasciculus (Gowers' tract); (2) fibers from the olive of the same but chiefly from that of the opposite side of the medulla oblongata; (3) fibers

FIG. 678.—SECTION OF CEREBELLUM AND BRAIN-STEM PASSING OBLIQUELY THROUGH INFERIOR PORTION OF CEREBELLUM TO SUPERIOR MARGIN OF PONS. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York).



from the nuclei of the funiculus gracilis and cuneatus of the same and opposite sides (dorsal and ventral external arcuate fibers); (4) fibers to the olive of the opposite side; (5) fibers to the nuclei of the motor cranial nerves; (6) fibers descending to the ventral horn cells of the spinal cord. The ascending or afferent fibers of the spinocerebellar and cerebello-olivary fasciculi are the principal components of the inferior peduncle; the existence of fibers (5) and (6) is not well established. The fibers of the direct cerebellar tract terminate in the cortex of the superior vermis of both sides of the midline, but, for the most part, in that of the same side. The olivary fibers end in the cortex of both the superior vermis and the adjacent cortex of the hemispheres, and some of them terminate in the nucleus dentatus.

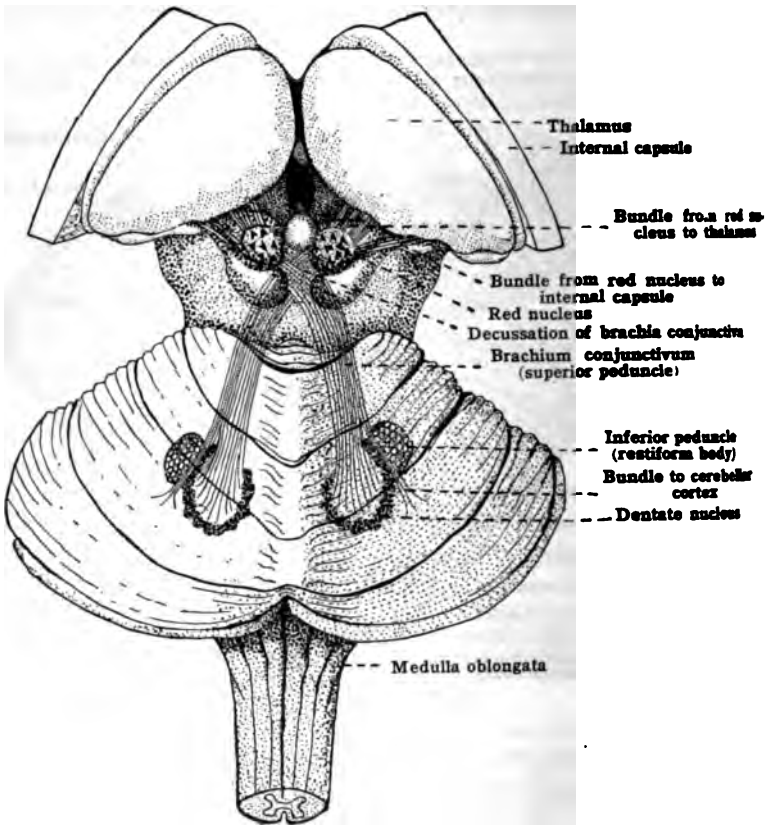
The brachium pontis or the middle peduncle (figs. 680, 698) is the largest of the three cerebellar peduncles. In it the pons fibers pass into the cerebellar hemisphere, between the lips of the anterior part of the horizontal fissure, entering lateral to the inferior peduncle.

It consists of the transverse fibers of the pons, and within the cerebellum its fibers are distributed in two main groups—the upper transverse fibers of the pons apparently pass downward to radiate in the lower portion of the hemisphere, while the lower transverse fibers pass upward and medialward to radiate in the superior part of the hemisphere and vermis. For the most part the fibers of the middle peduncle may be considered as commissural fibers, passing from one side of the cerebellum to the other. Each peduncle contains fibers coursing in opposite directions. Many of these fibers are interrupted in their course to the opposite side by cells scattered throughout the pons, *nuclei pontis*, and, therefore, in each brachium pontis some of the fibers are processes of the cells of the cerebellum and course toward the opposite side, while others are processes of the cells of the pontine nuclei, which receive impulses from cerebel-

lar axones, and course to the cerebellar hemisphere chiefly of the same side. Many cell-bo of the nuclei of the pons whose axones terminate in the cerebellum receive impulses from fib descending from the *cerebral* cortex of the opposite side—*corticopontine fibers*. Further there are evidences after degeneration that the brachium pontis also contains a few fibers to from the cerebellum and the structures of the brain-stem and spinal cord.

The **brachium conjunctivum** or superior peduncle (figs. 679, 680) emerges fr the cerebellum on the medial side of the brachium pontis and also on the superi and medial side of the course of the restiform body. It forms the lateral bounda of the superior portion of the fourth ventricle and is the cerebello-cerebral pe uncle. Its transverse section appears semilunar in shape, with the concave sid next to the cavity of the ventricle. The medial border, which inclines toward th

FIG. 679.—TRANSPARENCY DRAWING SHOWING THE ORIGIN, COURSE, AND CONNECTIONS OF TH SUPERIOR CEREBELLAR PEDUNCLES (BRACHIA CONJUNCTIVA) IN THE FORMATION OF 'STILLING'S SCISSORS.'



midline, is connected with that of the corresponding peduncle of the opposite si by the *anterior medullary velum*, which thus roofs over the superior part of t fourth ventricle. The lateral border is distinguished from the pons by an op furrow or lateral sulcus.

The superior cerebellar peduncles are almost entirely efferent pathways as to the cerebell and form the chief connections between the cerebellum and the cerebrum. They arise alm wholly from the dentate nuclei. As they course forward they slightly converge and disap under the inferior quadrigeminate bodies. Here, in the tegmentum of the mesencepha they undergo an almost total decussation, and then the majority of the fibers of each pedu having thus crossed the midline, terminate in the *red nucleus* of the opposite side. The nucleus lies in the tegmentum of the mesencephalon, below the superior quadrigeminate bo and therefore quite close to the decussation. The cells of the red nucleus, about which fibers of the peduncle terminate, in their turn send processes (axones) into (1) the rubros tract of the spinal cord and (2) into the prosencephalon, most of which latter terminate in thalamus whose cell-bodies give fibers to the cerebral cortex by way of the internal cap but some pass from the red nucleus under the thalamus to join the internal capsule.

In addition to the fibers having the origin and course described above, and which consti the greater mass of the superior cerebellar peduncle, each peduncle is said to contain fi which—(1) arise in the cerebellar cortex of the same and opposite sides of the midline, ma

om the dentate nucleus, and which join the peduncle at the side of the dentate nucleus, een it and the restiform body; (2) fibers which do not cross the midline in the decussation, erminate in the red nucleus of the same side; (3) some fibers are not interrupted in the red us, but pass directly into the thalamus; (4) a small proportion of fibers afferent as to the ellum, which arise in the structures of the cerebrum and pass into the cerebellum; and he greater part, if not all, of the ascending fibers of the superficial ventrolateral spino-ellar fasciculus (Gowers' tract) of the spinal cord. The latter, instead of entering the ellum by way of the restiform body, are deflected in the upper medulla and pass in the al tegmentum of the pons to the anterior medullary velum, where they turn backward to the cerebellum in its superior peduncle and pass to its cortex, probably from the lateral of the dentate nucleus (see fig. 697).

The anatomy of the fourth ventricle.—The fourth ventricle (figs. 672, 675, 681) is rhomboidal in shape, being considerably widened at the level of the hia pontis and pointed at each end. Its floor consists of a slight depression ne brain-stem, the *fossa rhomboidea*, and corresponds to the floor of the central al. Its pointed inferior end, the **calamus scriptorius**, is directly continuous i the central canal, and its narrowed superior end is continued into the aeductus cerebri (Sylvii) of the mesencephalon, which is nothing more than sumption of the tubular form of the canal.

The entire cavity of the ventricle is lined with an epithelium which is continuous with the nelioid ependyma of the central canal below and the aqueduct above. The entire ricle involves the *isthmus of the rhombencephalon*, the *metencephalon* and a portion of the *ulla oblongata*. It is divided for study into an inferior, an intermediate and a superior

The *roof of the superior portion* of the fourth ventricle is nervous, consisting of a lamina of white substance, the *anterior* (superior) *medullary velum*, thickened he sides by the brachia conjunctiva. At its extreme mesencephalic end (in the mus of the rhombencephalon) the anterior medullary velum is slightly thick-l by a continuation of the white substance of the inferior quadrigeminate ies, forming the **frenulum veli**. The inferior portion of the velum is continu-with the white substance of the cerebellum, and is covered by the *lingula belli*, an extension of the cortical substance of the superior vermis (figs. 672,).

The *roof of the intermediate portion* of the fourth ventricle is formed by the ebellum proper, the vermis and the medial portions of the hemispheres. The vous portion of the roof terminates with the *posterior* (inferior) *medullary m*, a thin, narrow band of white substance which is the continuation of the uncles of the floccular lobes, and which connects them at the midline with the ule of the inferior vermis.

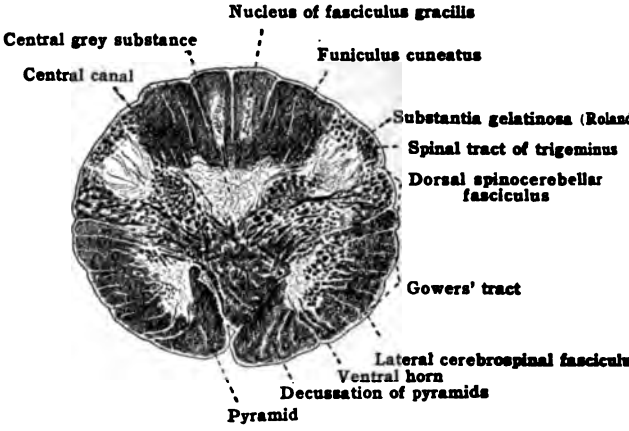
The *roof of the inferior portion* of the fourth ventricle is non-nervous. It is **choroid tela** of the fourth ventricle, a semilunar lamina consisting of the epi-al lining of the ventricle, reinforced by a continuation of the connective tissue ne pia mater and the adjacent portion of the arachnoid. Along the line of its chment to the surface of the medulla it is thickened, and in sections this por-bears the name **ligula** [*tenia ventriculi quarti*]. The thickest portion spans tip of the calamus scriptorius and is termed the **obex**. The width of the ven-ular cavity is extended laterally from its widest part into the *lateral recesses*, ow pockets on each side and around the upper parts of the restiform bodies, rior to the choroidal branches of the posterior inferior cerebellar artery ring to supply the choroid plexus of the fourth ventricle. In the midline of lower part of the choroid tela there is a more or less well-marked opening, the *men of Magendie* (medial aperture of the fourth ventricle), which is a lymph-anel connecting the cavity of the ventricle with the subarachnoid space 680). There is a similar opening from each lateral recess (*lateral apertures ey and Retzius*).

The choroid plexuses of the fourth ventricle consist of highly vascular, lobu-villus-like processes of the ventricular lining (and pia mater) of the choroid . They are reddish in the fresh specimen, and the ependymal lining of the tricle is closely adapted to the unevennesses of their surfaces. From below y run as two parallel masses on either side of the midline, which become united ve, and then are separated again into two lateral processes which bend at t angles and project into the lateral recesses. Portions frequently protrude ough the three openings of the ventricle into the subarachnoid space.

The entire brain-stem may be regarded as an upward continuation of the spinal cord, to which structures are added giving each part its peculiar character and conformation, and in which the structures characteristic of the spinal cord are modified in varying degrees.

The **pyramids,** the great descending or motor cerebrospinal fasciculi, are directly continuous into the pyramidal fasciculi of the spinal cord. They form the extreme ventromedial portion of the medulla, and from the fact that they contribute numerous fibers to the efferent nuclei (nuclei of origin) of the cranial nerves and to other portions of the gray substance of the brain-stem, they decrease appreciably in bulk in descending toward the spinal cord. Most of the fibers contributed to the medulla, as well as to other divisions of the brain-stem, decussate as they leave the pyramids, and terminate in the gray substance of the opposite side. However, the chief **decussation of the pyramids** occurs in the lower end of the medulla. Here usually about three-fourths of the fibers then comprising the pyramids cross the midline to form the lateral cerebrospinal fasciculus (crossed pyramidal tract) of the spinal cord immediately below (fig. 671). The remaining fourth, comprising the more lateral fibers, furthest away from the midline, continues uncrossed into the spinal cord as the ventral cerebrospinal fasciculus or direct pyramidal tract. The majority of the latter fibers decussate gradually in the commissural bundle and in the ventral white commissure of the cord as they approach the levels of their termination. In practically all vertebrates except man and the apes there are no ventral pyramidal fasciculi, the decussation in the medulla being a total one. In man, the proportion of fibers crossing in the chief decussation varies. Cases have been noted in which apparently the entire pyramids decussate at this level. In other cases the direct or ventral pyramidal tract

FIG. 682.—TRANSVERSE SECTION OF MEDULLA OBLONGATA AT THE LEVEL OF THE DECUSSATION OF THE PYRAMIDS.



may be much larger than usual, at the expense of the lateral. The chief decussation usually appears to be symmetrical and it occurs so suddenly that the fibers, in coursing from the ventral to the lateral positions, 'sew up' the ventral median fissure and detach the tips of the ventral horns of the spinal cord from the remainder of the gray figure, and these appear as isolated, irregularly shaped masses of gray substance in transverse sections (fig. 682). From this level upward the outline of the gray figure of the cord is lost, and the cell-columns of the ventral horns occur in more or less detached groups as the motor nuclei of the cranial nerves.

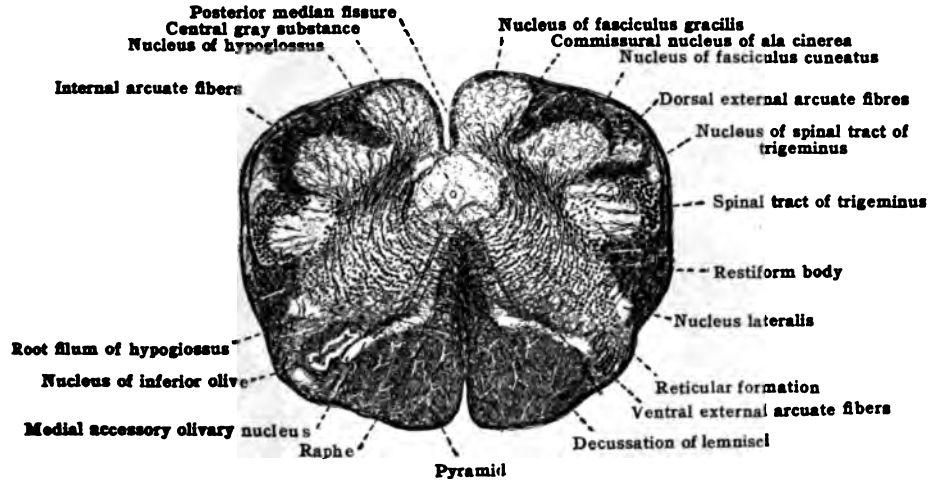
The **origin and decussation of the lemnisci** (medial lemnisci, fillet) begins immediately above the decussation of the pyramids, and here the arrangements characteristic of the spinal cord are further modified. The dorsal portion of the gray figure of the cord is manifest up to this level, but here, after a considerable increase in its thickness, the gray commissure gives rise to two thick dorsal outgrowths on each side of the midline. These dorsal projections of gray substance comprise the nuclei of termination (relays) of the chief ascending or sensory spinocerebral fasciculi of the spinal cord. The nucleus of the fasciculus gracilis (nucleus of Goll's column) arises a little before the nucleus of the fasciculus cuneatus (nucleus of Burdach's column). The former extends slightly downward from its point of origin, so that its inferior extremity is included in sections through the decussation of the pyramids (fig. 682). It produces a slight bulbous enlargement (the *clava*) of the end of the funiculus gracilis, while the nucleus of the fasciculus cuneatus corresponds to the *cuneate tubercle* of the dorsolateral contour of the medulla (figs. 673, 681). From the cells of these nuclei arise the lemniscus—the cephalic continuation of the spinocerebral pathway which conveys general bodily sensations (proprioceptive) to the cerebrum. In passing out of the nuclei the fibers of the lemniscus course in a ventromedial direction. Curving around the region of the central canal, they contribute largely to the internal arcuate fibers, then, sweeping across the midline, they convert it into the raphe, and immediately after crossing (decussating) they turn cephalad and collect to form the bundle known as the lemniscus.

In the medulla, the lemnisci are two thin bands of fibers spread vertically on each side of the raphe, with their lower or ventral edges thicker than their dorsal edges. In their course toward the cerebrum they increase in bulk, owing chiefly to fibers being added to them from the nuclei of termination of the afferent roots of the cranial nerves, which fibers likewise cross the midline as internal arcuate fibers to join the lemniscus of the opposite side. In passing through the pons, the lemnisci gradually become spread laterally (horizontally) and beyond the

their then more lateral portions are further displaced and come to course in the lateral fibers of the isthmus rhombencephali and mesencephalon, while the medial portions remain nearer the midline. This lateral spreading of each lemniscus produces the **lateral lemniscus** and the **medial lemniscus,** distinguished in sections of the superior pons and lower mesencephalic regions of the brain-stem (fig. 702). The lateral lemniscus is contributed very largely by the cell-bodies of the nuclei of termination of the cochlear nerve of the opposite side and is known as the *'auditory lemniscus.'* The **spinal lemniscus** (spinothalamic and spinotectal paths) appears in the dorsal part of the medial lemniscus during its vertical position throughout the medulla and in the lateral part of it, medial to the lateral lemniscus proper, throughout the pons and midbrain.

The reticular formation of the medulla and pons region is considerably more abundant than in the spinal cord. As in the spinal cord, it consists of gray substance through which nerve-fibers, singly and in small bundles, course in all directions, and more sparsely than in other regions. In the medulla it is traversed by the internal arcuate fibers. It may be con-

FIG. 683.—TRANSVERSE SECTION OF MEDULLA OBLONGATA AT LEVEL OF THE DECUSSATION OF THE LEMNISCI.



sidered an enlarged continuation of the middle portion of the gray column of the cord, dispersed by numerous fibers, giving it the reticulated appearance which suggests its name. Its numerous nerve-cells belong, for the most part, to the association and commissural systems of the brain stem, and, therefore, the fibers arising in it correspond largely to the fasciculi proprii of the spinal cord. As in the cord, most of the fibers are of short course, serving to associate different portions of the same level and adjacent levels with each other. Those of long course show a tendency to collect into a small, well-marked bundle which courses one on each side close to the midline, ventral to the central canal in the closed part of the medulla, and near the median sulcus of the floor of the fourth ventricle, in the open part. In the mesencephalon this bundle is continued closely ventral to the aqueductus cerebri. This bundle is known as the **medial longitudinal fasciculus** (posterior longitudinal bundle). It corresponds more nearly to the ventral fasciculus proprius of the spinal cord than to others of the fasciculi proprii. In the medulla it appears as the dorsal edge of the lemniscus, but in the shifting of the position of the lemniscus in the pons region, it retains its medial position and thus becomes isolated. By position it is especially adapted for the association of the nuclei of the cranial nerves. Evidence has been found that those fibers which arise in the superior corpora quadrigemina and descend the spinal cord in its sulcomarginal or ventral mesencephalospinal fasciculus, pass through the medulla in the medial longitudinal fasciculus. The nuclei of termination of the vestibular nerve are said also to contribute many fibers to it.

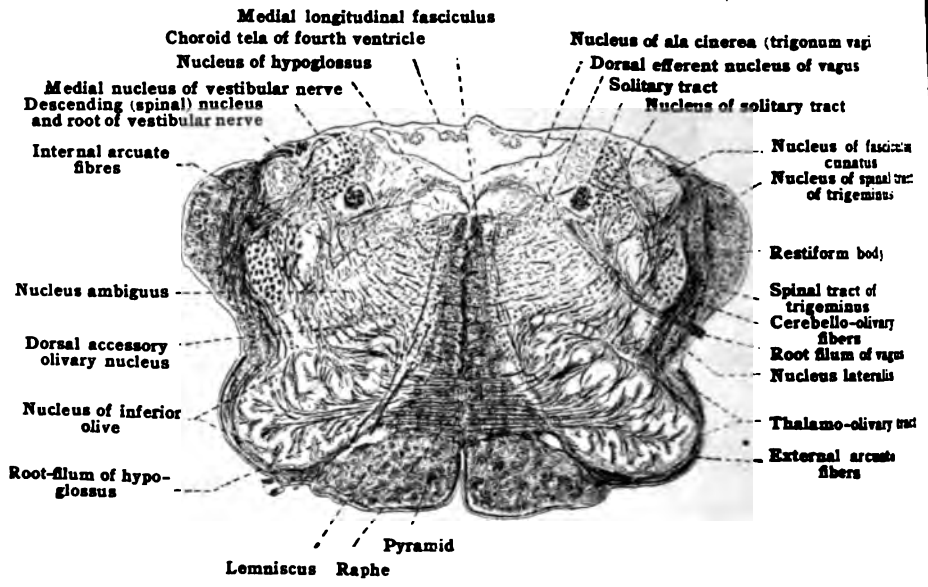
The inferior olivary nucleus is an added structure in the medulla oblongata, i. e., it has no homologue in the spinal cord. The two of them occupy the olivary prominences, *the olives* of the exterior, and constitute the most conspicuous and striking isolated masses of gray substance in sections of the medulla. They appear as crenated laminæ of gray substance folded so as to encup a dense mass of white substance, and in actual shape the entire nucleus has the form of an irregular corrugated cup with the opening or hilus on the side toward the midline (fig. 685). The mass is so crumpled that the diameter of the hilus is appreciably less than the length of the nucleus, and thus transverse sections of either extremity of it appear as closed capsules.

There are several small detached portions of the olivary nucleus known as the **accessory olivary nuclei.** These are named according to their position with reference to the chief portion or olive proper. They are plates less corrugated than the chief nucleus, and appear rod-like in sections. The largest is the *dorsal accessory olivary nucleus.* The *medial accessory olivary nucleus* is widest at its inferior end, which extends a little below the inferior extremity of the olive proper. The *lateral accessory olivary nucleus* is the smallest. In serial sections the accessory nuclei are found to be plates of gray substance usually continuous with one another.

The olivary nuclei are mainly cerebellar connections. By both ascending and descending fibers each cerebellar hemisphere is connected with the olivary nucleus of the same and opposite sides. Serial sections of a human brain with congenital absence of one cerebellar hemisphere described by Strong, show that the chief connection of a hemisphere is with the olive of the opposite side. These fibers necessarily pass between the cerebellum and the olives by way of the restiform body, and, in so doing, form an obliquely coursing bundle in the lateral border of the medulla known as the **cerebello-olivary fibers** (fig. 684). The olivary nuclei also comprise a secondary relay between the spinal cord and the cerebellum by way of the spino-olivary fasciculus of the cervical cord, and it will be noted that they receive fibers from the thalami. The latter fibers, the **thalamo-olivary tract,** approach the olive at its lateral periphery, while above through the brain-stem the tract courses in a more medial position. This tract comprises one of the cerebrocerebellar paths. Arising in the thalamus and terminating in the olive, its impulses reach the opposite cerebellar hemisphere by way of the cerebello-olivary fibers.

The **arcuate fibers** are referred to as internal and external, according as they course dorsal or ventral to the inferior olivary nucleus. The **internal arcuate fibers** comprise fibers destined for both the cerebellum and cerebrum, and also for the association of the tegmental gray substance of the two sides in which they course. Certain of the fibers pass between one restiform body (cerebellar hemisphere) and the olive of the opposite side course internal to the oliv-

FIG. 684.—TRANSVERSE SECTION OF MEDULLA OBLONGATA THROUGH NUCLEI OF VAGUS AND HYPOGLOSSUS AND THROUGH THE MIDDLE OF THE OLIVES.



of the same side, and thus form the ventral portion of the internal arcuate fibers. As noted above, the internal arcuate fibers consist in greatest part of fibers being contributed to the lemnisci, arising from the cells of the nucleus of the fasciculus gracilis and fasciculus cuneatus and sweeping downward and decussating to form the lemniscus of the opposite side. However, all the fibers arising in these nuclei do not enter the lemniscus. A few of them cross the midline with the internal arcuates, but pass on to enter the restiform body (cerebellar hemisphere) of the opposite side. Some of these course ventrally and, upon approaching the olive of the opposite side, are deflected around the ventral side of both the olive and the pyramid, and thus pass to the restiform body as external arcuate fibers also. Certain of the internal arcuate fibers arise from the cells of the nuclei of termination of the cranial nerves and from small cells situated in the gray substance of the reticular formation. These, in crossing the midline, correspond to the white commissures of the spinal cord. Some of them terminate in the medulla; others, especially those from the nuclei of termination of the sensory cranial nerves, join the lemniscus and pass toward the cerebrum; others reach the cerebellar hemisphere of the opposite side.

The **external arcuate fibers,** in addition to those mentioned above, comprise certain fibers which arise in the nuclei of the fasciculus gracilis and cuneatus and pursue a dorsolateral course to enter the restiform body (cerebellar hemisphere) of the same side. These form the dorsal segment of the external arcuates. The greater mass of the external arcuates are cerebello-olivary fibers. Certain of those passing from one olive to the restiform body of the opposite side are deflected at the raphe, and course on the ventral side of both the other olive and the pyramid in order to reach the opposite cerebello-olivary bundle. Likewise, those passing from the restiform body to the opposite olive are deflected by the olive of the same side and pursue a similar course to the raphe. While out of the hilus of each olive streams a dense mass of white substance, yet many of the fibers concerned with the olive pierce its walls from all sides. Many of the external arcuate fibers are said to be interrupted in the **nucleus arcuatus.** This is a thin sheet of gray substance, variable in amount, which lies on the ventral aspect of each pyra-

ıough it decreases inferiorly, it may be evident down to the decussation of the pyra-
nucleus receives its name from the fact that its larger portion is interpolated in the
ernal arcuate fibers. It is continuous anteriorly with the gray substance or nuclei
. The external arcuate fibers of longer course, like the olives with which they are
erned, have no homologs in the spinal cord
tral canal of the closed portion of the medulla is surrounded by a greater amount
gray substance [substantia grisea centralis] than is the canal in the spinal cord.
ly *the central gelatinous substance*, and the nerve-fibers in coursing through the gray
re partially deflected by it, leaving it as a cylindrical, more evident area of gray sub-
in other regions. In the open portion of the medulla the central gray substance
rms a more transparent lamina just under the floor of the fourth ventricle. In the
lon, occurring in still greater amount, it again surrounds the reformed canal or
f the cerebrum.

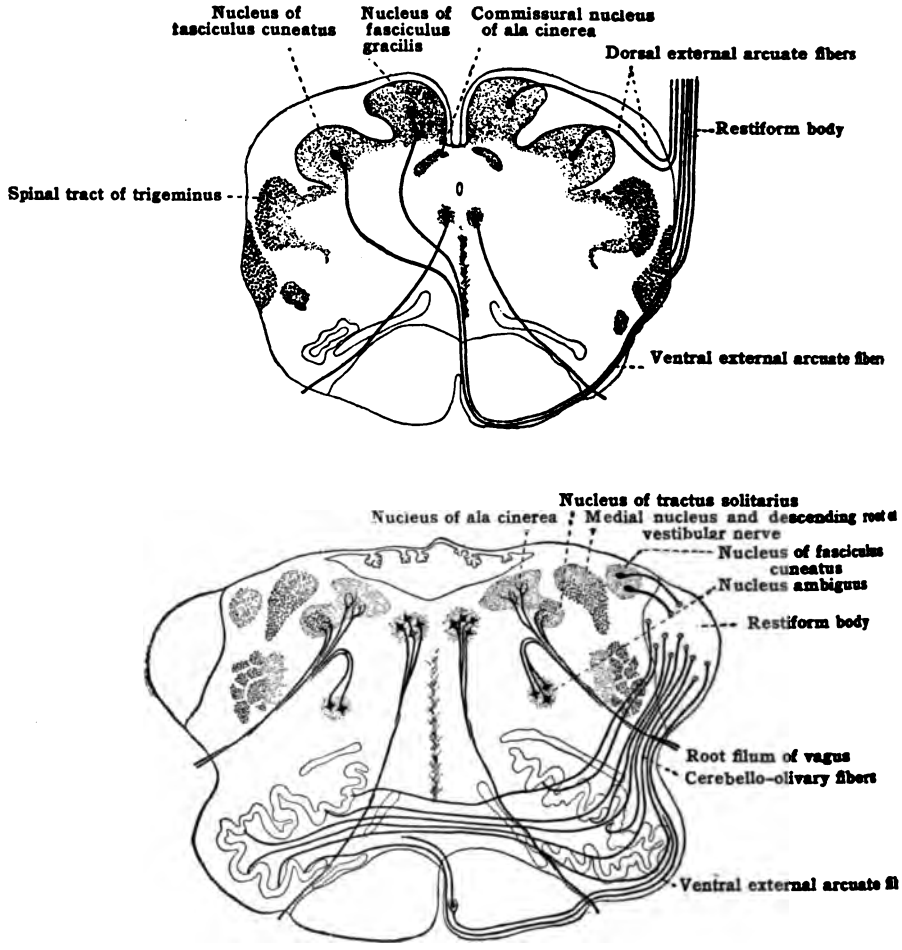
5.—Reconstruction of the Inferior Olivary Nucleus, Dorsolateral View. (After Sabin.)

entral connections of the cranial nerves are easily homologized with
d structures. Functionally the cranial nerves are of three varieties:—
notor or efferent nerves, comprising the oculomotor, the trochlear,
r, the abducens, the facial, the spinal accessory, and the hypoglossus;
nsory or afferent, comprising the olfactory, the optic, the trigeminus, the
', and the cochlear and (3) the mixed, motor and sensory nerves, com-
e glossopalatine, the glossopharyngeal, and the vagus. The **nuclei of**
the motor or efferent cranial nerves and the efferent portions of the
ves are directly continuous with the cell-columns of the ventral horns
nal cord, while the emerging root-filaments and roots of these nerves
d to the ventral roots of the spinal nerves. The **nuclei of termination**
rent or sensory cranial nerves and of the sensory portions of the mixed
rrespond directly to the nuclei of the fasciculus gracilis and fasciculus
and to the cell-bodies of association and commissural neurones of the
nd cord and, functionally, are merely anterior continuations of these.
uclei of the efferent or motor cranial nerves lie in two parallel lines, one
midline and the other more laterally placed. The nuclei giving origin
ılomotor, the trochlear, the abducens, and the hypoglossus are near the
ınd correspond to the ventromedial and dorsomedial cell-groups of the
orns of the spinal cord; the nuclei of origin of the masticator (motor
ıe trigeminus) of the facial, and the nucleus ambiguus contributing to
: portions of the glossopharyngeal and vagus nerves, together with the
f the spinal accessory, correspond to the ventrolateral and dorsolateral
ıs of the ventral horns of the spinal cord. The nerve-roots having medial
origin are those which make their exit from the brain-stem along the
lial superficial line, while those having the more lateral nuclei comprise
lateral line of roots apparent on the surface of the stem. Some of the
bers of the vagus, supposedly visceral efferent, arise from a small nucleus
lial to the nucleus ambiguus, the *dorsal efferent nucleus of the vagus.*
efferent fibers in the glossopharyngeal and glossopalatine nerves arise
nuclei corresponding to the dorsal efferent nucleus of the vagus, that for
palatine being called the *salivatory nucleus.* The first two pairs of cranial

nerves, the olfactory and optic, are attached to the prosencephalon. These a purely sensory, and make their entrance near the midline of the brain, both hav superficially placed nuclei of termination. Of the other nerves, all having sens or afferent functions enter the brain along the lateral or more dorsal line, and t ganglia giving origin to their afferent axones correspond directly to the spi ganglia of the dorsal or afferent roots of the spinal nerves.

Commissural and associational neurones are much more numerous in t brain-stem than in the spinal cord. Their axones serve to correlate the structu

FIGS. 686 AND 687.—DIAGRAMS SHOWING THE COMPOSITION OF THE CEREBELLAR PORTI OF THE INTERNAL AND EXTERNAL ARCUATE FIBERS.



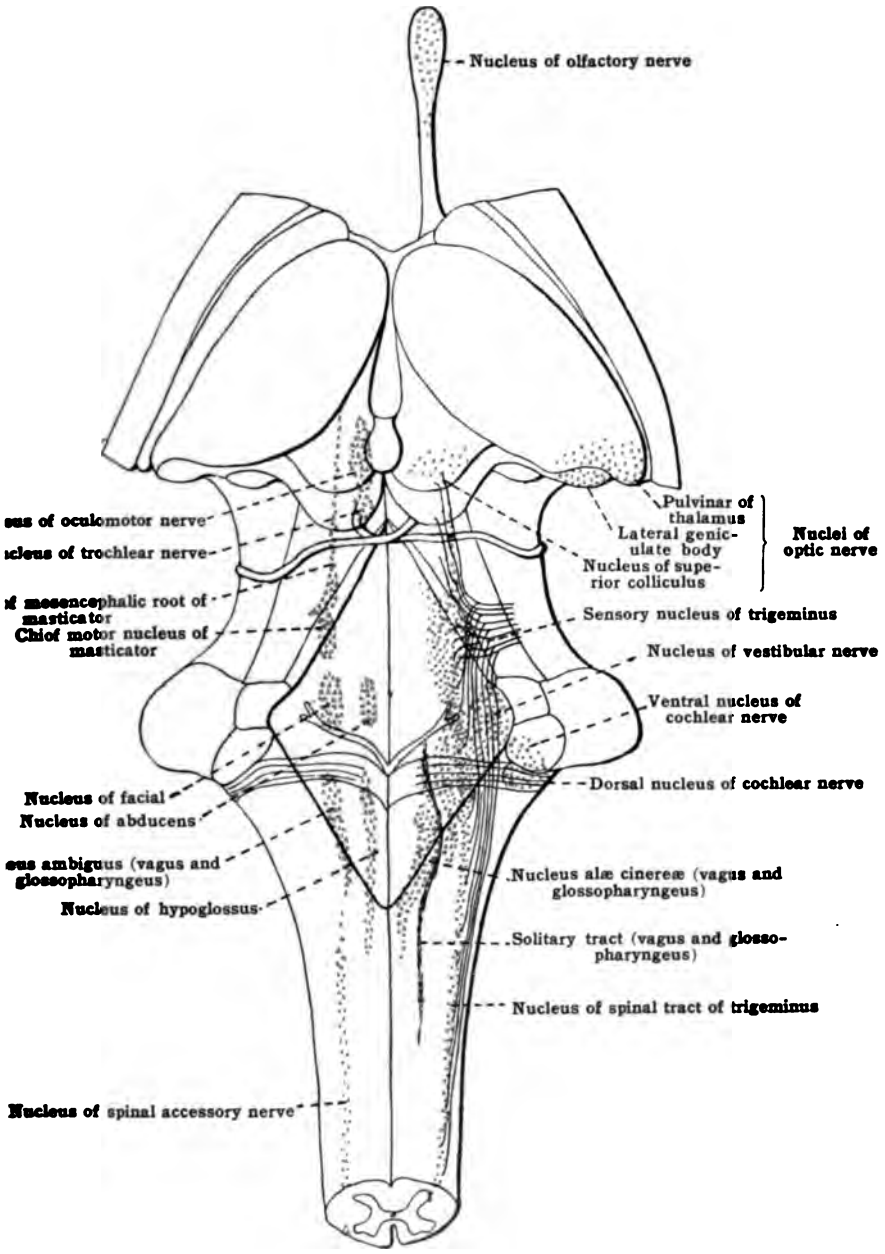
on the two sides of the midline and to associate the different levels of the s side. Just as in the spinal cord, those of longer course form fasciculi pro Many of their axones descend into the spinal cord.

Of the fifteen pairs of cranial nerves, eleven pairs are attached to the med oblongata and pons, viz., the trigeminus, the masticator, abducens, fa glossopalatine, vestibular, cochlear, glossopharyngeal, vagus, spinal access and hypoglossus.

The hypoglossus, the motor nerve of the tongue, has its nucleus of origin beginni the lower portion of the floor of the fourth ventricle caudal to and at the level of the acc striæ. It is a long nucleus, lying close to the midline and just under the floor of the ven (hypoglossal eminence) and extending down to the region of the funiculus separans. H curves ventrally to a slight degree, and below the obex assumes a position ventrolateral t central canal, and thus extends a short distance below the level of the inferior tip of the The nerve arises as a series of rootlets which traverse the entire thickness of the medulla 684), to emerge in line in the furrow between the olive and the pyramid and fuse to forr

the nerve. The lowermost of the rootlets usually emerge below the olive. The nucleus impulses—(1) from the cerebrum by way of divergent fibers from the pyramid of the side (voluntary); (2) impulses brought in by the sensory fibers of the cranial nerves and (3) by axones from other levels of the medulla (associational). None of its axones osed to decussate, though numerous commissural fibers are known to pass between ei of the two sides.

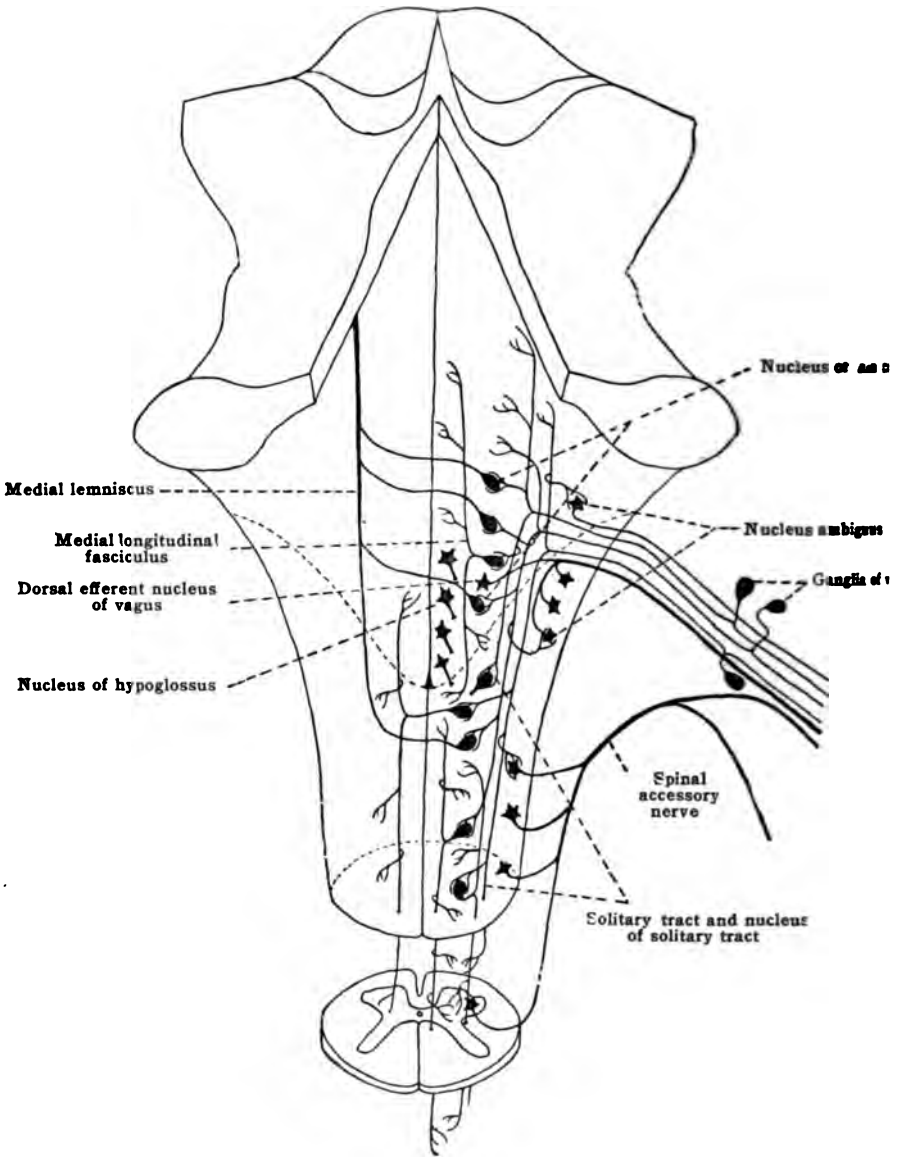
.—SCHEME SHOWING THE RELATIVE SIZE AND POSITION OF THE NUCLEI OF ORIGIN D) OF THE MOTOR AND THE NUCLEI OF TERMINATION (BLUE) OF THE SENSORY CRANIAL IVES.


Nucleus of olfactory nerve
Pulvinar of thalamus
Lateral geniculate body
Nucleus of superior colliculus
Nuclei of optic nerve
Sensory nucleus of trigeminus
Nucleus of vestibular nerve
Ventral nucleus of cochlear nerve
Dorsal nucleus of cochlear nerve
Nucleus alæ cinereæ (vagus and glossopharyngeus)
Solitary tract (vagus and glossopharyngeus)
Nucleus of spinal tract of trigeminus
Nucleus of spinal accessory nerve
Nucleus of facial
Nucleus of abducens
Nucleus of hypoglossus
Chief motor nucleus of masticator

spinal accessory is likewise a purely motor nerve, and has a laterally placed, long, and tenuated nucleus of origin. Above, its nucleus is in line with and practically continuthe nucleus giving motor fibers to the vagus and glossopharyngeus (nucleus ambiguus). consists of the lateral and dorsolateral groups of cells of the ventral horn of the first ix segments of the spinal cord. The nerve arises as a series of rootlets which emerge and join a common trunk, which passes upward between the dorsal and ventral roots

of the upper cervical nerves and parallel with the medulla to turn lateralward in com with the vagus. (See fig. 709). The upper rootlets arise from that part of the nucleus tiguous to the inferior end of the nucleus ambiguus, and are described as comprising the ullary (bulbar) or *accessory part* of the nerve; those which arise from the ventral horn cells are described as the *spinal part.* The trunk of the spinal accessory fuses with the vagus i region between its two ganglia, and, before separation, contributes fibers (the accessory to the trunk of the vagus. Some of the accessory fibers are distributed as motor fibers t

FIG. 689.—DIAGRAM ILLUSTRATING PRINCIPAL CENTRAL RELATIONS OF THE VAGUS N EXCLUSIVE OF RELATIONS TO DESCENDING CEREBRAL OR PYRAMIDAL FIBERS.

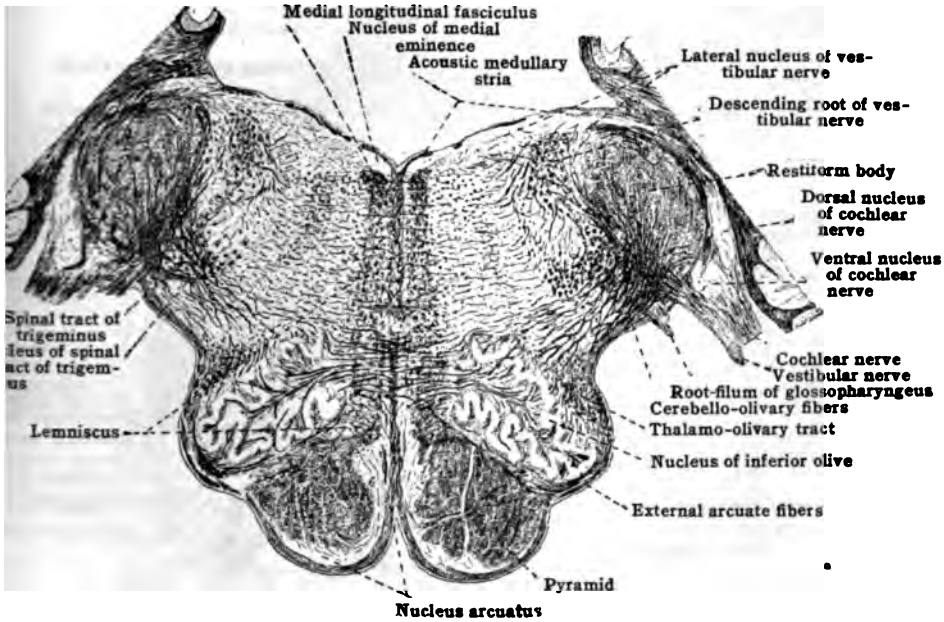


muscles of the larynx and some of them are visceral efferent fibers (visceral effectors). latter probably terminate chiefly in sympathetic ganglia which send axones to the heart. spinal part is distributed to the sternomastoid and trapezius muscles. The nucleus of the accessory receives terminal twigs of pyramidal fibers from the opposite side and is oth subjected to sensory impulses similar to those affecting the cells giving origin to the cranial nerves and motor roots of the spinal nerves.

The vagus or pneumogastric and the glossopharyngeal, though they have widely di peripheral distributions, are so similar in origin and central connections that they m described together. Both contain efferent fibers, though both are in greater part sensory. are similar as to the origin of both their efferent and afferent components. The afferent fi the vagus arise in its jugular ganglion and its nodosal ganglion (ganglion of the trunk); the a

of the glossopharyngeal arise in its superior ganglion and its petrosal ganglion. In both these fibers enter the lateral aspect of the medulla and bifurcate into ascending and descending branches, similar to those of the dorsal root-fibers in the spinal cord. Some of these fibers terminate in practically the same level of the medulla about cell-bodies situated on the same and the opposite sides. Such branches end chiefly in the nuclei of the hypoglossal and spinal accessory, and about the cells giving origin to the efferent components of the vagus and glossopharyngeal themselves—short reflex arcs. However, most of the afferent fibers terminate in the nucleus of termination of the vagus and glossopharyngeal:—(1) the **nucleus of the ala cinerea**, the middle portion of which is indicated in the floor of the fourth ventricle by the ala cinerea; (2) in the closed portion of the medulla, the lower end of the nucleus of the ala cinerea is seen to lie in the dorsolateral proximity of the central canal, and this portion is known as the *commissural nucleus of the ala cinera* (figs. 683 and 686) from the fact that fibers may be seen to pass directly from it across the mid-line; (3) the longer of the descending branches of the terminated fibers collect to form the **solitary tract**, a compact bundle situated dorsally just ventrolateral to the nucleus of the ala cinerea and quite conspicuous in sections of the medulla. The fibers of this bundle terminate in the *nucleus of the solitary tract*, which is but a ventrolateral downward continuation of the nucleus of the ala cinerea enclosing the bundles forming the

FIG. 690.—TRANSVERSE SECTION OF MEDULLA AT INFERIOR BORDER OF PONS.



t. It is most probable that the fibers of the solitary tract are chiefly from the vagus (pneumogastric), though Bruce has found evidence that the glossopharyngeal contributes to it appreciably. It decreases rapidly in descending the medulla, owing to the rapid termination of its fibers about the cells of its nucleus. It, with the axones given by the cells of its nucleus, is believed to extend as far downward as the level of the fourth cervical segment of the spinal cord. This being in the level of origin of the phrenic nerve, the tract forms a link in the respiratory apparatus which aids in the coordinated respiratory movements. The axones given off by the cells of the nucleus of the ala cinerea (terminal nuclei of the vagus and glossopharyngeal—) arise on both sides of the midline, associating nuclei of other cranial nerves with vagus and glossopharyngeal impulses, many decussating to be distributed to the structures of the opposite side. Many join the lemniscus of the opposite side and pass into the cerebrum; others are distributed to the motor neurones of the cervical cord of the same and opposite sides (reflex arcs), and no doubt others form central connections with the cells of the reticular formation of the medulla, though their precise relations have not been determined.

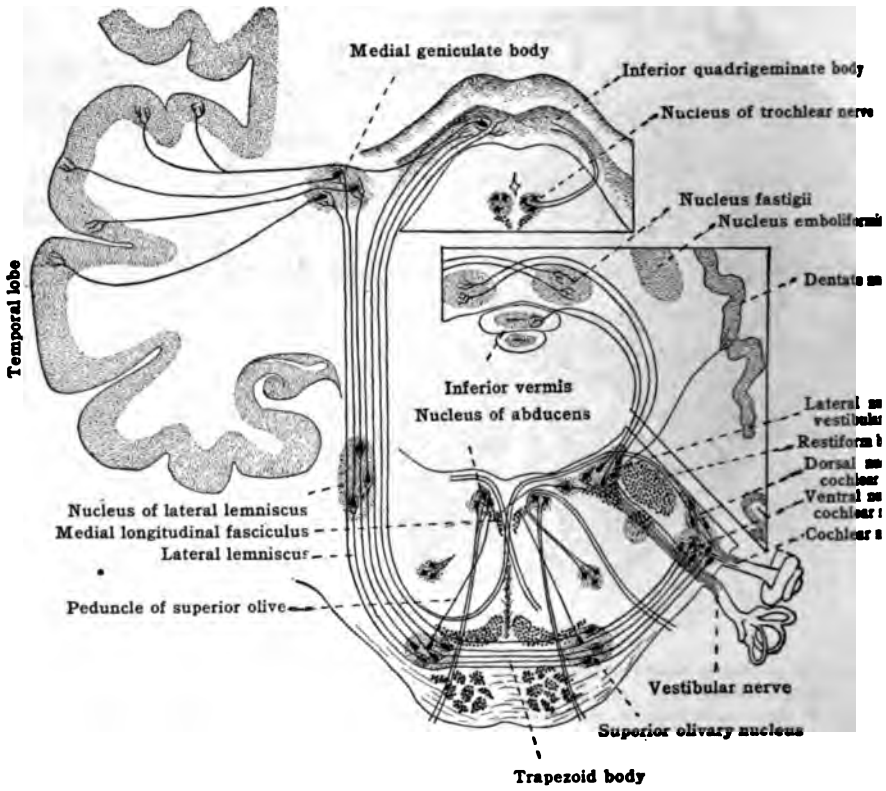
Cell-bodies in the nucleus of the ala cinerea, the nucleus of the solitary tract and in the commissural nucleus of the ala cinerea comprise the so-called **respiratory and vasomotor nuclei (centers')** of the medulla. Some of the caudal branches of the axones given off by the cells of these nuclei descend the spinal cord, not only to the segments giving origin to the phrenic nerve, but also to those supplying the intercostal and levatores costarum muscles. Some of these augment the solitary tract; most of them descend in the reticular formation of the medulla and cord. Further, axones given off by these cells convey vasomotor impulses which are distributed to visceral efferent neurones throughout the cord.

The nuclei of origin of the motor fibers of the vagus and glossopharyngeal are the **dorsal efferent nucleus of the vagus** and the **nucleus ambiguus.** The cells of the dorsal nucleus of the vagus lie somewhat clustered in the ventromedial side of the nucleus of the ala cinerea and lateral to the nucleus of the hypoglossus. Their axones pass outward among the entering or efferent vagus fibers, and it is suggested that most of them are visceral efferent fibers of the

vagus, i.e., they form synapses with sympathetic neurones. The *nucleus ambiguus* or v efferent nucleus of both nerves lies in the lateral half of the reticular formation, about m between the olive and the line traversed by the rootlets of the two nerves. Its upper larger. Its cells are considerably dispersed by the fibers of the reticular formation. axones arising from its cells course at first dorsalward and then turn abruptly outward the rootlets of the vagus or glossopharyngeal, as the case may be. The vagus is thou receive more efferent fibers from the nucleus ambiguus than does the glossopharyngea Cunningham notes that it may be questioned whether the latter nerve contains any fibers at all, there being paths by which the fibers of its motor branch (to the stylophar muscle) might enter it other than direct from motor nuclei.

The *vestibular* and *cochlear* nerves have been considered as one nerve and together desi as the acoustic or eighth cranial nerve. While both are purely sensory, are similar in de ment and their roots course together, they are distinct as to function and origin and their of termination differ. They are here described as separate cranial nerves. The two approach the brain stem together and enter it at the lateral aspect of the junction of m oblongata and pons.

FIG. 691.—SCHEME SHOWING SOME OF THE CENTRAL CONNECTIONS OF THE ACOUSTIC N (In part after Edinger.)



The **vestibular nerve** (nerve of equilibration) arises as the central processes of the bipo of the *vestibular ganglion*, and passes into the brain-stem on the ventromedial side of t form body to find its nucleus of termination (nucleus vestibularis) in the floor of th ventricle. This nucleus occupies a triangular area of considerable extent (area acus 681), and is usually subdivided into a *lateral nucleus* (Deiters'), a *medial nucleus* (Schwa *superior nucleus* (Bechterew's), and an *inferior nucleus* (nucleus spinalis). The lat downward prolongation of the general nucleus vestibularis which accompanies the *de or spinal root* of the nerve.

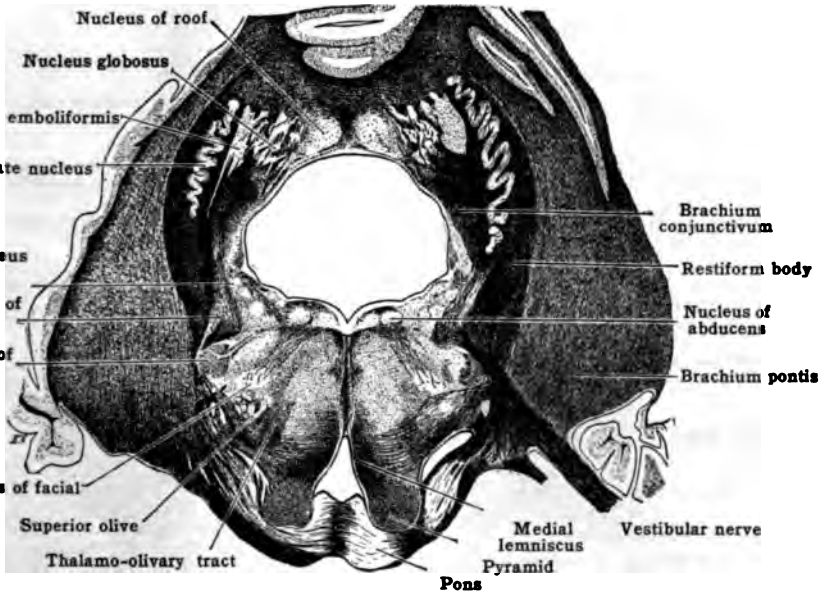
From the cells of the lateral and inferior nuclei axones are given off which form the lateral funiculus of the spinal cord (lateral vestibulospinal fasciculus, fig. 661) a anterior marginal fasciculus (ventral vestibulospinal tract). From both the lateral nuc the superior nucleus a special path is given off which passes upward and terminates in nucleus of the cerebellum (nucleus fastigii) of the opposite side and in the nucleus dent the cortex of the vermis. Also, fibers arising in the nuclei fastigii are said to termina lateral (Deiters') nucleus and other gray substance of the medulla (forming the *fastig tract*). Some fibers from the roof nucleus possibly descend into the anterior marginal fa of the spinal cord. From the medial and also from the superior nucleus fibers pas medial longitudinal fasciculus of both sides, and are distributed to the nucleus of the a of the same side and to the nuclei of the trochlear and oculomotor nerves of the opposite of the masticator nerve of the same and opposite sides. From the lateral and medi

probably from all, a few fibers arise which cross the midline to enter the lemniscus and end to the cerebrum (lateral portion of the thalamus) on the opposite side. The lateral (Deiters') nucleus is said to contribute more fibers to the medial longitudinal fasciculus than any nucleus of any other sensory cranial nerve and fewer fibers to the lemniscus. If any of these fibers descend the cord, they must do so in its anterior marginal fasciculus.

The *inferior nucleus* is accompanied by the *descending* or *spinal root* of the vestibular nerve, which begins to assemble in the nuclei above. This root is composed of both caudal branches of the entering fibers of the nerve and chiefly of fibers arising from the cells of its nuclei. Thus the vestibular nerve it corresponds in every way to the solitary tract for the vagus, and to the spinal tract of the trigeminus. Such of its fibers as descend into the spinal cord most probably do so in the lateral vestibulospinal fasciculus.

Many of the anatomical details of the central connections of the vestibular nerve have not yet been determined with exactness. In addition to whatever other functions it may have, it is considered to be the nerve of equilibration, and the connections noted above may be considered the pathways by which it exercises this function. The fibers of the apparatus which are represented in the spinal cord are supposed to convey impulses to the ventral horn (motor) cells of the cord as far down as the lumbar region.

Fig. 692.—Transverse Section through Inferior Border of Pons and Portion of Overlying Cerebellum. (From Villiger.)



The **cochlear nerve**, the auditory nerve proper, arises as the central processes of the bipolar cells of the *spiral ganglion* of the cochlea. In the lateral periphery of the restiform body, just before the latter enters the cerebellum, the nerve finds its two nuclei of termination, the *ventral nucleus* and the *dorsal nucleus* (tuberculum acusticum, fig. 681, 690).

From the **dorsal nucleus** arise the *acoustic medullary striæ*. These bundles pass around the dorsal aspect of the restiform body and course just under the ependyma of the floor of the fourth ventricle to the midline, where they suddenly turn downward into the substance of the medulla and in doing so, cross to the opposite side and join the lemniscus. As the lemniscus becomes separated higher up into a medial and lateral portion, these fibers course in the lateral lemniscus and are distributed chiefly to the grey substance of the inferior quadrigeminate body and medial geniculate body of that side. At the midline some of their fibers join the medial longitudinal fasciculus and by way of it are distributed to the nuclei of origin of the efferent fibers of other cranial nerves. In frequent cases, the acoustic striæ course so deeply beneath the ependyma as not to be superficially visible in the floor of the fourth ventricle.

From the **ventral nucleus**, fibers arise which terminate about (or give collaterals to) the cells of the **superior olivary nucleus** of the same and opposite sides. The superior olive is a small accumulation of gray substance which lies in the level of the inferior portion of the pons, and in line with the much larger inferior olivary nucleus of the medulla. However, it is not analogous to the latter in any sense. The two superior olives form links in the central acoustic chain. From cells of the superior olivary nucleus of the same and opposite sides, fibers arise which join the lateral lemniscus and terminate in the gray substance of the inferior quadrigeminate body and in the medial geniculate body, thus associating these bodies with the ventral nucleus of cochlear termination of the opposite side. From the medial geniculate body fibers arise which pass to the cortex of the superior temporal gyrus. Only a few of the fibers arising in the inferior quadrigeminate body terminate in the cortical area of hearing. In the lateral lemniscus some of the acoustic fibers are interrupted by cells of the *nucleus of the lateral lemniscus*. In crossing the midline, between the superior olives, the ventral fibers from the

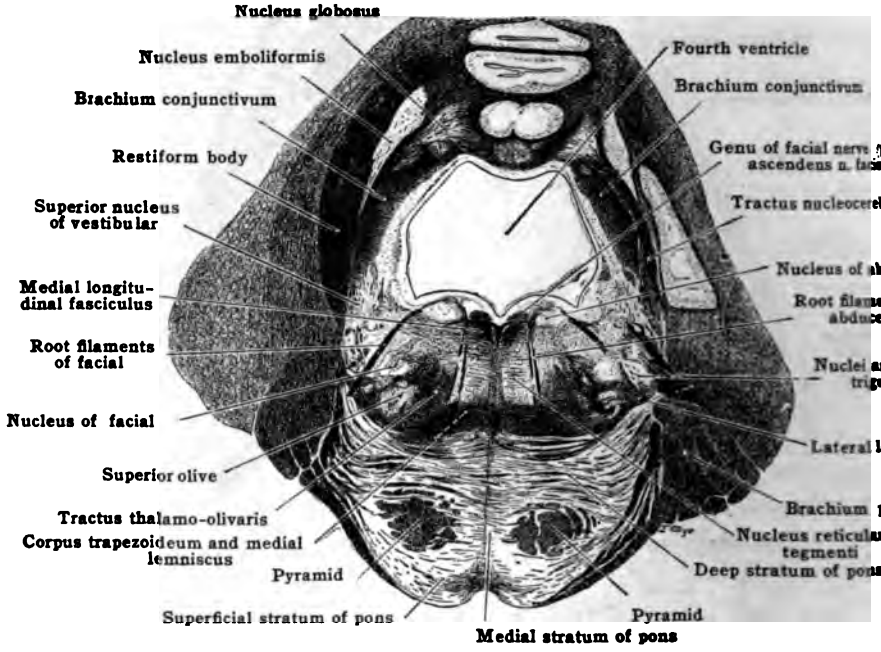
two sources form a more or less compact bundle, the **corpus trapezoideum** (trapezium). To this are added fibers crossing between the **nuclei trapezoidei, smaller masses** of gray substance just ventral to the superior olive and probably of the same significance.

Also, some fibers arising in the nuclei of termination of the cochlear nerve pass to the inferior quadrigeminate body of the same side. On the other hand, the relation with the medial geniculate body is thought to be wholly a crossed one. Further, some fibers are described as terminating in the *superior quadrigeminate body* of both the same and the opposite side. These, forming the *stratum lemnisci* of this body, are especially suggestive of associating auditory impulses with eye-movements.

All the fibers arising in the superior olivary nucleus do not enter the corpus trapezoideum and the lateral lemniscus. A small bundle, the **peduncle of the superior olive**, arises in the nucleus and courses dorsally to the region of the nucleus of the abducens. Here certain of its fibers terminate about the cells of the nucleus of the abducens, while others enter the medial longitudinal fasciculus and pass to the nuclei of the trochlear and oculomotor nerves, thus further establishing connections between auditory impulses and eye-movements.

The **facial nerve** is commonly described as consisting of the 'facial proper' and its so-called sensory root or *pars intermedia*, the two together being designated as the seventh cranial nerve. However, the pars intermedia neither serves as a sensory root for the facial nor is it part

FIG. 693.—TRANSVERSE SECTION THROUGH PONS AND PORTION OF CEREBELLUM AT LEVEL OF NUCLEI AND ROOT FILAMENTS OF ABDUCENS AND FACIAL NERVES. (From Villiger.)

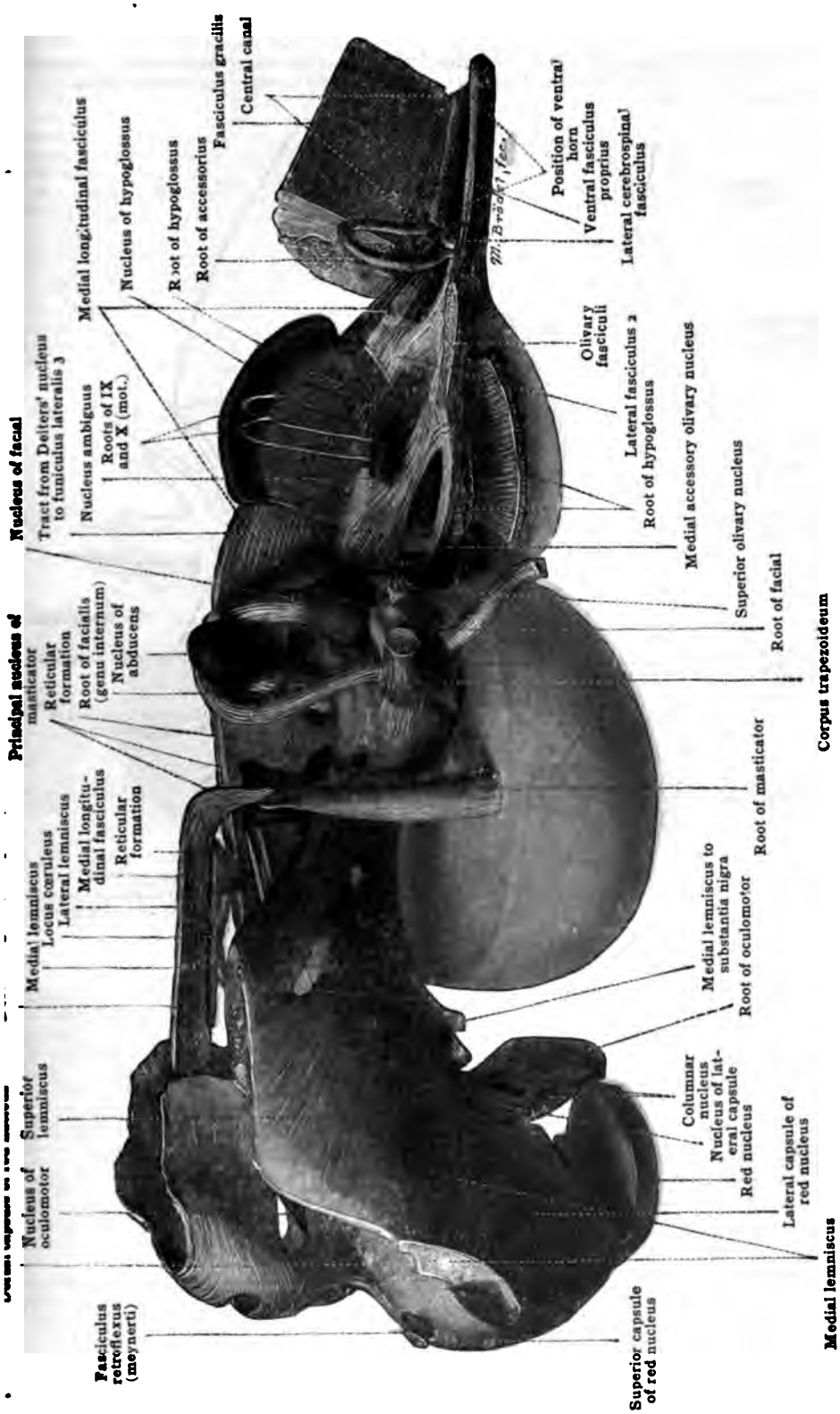


sensory. Many years ago Sapolini considered it a separate nerve and later it was called the *intermediate nerve of Wrisberg*. More recent investigations of its development and distribution, especially those of Streeter and Sheldon, further indicate that it merits a separate description and a separate name, and, indicative of its distribution, it is here described as the *glossopalatine nerve*. The facial, the glossopalatine and the abducens all have their nuclei within the level of the pons, though the roots of all appear from under its inferior border and are considered as attached to the medulla.

The **facial** [nervus facialis] has its nucleus (of origin) in the ventrolateral region of the reticular formation, superior to and in line with the nucleus ambiguus (figs. 688, 692). The axones given off by the cell-bodies of the nucleus collect into a bundle which, instead of passing ventrally and directly to the exterior of the pons, courses at first dorsomedially to the mesial side of the nucleus of the abducens (ascending root of the facial); then it turns and courses superiorly for a few millimeters, parallel with the nucleus of the abducens immediately beneath the floor of the fourth ventricle (*genu internum*, figs. 693 and 694); then it turns abruptly in a ventrolateral and inferior direction to its point of exit at the inferior border of the pons, just lateral to the olive and medial to the entrance of the vestibular nerve. Its exit usually involves a few pons fiber. In transverse sections through the middle of the nucleus of the abducens the genu of the facial appears as a compact transversely cut bundle at the dorsomedial side of this nucleus.

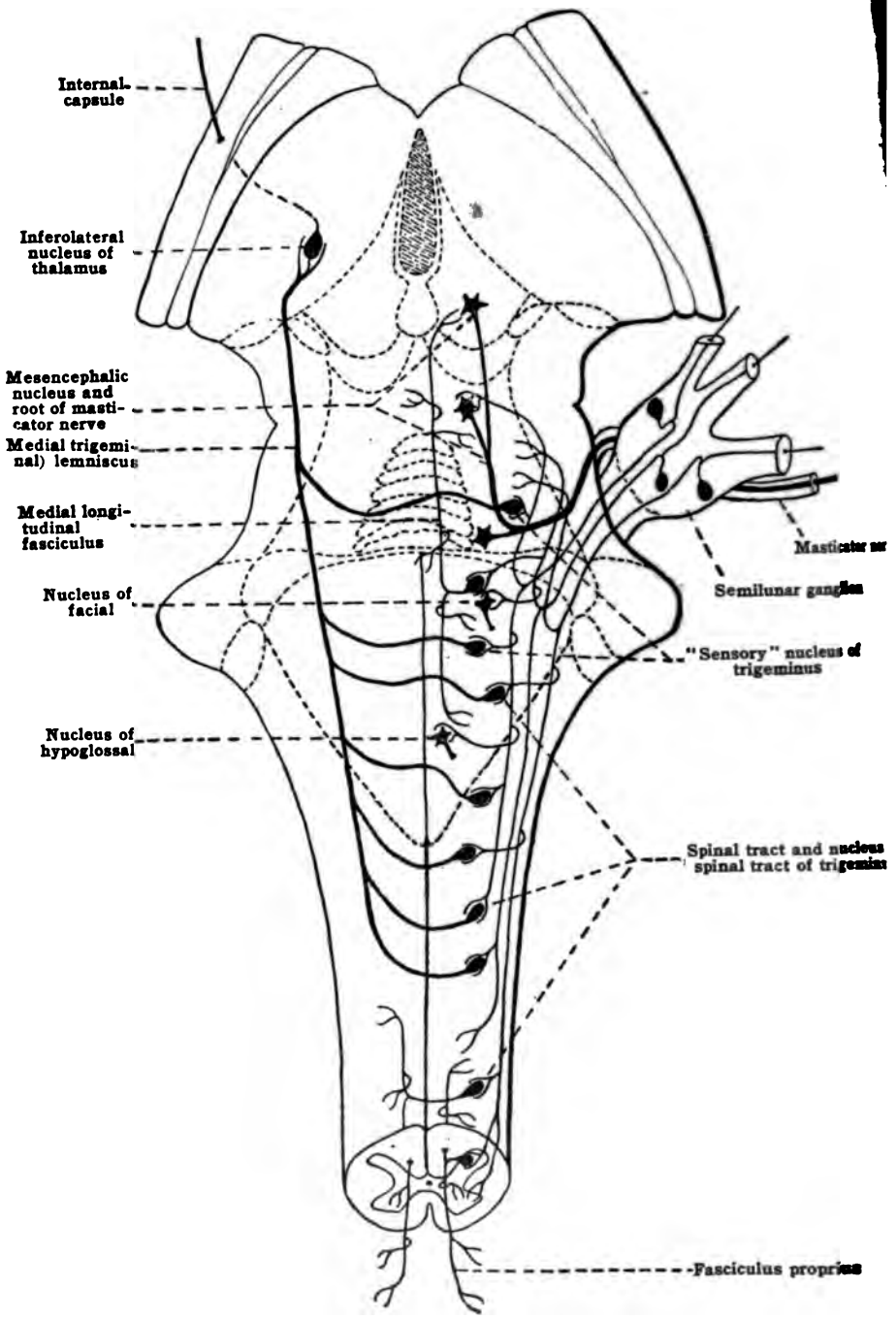
The nucleus of the facial is described as consisting of two chief groups of cells, an anterior and a posterior group which give rise respectively to the axones of the superior and inferior branches of the facial nerve. It receives cortical impulses from the lower portion of the anterior central gyrus of the cerebral cortex, from the root fibers of the trigeminus of the same side, which serves as its sensory root, and (chiefly) fibers arising from the nuclei of termination of the

Fig. 694.—Drawing of Model of Brain-stem of an Infant, showing the Nuclei of Origin of the Motor Cranial Nerves. (After Sabin.)



trigeminus. The nuclei of termination of the optic and the cochlear nerves of the same opposite sides give rise to fibers which terminate about its cells. The fibers from the cortex descend in the pyramidal fasciculi and cross by way of the raphe and arcuate fibers terminate in the nucleus of the opposite side. The anterior group of the cells of the

FIG. 695.—DIAGRAM ILLUSTRATING THE PRINCIPAL CENTRAL CONNECTIONS OF THE TRIGEMINUS AND MASTICATOR NERVES, EXCLUSIVE OF THEIR RELATIONS TO DESCENDING CEREBRAL OR PYRAMIDAL FIBERS.

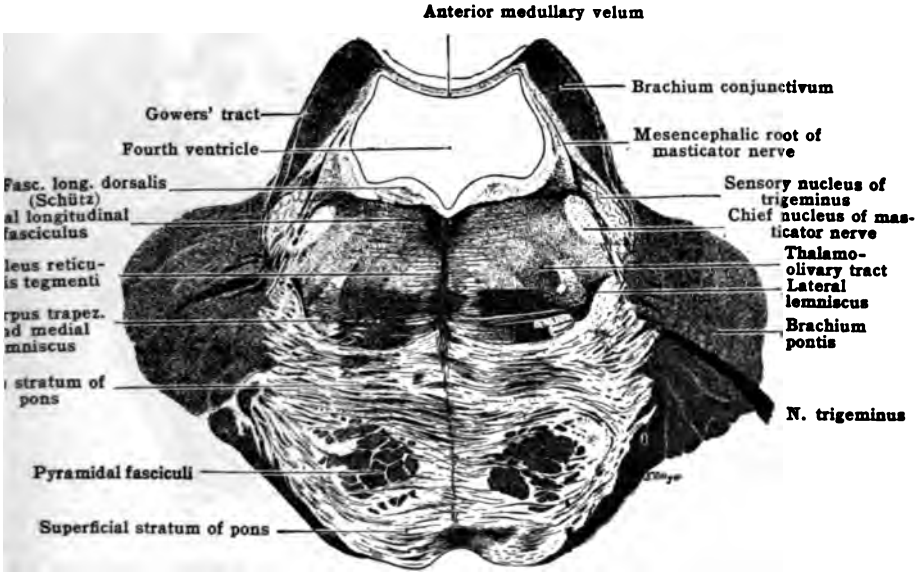


nucleus must receive cortical fibers not only from the cerebral hemisphere of the opposite also from that of the same side, evidenced by the fact that the superior branch of the nerve but little affected in facial paralysis resulting from a lesion in the cerebral cortex of one A lesion destroying the root of the nerve or its nucleus of origin will of course give total paralysis of the side of the lesion.

The glossopalatine nerve (*nervus intermedius*, sensory root of facial, etc.) is a mixed nerve largely sensory. It accompanies the facial nerve trunk from a short distance beyond the ganglion (genu externum) of the facial to its attachment to the brain stem. Its *sensory fibers* are T-fibers of the cells of the *geniculate ganglion* (at the geniculum of the facial). The peripheral processes go as the *chorda tympani* to supply the epithelium of the anterior part of the tongue and that of the palate, especially of the palatine arches, and some of its fibers share with the glossopharyngeal nerve the innervation of the taste-buds. The central processes enter the brain stem, bifurcate into caudal and cephalic branches, and find their nucleus of termination in a superior extension of the nucleus of the solitary tract (the ventral portion of the nucleus of the ala cinerea). The geniculate ganglion contains some cell-bodies of sympathetic neurones, left over in it during the period of migration form its homologue of the ganglion crest. The *efferent fibers* of the glossopalatine arise from cell-bodies lying dorsomedial to the nucleus of the facial and in the level between this and the nucleus of the masticator nerve anterior to it. Its cells are usually scattered in the reticular formation in line with the dorsal efferent nucleus of the vagus. Since most of its fibers, at least, are visceral efferent and connected with sympathetic neurones (terminate in sympathetic ganglia) and convey secretory impulses destined for the salivary glands, chiefly the submaxillary and sublingual, it has been called **the nucleus salivatorius.**

The abducens is a small, purely motor nerve, which supplies the lateral rectus muscle of the eye. Its *nucleus of origin* lies close to the midline in the medial eminence of the floor of the fourth ventricle, superior to and in line with that of the hypoglossus. Its root fibers, unite, pursue a ventral course, inclining a little laterally and curving inferiorly to emerge from

696.—Transverse Section Through Upper Part of Pons at the Level of the Entrance of the Trigeminus. (From Villiger.)



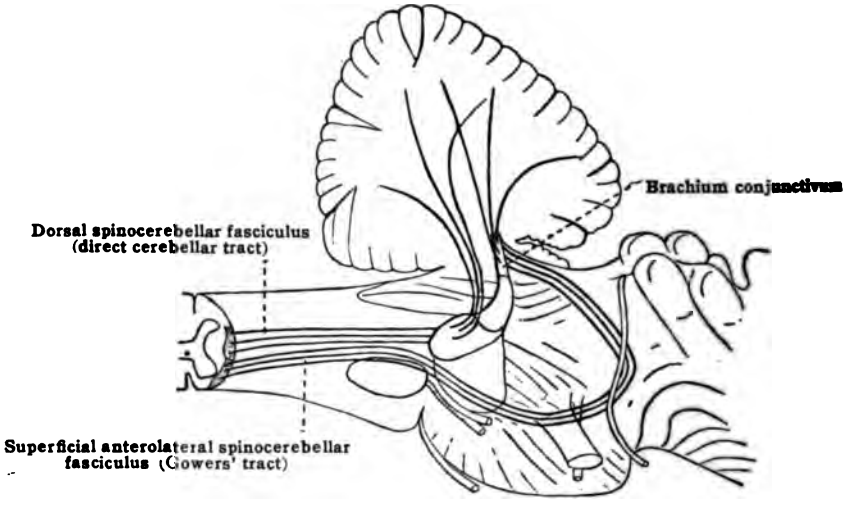
the inferior border of the pons. They pass lateral to the pyramid, and often between of its fasciculi. The nucleus receives cortical or voluntary impulses by way of the pyramidal fasciculi chiefly of the opposite side. Its connection with the auditory apparatus and the medial longitudinal fasciculus has already been noted. It probably receives afferent impulses through the fibers of the trigeminus as well as by fibers descending from the nuclei of termination of the optic nerve. It is also associated, by way of the medial longitudinal fasciculus, with the nucleus of the oculomotor nerve of the same and opposite side.

The trigeminus is considerably larger than any of the nerves inferior to it, and has the most extensive central connections of any of the cranial nerves. It is a purely sensory nerve which leaves through the brachium pontis in line with the facial nerve. It serves as the nerve of general sensibility for the face from the vertex of the scalp downward, and thus it corresponds to the afferent fibers (dorsal root) for all the nerves giving motor supply to structures underlying this domain, including the eye-muscles. Its fibers arise from its large, trilobed, **semilunar** (Gasserian) **ganglion**, situated outside the brain. This corresponds to the dorsal root-ganglion of a spinal nerve, and its cells give off the characteristic T-fibers with peripheral and central branches. The central or afferent branches upon entering the brain-steam bifurcate into ascending and descending divisions, just as the entering dorsal root-fibers of the spinal nerves, and find their *nucleus of termination* in a dorsolateral column of gray substance, lying deeply and extending longitudinally through the brain stem, and consisting of the upward continuation of the gelatinous substance of Rolando of the spinal cord. Opposite the entrance of the nerve is a considerably thickened portion of this column of gray substance, known as the *sensory nucleus* of the trigeminus, and the remainder below is called the *nucleus of the spinal tract* (figs. 688, 695). These parts are equally 'sensory.' After bifurcation the branches of the entering fibers of the trigeminus terminate about the cells of these nuclei. The descending branches are much longer

than the ascending, and in passing downward from the spinal tract of the trigeminus, which is marked in all transverse sections of the medulla oblongata (figs. 682–684, 690). The spinal tract decreases rapidly in descending the medulla, owing to the rapid termination of the fibers in the nucleus of the tract. It has been traced as far down as the second cervical segment of the spinal cord. The ascending branches terminate in the 'sensory nucleus,' and in it extension upward into the mesencephalon. This mesencephalic nucleus of termination of the trigeminus is both shorter and more scant than the spinal extension. It may extend to the superior quadrigeminate body.

Axones from the nucleus of termination of the trigeminus are distributed—(1) to the nuclei of the masticator nerve of the same and opposite sides (short or simple reflex fibers); (2) to the motor nuclei of the other motor cranial nerves, especially of the facial; (3) to the thalamus of the same and chiefly the opposite side, and thus, through interpolation of thalamic neurones, their impulses reach the somesthetic area of the cerebral cortex. These fibers form a '*trigeminal lemniscus*.' They ascend in the recticular formation of the opposite side, most of them finally coursing within the medial lemniscus. In crossing the midline they contribute to the internal arcuates. (4) Some fibers of both the trigeminus direct and from its nucleus pass laterally into the cerebellum. (5) Fibers to the quadrigeminate bodies. The longer of the reflex or association axones arising in the nucleus of termination may contribute to the medial longitudinal fasciculus; many of them descend to terminate in the gray substance of the spinal cord below the levels in which the fibers of the spinal tract proper terminate. The nucleus of termination is directly homologous to the nuclei of the fasciculus gracilis and fasciculus cuneatus, and, like the nuclei of termination of all sensory cranial nerves, it contains cell-bodies homologous to those which give rise to the fasciculi proprii and commissural fibers of the spinal cord.

FIG. 697.—DIAGRAM SHOWING THE RHOMBENCEPHALIC COURSE OF GOWERS' TRACT AND THE DIRECT CEREBELLAR TRACT.


Brachium conjunctivum
Dorsal spinocerebellar fasciculus (direct cerebellar tract)
Superficial anterolateral spinocerebellar fasciculus (Gowers' tract)

The **masticator nerve** [*portio minor n. trigemini*] is a purely motor nerve, usually called the motor root of the trigeminus from the fact only that it makes its exit from the pons by the side of the entering fibers of the trigeminus, passes outward over the ventromedial side of the semilunar ganglion and accompanies the inferior maxillary division (mandibular nerve) of the trigeminus till it divides totally into its branches for the motor supply of the muscles of mastication. It serves, therefore, as but a relatively small part of the 'motor root' of the trigeminus.

The nucleus of origin of the masticator nerve is attenuated into two parts: (1) The *chief nucleus* (*nucleus princeps*) lies on the dorsomedial side of the larger portion (sensory nucleus) of the nucleus of termination of the trigeminus. It is the larger of the two parts and gives origin to much the greater part of the masticator. (2) Scattered anteriorly and continuous with the mesencephalic extension of the chief nucleus, in line with the *locus ceruleus*, are the cell-bodies usually described as the *nucleus of the mesencephalic* (descending) *root*. These cells lie in decreasing linear distribution, through the mesencephalon, as far anterior as the posterior commissure of the cerebrum, and the *mesencephalic root* of the nerve accumulates as it descends to join the exit of the fibers arising from the chief nucleus. The average diameter of its cells is somewhat less than for the chief nucleus.

It is not clearly settled that the fibers arising from the mesencephalic nucleus of the masticator nerve go to the muscles of mastication. As suggested by Kölliker, some of these may supply the tensor veli palatini and tensor tympani muscles. Investigations of lower animals by Johnston and Willems indicate that the mesencephalic root may contain but few motor fibers, representing instead a portion of the sensory trigeminus fibers, whose cell-bodies of origin are retained during development within the central system, their peripheral processes passing out in the root of the trigeminus. It is claimed that some fibers, probably sensory, in descending give off collaterals which terminate about cells in the chief nucleus, to form simple reflex arcs.

It is claimed that each masticator nerve receives a few fibers arising from the cells of the nucleus of that of the opposite side.

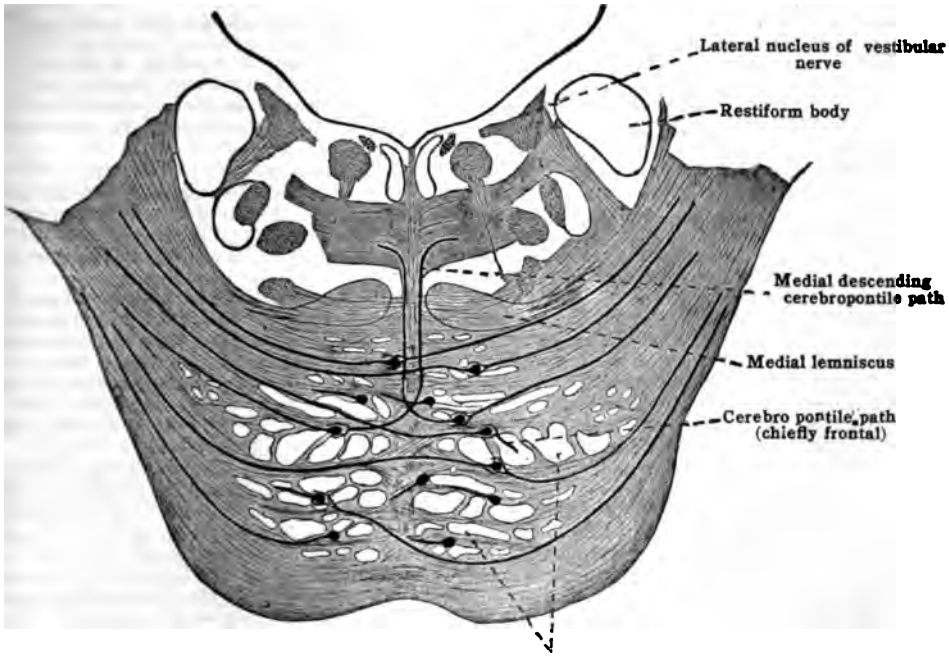
Both parts of the nucleus of the masticator receive afferent impulses brought in by the [illegible]minus of the same (chiefly) and of the opposite side, and both receive cortical impulses [illegible]bers from the inferior portion of the precentral gyrus which descend in the cerebral ped[illegible]s and cross to terminate in the nucleus of the opposite side.

The internal structure of the pons.—The nuclei and roots of the trigeminus, masticator, [illegible]ucens, facial, glossopalatine, cochlear and vestibular nerves are extended within the level [illegible]he pons, and their position and course have been described above. The pons proper [illegible] bridge) consists of a mass of transversely running fibers continuous on either side into [illegible]brachia pontis or middle cerebellar peduncles. In the animal series the relative amount [illegible]these fibers varies with the size of the cerebellum upon which they are dependent. They [illegible]relatively more abundant in man than in other animals.

In transverse sections the pons fibers are seen to course ventrally about the main axis of [illegible]brain-stem, making it possible to divide the section into a *basilar* or *ventral part* (pons proper) [illegible]a *dorsal part* (*tegmentum*). The fibers in their transverse and ventral course around the [illegible]ulla oblongata involve the pyramids. At the inferior border of the pons the fibers little [illegible]re than separate the pyramids as such from the main axis of the brain-stem, but more su[illegible]iorly the pons fibers pass through the pyramids, splitting them into the **pyramidal fasciculi.**

FIG. 698.—DIAGRAM SHOWING CONNECTIONS OF THE NUCLEI OF THE PONS

The plane of the section is obliquely transverse or parallel with the direction of the brachia pontis.



These pyramidal or chief *longitudinal fibers* of the pons are the continuation of the basal portion of the cerebral peduncles through the pons, to emerge as the pyramids proper at its inferior border. They occupy an intermediate or central area among the pons fibers of either side, leaving the periphery of the pons uninvaded. The *superficial pons-fibers* form the solid bundle of its ventral and lateral periphery and the *deep pons-fibers* form similar bundles dorsally enclosing the area of pyramidal fasciculi (figs. 693, 696, 698).

In the transverse sections through the *inferior portion* of the pons, the *dorsal or tegmental part* consists of structures continuous with and analogous to the structures of the medulla oblongata immediately below, exclusive of the pyramids. In addition, this region contains the superior olivary nucleus and the corpus trapezoideum. The significance of these structures and their relation to the nucleus of termination of the cochlear nerve is shown in figs. 691–693. In this region the *lemnicus* (fillet) changes from the sagittal to the coronal plane, and its lateral edges are becoming drawn outward and carry the lateral lemniscus of the regions superior to this. The medial longitudinal fasciculus, left alone by the change in the arrangement of the lemniscus, maintains its dorsal and medial position throughout the pons and into the mesencephalon above. The thalamo-olivary tract appears loosely collected in the dorsal part of the pons, dorsomedial to the nucleus of the superior olive.

The restiform body acquires in this inferior region a more dorsolateral position than in the medulla below. Its fibers are beginning to turn upward in their course to the cerebellum mesial to the brachium pontis. Here the restiform body is nearing completion, and the fibers now contained in it may be summarized as follows:—

(1) The fibers of the dorsal spinocerebellar fasciculus (direct cerebellar tract) of the same side

(2) Fibers from the nuclei of the fasciculus gracilis and fasciculus cuneatus of the same and opposite side (external arcuate fibers).

(3) Fibers to and from the inferior olives of the same and (chiefly) the opposite side (cerebello-olivary fibers).

(4) Sensory cerebellar fibers from the nuclei of termination of the vagus, glossopharyngeal, vestibular and trigeminus, vestibular especially, and from the cells of the reticular formation.

(5) Descending fibers to the motor nuclei of the vagus and glossopharyngeal, and probably some fibers descending into the anterior marginal fasciculus of the spinal cord, the latter, however, being in large part interrupted by cells in the nuclei of the vestibular nerve.

(6) A few fibers arising from the arcuate nuclei. These nuclei are continuous superiorly with the nuclei of the pons and some of their fibers are described as entering the cerebellum by way of the restiform body instead of by way of the brachium of the pons as in the levels above.

The ascending fibers of the restiform body are distributed to the cortex of the vermis, the nucleus of the roof (*fastigii*), the nucleus dentatus, nucleus emboliformis, and nucleus globosus.

Very few if any of the fibers ascending the cord in *Gowers' tract* enter the cerebellum by way of the restiform body. This tract (the superficial anterolateral spinocerebellar fasciculus) ascends the medulla, dispersed in the reticular formation, and therefore in a more ventral position than that of the direct cerebellar tract. In this position it becomes enclosed by the fibers of the pons, and so it passes upward, beyond the pons, around the lateral lemniscus to the brachium conjunctivum, and there turns back to enter the cerebellum by way of this brachium. Certain clinical phenomena, probably purely psychological, have been alleged to indicate that some of the fibers of Gowers' tract pass on to the cerebrum instead of turning in the medullary velum to enter the cerebellum.

The dorsal part of a transverse section through the *upper part* of the pons contains the **superior cerebellar peduncles** [brachia conjunctiva] instead of the restiform bodies or inferior peduncles. Instead of the cerebellum forming the roof of the fourth ventricle, in this region the roof is formed by the anterior medullary velum bridging the space between the two brachia conjunctiva (fig. 696). Adhering upon the medullary velum is the **lingula cerebelli**—the superior and ventral extremity of the superior vermis. This is the only portion of the cerebellum attached to this region.

The lemniscus (fillet) is found more lateral than at the inferior border of the pons, and is divided into the *medial lemniscus* and *lateral lemniscus* proper. The lateral lemniscus has shifted dorsally until in this region it courses in the dorsolateral margin of the section external to the brachium conjunctivum. The mesencephalic root of the masticator nerve occurs in the dorsolateral margin of transverse sections through this region, and this and the trigeminus are the only cranial nerves represented here.

The transverse fibers of the ventral part of the section (pons proper), and therefore the brachia pontis, consist of fibers coursing in opposite directions. Many are fibers which are outgrowths of the Purkinje cells of the cortex of the cerebellar hemispheres, and pass either directly to the cerebellar hemisphere of the opposite side or turn dorsalward in the raphe to course longitudinally in the brain-stem both toward the spinal cord and toward the mesencephalon. Others terminate in the gray substance (nuclei) of the pons. Others are fibers which arise in the gray substance of the pons and pass to the cerebellar hemispheres, and still others are the cerebropontile fibers, from the temporal, occipital and frontal lobes.

The **gray substance of the pons** [nuclei pontis] occurs quite abundantly. At the inferior border of the pons it is found concentrated about the then more accumulated bundles of the emerging pyramids, and serial sections show it to be a direct upward continuation of the arcuate nuclei of the medulla oblongata below. Higher up it is dispersed throughout the central area in the interspaces between the transverse pontile and longitudinal pyramidal fasciculi. A large portion of the nerve-fibers passing through it are thought to be interrupted by its cells, which thus serve as links in some of the neurone-chains represented by the fibers of the pons. Of the more important of such relations, the following are said to exist:—

(1) Fibers which arise in the cortex of one cerebellar hemisphere and terminate about cells of the nucleus pontis of the same and opposite side of the midline. These cells give off axones which pass to the other cerebellar hemisphere. In this relation the nuclei of the pons are analogous to the arcuate nuclei, save that the cerebellar fibers interrupted in the former are connected with the cerebellum by way of the brachia pontis instead of the restiform bodies.

(2) Certain of the descending cerebropontile fibers terminate about cells of the nuclei of the pons. Such cells give off fibers which probably, for the most part, pass to the cerebellar hemispheres, the impulses from the cerebral hemisphere of one side being conveyed to the opposite cerebellar hemisphere. Most of the descending cerebropontile fibers are thought to cross the midline to terminate about cells of the nuclei of the pons of the opposite side, a relation not sufficiently emphasized in the accompanying diagram (fig. 698).

Of the cerebropontile paths, the **frontal pontile path** (Arnold's bundle) is described as arising in the cortex of the frontal lobe (frontal operculum) passing in the anterior portion of the internal capsule down into the medial part of the base of the cerebral peduncle, and terminating in the gray substance of the pons. The descending **temporal pontile path**, (Türk's bundle), arises in the cortex of the temporal lobe, traverses the posterior portion of the internal capsule, lies lateral in the pyramidal portion of the cerebral peduncle, and terminates in the gray substance of the pons. In the posterior part of the internal capsule, the temporal pontile path is joined by a small bundle arising in the occipital lobe and going to the pons nuclei. This, supposedly smaller than the other two, adds an **occipitopontile path.**

The total area in cross section of the pyramidal fasciculi as they enter the pons above is considerably greater than that which they possess as they emerge as the pyramids of the medulla below. The difference is considered very appreciably greater than can be explained as due to the loss of pyramidal fibers supplied to the nuclei of origin of the motor cranial nerves lying within the level of the pons, and the additional difference is explained as due to the termination within the pons of the cerebropontile paths.

THE ISTHMUS OF THE RHOMBENCEPHALON

The isthmus of the rhombencephalon is nothing more than the transition of the metencephalon into the mesencephalon above. It is quite short and comprised of only the structures which run through it, namely, the *brachia conjunctiva* (superior peduncles of the cerebellum), the anterior medullary velum, the lateral sulcus of the mesencephalon, the substantia nigra, the cerebral peduncles, and the inferior end of the interpeduncular fossa. It surrounds the superior extremity of the fourth ventricle. The lateral and medial lemnisci, the superior extension of the nucleus of the trigeminus, the mesencephalic nucleus and root of the masticator nerve and Gowers' tract extend through it. At the midline, just inferior to the inferior quadrigeminate bodies is the **frenulum** of the anterior medullary velum and the trochlear nerves, decussating in this, emerge at its sides and course ventrally around the sides of the isthmus. In the lateral sulcus, the isthmus shows usually a small triangular elevation known as the **trigonum lemnisci** from the fact that the lateral lemniscus tends towards the surface in this region and the nucleus of the lateral lemniscus begins there.

Functions of the cerebellum.—From the above descriptions involving the structures of the metencephalon, it may be noted (1) that a given side of the cerebellum is associated chiefly with the same side of the general body and with the opposite side of the cerebrum. (2) That it receives afferent impulses from the spinal cord (brought into the cord by the dorsal roots of the spinal nerves) by way of the direct cerebellar fasciculus of the same side, and by Gowers' tract, arising in the same and opposite sides of the cord, and from the nuclei of the fasciculus gracilis and cuneatus of the same and opposite sides. It further receives afferent impulses from the nuclei of termination of the trigeminus, glossopharyngeal and vagus of the same side chiefly, and especially does it receive afferent impulses from the nuclei of the vestibular nerve of the opposite and same side. (3) That the cerebellum sends impulses to the red nucleus, the thalamus and the cerebral cortex of the opposite side, and some of its fibers terminate in the nuclei of termination of the vestibular nerve and probably some fibers arising in its roof nuclei descend into the spinal cord direct. (4) That the cerebellum receives impulses from the thalamus of the opposite side by way of the thalamo-olivary tract and the inferior olive, and especially from the cerebral cortex of the opposite side by way of the frontal, temporal and occipital pontile paths and the nuclei of the pons. Further, fibers from the general pyramidal fasciculi are described as terminating about cells of the nuclei of the pons and bearing impulses which are distributed to the opposite side of the cerebellum.

Taking into consideration these known associations of the cerebellum, the anatomically possible paths which in part may distribute cerebellar impulses to the gray substance sending efferent fibers to the peripheral tissues are (1) the general pyramidal fasciculi whose cortex of origin may receive impulses by *fibræ propriæ* from the cortical areas receiving impulses from the cerebellum. The pyramidal fasciculi, decussating, distribute impulses to the gray substance of the medulla and cord of the same side as that from which the cerebellocerebral impulses passed to the cortex. (2) The lateral vestibulospinal and the anterior marginal fasciculi to the ventral horn of the spinal cord of the same side, probably carrying impulses descending from the cerebellum as well as impulses brought in by the vestibular nerve and descending direct from its nuclei of termination into the spinal cord. (3) The rubrospinal tract of the cord and probably some of the thalamospinal fibers (corpora-quadrigemina-thalamus path), the red nuclei and thalami being associated abundantly with the cerebellum. These tracts likewise decussate in descending but likewise do the cerebellar impulses ascending to the red nuclei and thalami.

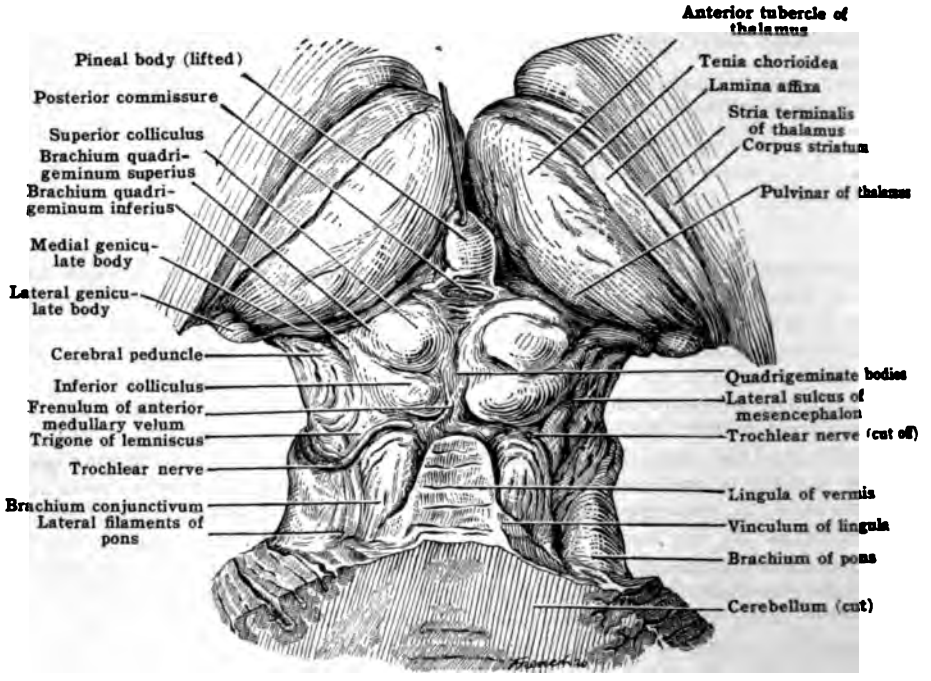
Whatever other functions it may possess, developmental defects and pathologic lesions show that the cerebellum has to do with muscular tone, with the equilibration of the body and the finer coördinations, the adjustive control of contractions of functionally correlated groups of muscles. Making this possible, in part at least, it is seen above that it is associated (1) directly with the special nerve of equilibration, the vestibular; (2) with the optic apparatus by way of the thalamus, and (3) with the afferent impulses from the general body, by way of the direct cerebellar and Gowers' tracts, by way of the nuclei of the fasciculus gracilis and cuneatus, and the nuclei of termination of the trigeminus, glossopharyngeal and vagus. It has been suggested that by way of these latter paths the cerebellum deals especially with those general afferent impulses which arise within the muscles of the body (sensory fiber-terminations on tendons, muscle-sheaths, neuromuscular spindles, etc.), and which are grouped under the name 'Proprioceptive.' Its activities are considered as not entering 'consciousness,' while sensations of 'muscular sense,' and pain from joints, muscles and tendons must reach the *cerebral* cortex and are there recognized as such.

Studies of the comparative anatomy of the cerebellum by Elliot Smith, Bolk and van Rynberk, experimental studies by André-Thomas and Durupt, and clinical studies of symptoms resulting from localized lesions in the human cerebellum by Bárány and others have led to the conclusion that there is a certain amount of localization of function in the cerebellar gray substance. In fig. 699 are indicated some of the functional areas of the cerebellar cortex suggested. It will be seen that the anatomical distinction made between the cerebellar hemispheres and the vermis is not functionally important, especially on the superior surface. Beginning on the superior surface, the following areas may be noted:—The anterior part of the quadrangular lobe, the culmen and the central lobule with its ala comprise an unpaired area for the coördinations of muscular contraction resulting in subconscious movements of the head. The posterior

colliculus, so do some fibers from the optic tract pass into the inferior colliculus. Also some fibers form the optic tract (medial root) are said to terminate in the medial geniculate body. Resting in the broadened medial groove between the superior quadrigeminate bodies lies the non-nervous **pineal body** (epiphysis). This also belongs to the thalamencephalon. Under the stem of the pineal body is a strong transverse band of white substance crossing the middle as a bridge over the opening of the cerebral aqueduct into the third ventricle. This is the **posterior commissure** of the cerebrum, and contains commissural fibers arising in both the thalamencephalon and mesencephalon. The triangular area bounded by the stem of the epiphysis, the thalamus, and the superior colliculus with its brachium, is known as the **habenular trigone.**

Inferiorly, the lamina quadrigemina is continuous with the isthmus of the rhombencephalon by way of the brachia conjunctiva or superior cerebellar peduncles, and the anterior medullary velum which bridges between the medial margins of these peduncles. The narrowed superior end of the velum, the part directly below the inferior quadrigeminate bodies, is thickened into a well-defined white

FIG. 700.—DORSAL SURFACE OF MESENCEPHALON AND ADJACENT PARTS. (After Spalteholz.)



band known as the **frenulum veli.** From the lateral margins of this band on each side and just below the inferior quadrigeminate bodies emerge the **trochlear nerves** (the fourth pair of cranial nerves), and the increased thickness of the band is largely due to the decussation of this pair of nerves taking place within it.

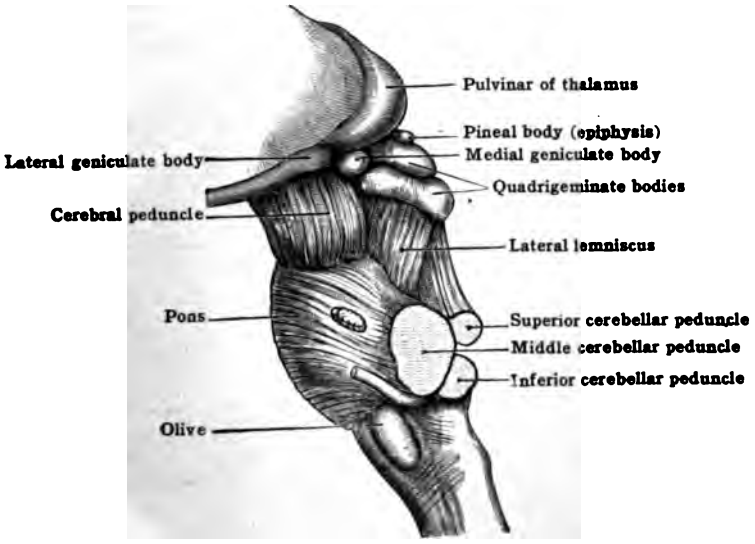
The brachium conjunctivum, together with the inferior and superior colliculi of each side, form a marked ridge which results in the *lateral sulcus* of the mesencephalon, a lateral depression between the base of this ridge and the cerebral peduncle below and continuous into the transverse sulcus at the superior border of the pons. The ridge is thickened laterally by the lateral lemniscus, which is disposed as a band of white substance passing obliquely upward from under the brachium pontis, applied to the lateral surface of the brachium conjunctivum and which enters the lateral margin of the mesencephalon. The region at which the lateral lemniscus approaches nearest the surface and in which the largest portion of its nucleus lies is the slightly elevated **trigone of the lemniscus.**

The **ventral surface** of the mesencephalon is formed by the **cerebral peduncles** (crura), two large bundles of white substance which are close to one another at the superior margin of the pons, but immediately diverge somewhat, producing the **interpeduncular fossa,** and in so doing pass upward and lateralward to disappear beneath the optic tracts (fig. 709). The *posterior recess* of the interpeduncular fossa extends slightly under the superior margin of the pons, while its *anterior*

[redacted] is occupied by the corpora mammillaria of the prosencephalon. The triangular floor of the fossa is the **posterior perforated substance,** a grayish area presenting numerous openings for the passage of blood-vessels. It is divided by a shallow median (oculomotor) groove and is marked off from the medial surface of each peduncle by the lateral furrows, out of which emerge the root filaments of the **oculomotor nerve.** Each oculomotor nerve, formed by assembly of its root filaments makes an impression in the medial surface of the peduncle, the *oculomotor sulcus.* The ventral surface of each peduncle is rounded and has a somewhat twisted appearance, indicating that its fibers curve from above medialward and downward (fig. 709).

Sometimes two small, more or less transverse bands of fibers may be noted crossing the peduncle—an inferior, the *tenia pontis,* and a superior, the *transverse peduncular tract.* The inferior represents detached fibers of the pons; the superior, running from the brachium of the inferior quadrigeminate body and disappearing in the oculomotor sulcus, appears to be derived from the quadrigeminate bodies. Since it is well developed in the cat, dog, sheep, and rabbit, but is absent or little marked in the mole, it is supposed to be concerned with the optic apparatus.

FIG. 701.—DIAGRAM OF LATERAL VIEW OF MESENCEPHALON AND ADJACENT STRUCTURES. (After Gegenbaur, modified.)

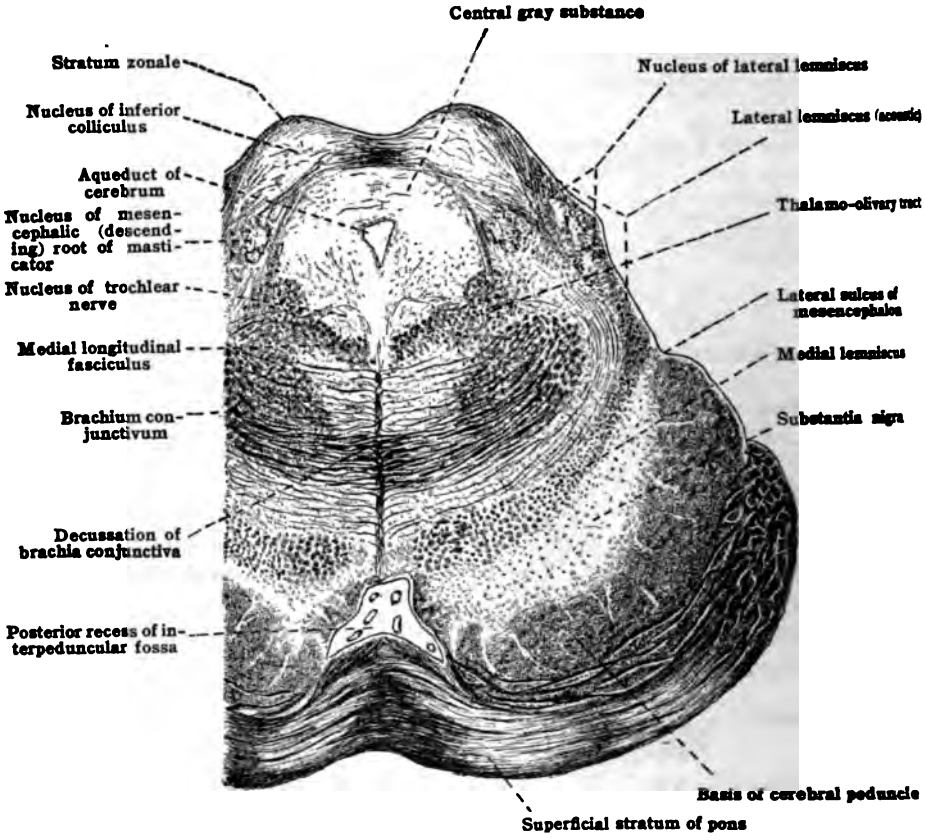


Internal structure.—Transverse sections of the mesencephalon (figs. 702, 703) throughout are composed of—(1) a *dorsal part,* consisting of the lamina quadrigemina or the gray substance of the corpora quadrigemina, with the strata and bundles of nerve-fibers connected with them, and the abundant central gray substance surrounding the aqueduct; (2) a *tegmental part,* consisting of the upward continuation of the reticular formation of the medulla oblongata and that of the dorsal (tegmental) portion of the pons region, to which are added the superior cerebellar peduncles and the red nuclei of the tegmentum in which these peduncles terminate; (3) a paired *ventral part,* the cerebral peduncles, each of which consists of a thick, pigmented stratum of gray substance, the *substantia nigra,* spread upon the large, superficial, and somewhat crescentic tract of white substance known as the *basis* of the peduncle. The bases of the peduncles correspond to the longitudinal or pyramidal fasciculi of the pons and medulla. Likewise the lemniscus and the medial longitudinal fasciculus of the medulla and pons continue through all sections of the mesencephalon, dorsal to the substantia nigra.

The **central gray substance** is a continuation of the central gelatinous substance of the spinal cord and the similar stratum of the medulla and that which immediately underlies the ependyma of the fourth ventricle. As in the spinal cord and medulla, it is largely composed of gelatinous substance. It is much more abundant in the mesencephalon, and in sections appears as a circumscribed area comparatively void of nerve fibers.

The nucleus of the *mesencephalic root of the masticator nerve* and that of the mesencephalic tract of the trigeminus may likewise be traced throughout the mesencephalon. The former consists of a few small bundles of fibers surrounding a thin strand of nerve cells which give origin to its fibers. It courses caudalward close to the lateral margin of the central gray substance, and is quite small at its begining in the extreme superior part of the mesencephalon, but as it descends toward the exit of its fibers from the pons, it increases slightly in size, due to the progressive addition of fibers. Its nucleus also increases slightly in bulk in approaching the region of the chief motor nucleus of the nerve. As mentioned above, the investigations of Johnston and Willems in lower animals suggest that many cells of the mesencephalic nucleus may be sensory instead of motor in character. The sensory nucleus (nucleus of termination) of the mesencephalic tract of the trigeminus tapers rapidly but probably extends throughout the mesencephalon.

FIG. 702.—TRANSVERSE SECTION THROUGH THE INFERIOR QUADRIGEMINATE BODIES.



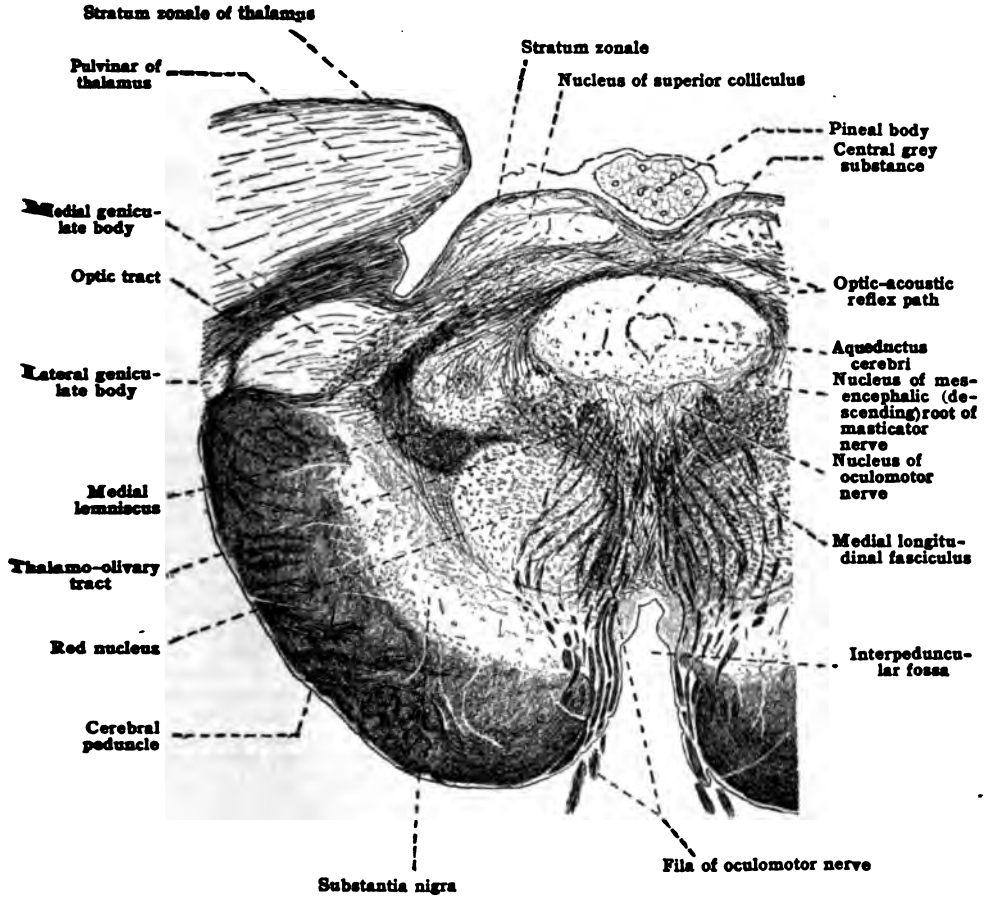
The nuclei of the *trochlear* and *oculomotor* nerves form a practically continuous column of nerve-cells extending close to the midline and ventral to the aqueduct of the cerebrum. They are in line with the nuclei of origin of the abducens and hypoglossus, and, like them, may be regarded as an upward continuation of the ventral group of the cells of the ventral horn of the spinal cord. The portion of the column giving origin to the oculomotor nerve is considerably larger than that for the trochlear.

A transverse section through the inferior quadrigeminate bodies involves a portion of the decussation of the brachia conjunctiva and the nuclei of origin of the trochlear nerves, while a transverse section through the superior quadrigeminate bodies passes through the red nuclei of the tegmentum and the nuclei of origin of the oculomotor nerves. The latter section will also involve the brachia of the inferior quadrigeminate bodies and the medial geniculate bodies connected with them, and, if slanting slightly forward it will involve the pulvinars of the thalami and the lateral geniculate bodies.

The trochlear (or fourth) is the smallest of the cranial nerves, and is the only one which makes its exit from the dorsal surface of the brain, as well as the only one whose fibers undergo a total decussation.

Its nucleus of origin is situated beneath the inferior quadrigeminate bodies in the ventral margin of the central gray substance, quite close to the midline and to its fellow nucleus of opposite side, and it is closely associated with the dorsomedial margin of the medial longitudinal fasciculus. Its root-fibers pass lateralward and dorsalward, curving around the margin of the central gray substance, medial to the mesencephalic root of the masticacor nerve. As the root curves toward the midline in the dorsal region just beneath the inferior quadrigeminate bodies, it turns sharply and courses inferiorly to approach the surface in the superior portion of the anterior medullary velum, the frenulum veli. In this it meets and undergoes a total decussation with the root of its fellow nerve, and then emerges at the medial margin of the superior cerebellar peduncle of the opposite side. Having emerged, it passes ventrally around the cerebral peduncle, and thence pursues its course to the superior oblique muscle of the eye. It receives optic impulses from the superior quadrigeminate bodies and impulses from the cerebral cortex of chiefly the same side, and it is associated with the nuclei of other cranial nerves by way of the medial longitudinal fasciculus.

FIG. 703.—TRANSVERSE SECTION THROUGH LEVEL OF SUPERIOR QUADRIGEMINATE BODIES.



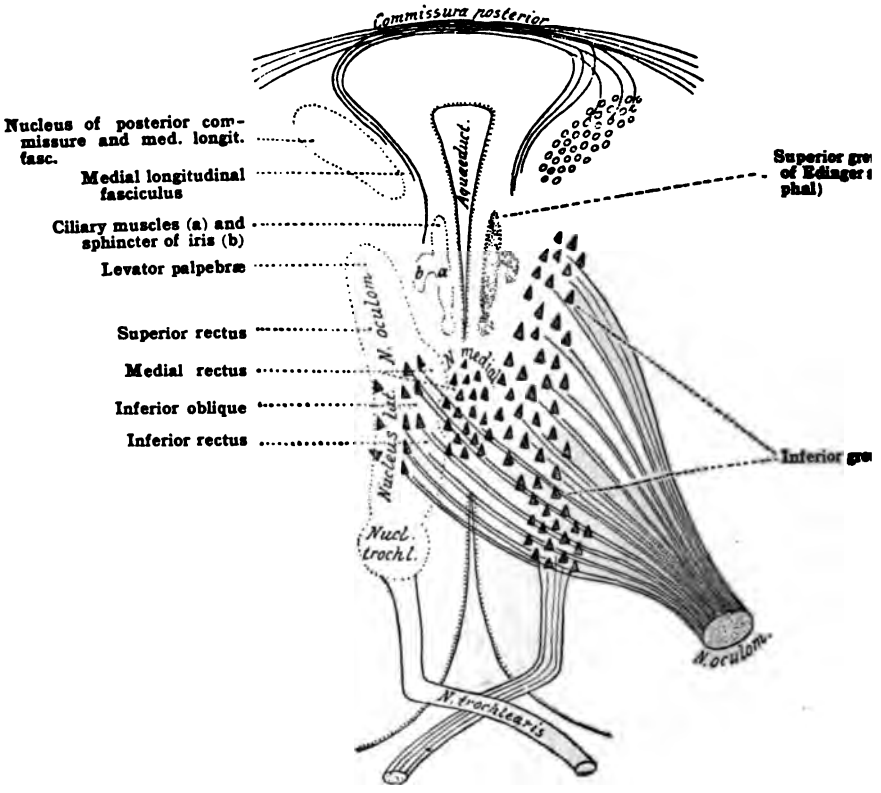
The oculomotor (or third) nerve, like the trochlear, is purely motor. It is the largest of the eye-muscle nerves. It supplies in all seven muscles of the optic apparatus:—two intrinsic, the sphincter iridis and the ciliary muscle (visceral efferent fibers), and five extrinsic (somatic efferent fibers). Of the latter, the levator palpebræ superioris is of the upper eyelid, while the remaining four, the superior, medial, and inferior recti and the obliquus inferior, are attached to the eyeball. As is to be expected, its nucleus of origin is larger and much more complicated than that of the trochlear nerve.

Practically continuous with that of the trochlear below, the nucleus is 5 or 6 mm. in length and extends anteriorly a short distance beyond the bounds of the mesencephalon into the gray substance by the side of the third ventricle. It lies in the ventral part of the central gray substance, and is very intimately associated with the medial longitudinal fasciculus. Its thickest portion is beneath the summit of the superior quadrigeminate body. The root-fibers leave the nucleus from its ventral side and collect into bundles which pass transversely through the medial longitudinal fasciculus and course ventrally to the medial portion of the substantia nigra,

where they emerge in from six to fifteen filaments which blend to form the trunk of the
the oculomotor sulcus of the cerebral peduncles. Those bundles which arise from t
lateral portion of the nucleus course in a series of curves through and around the substan
red nucleus below and, in the substantia nigra, join those which pursue the more direct
The trunk thus assembled passes lateralward around the medial border of the
peduncle.

A portion of the fibers of the oculomotor nerve upon leaving the nucleus decussat
tegmentum immediately below and pass into the nerve of the opposite side, in which
believed to be distributed to the opposite medial rectus muscle. The cells of the nucle
been variously grouped (fig. 704) and subdivided with reference to the different muscles
by the nerve. Perlia has divided them into eight cell-groups. The nucleus may be mo
considered as composed of an inferior and a superior medial group. The inferior group
of a long lateral portion continuous with the nucleus of the trochlear nerve below, and

FIG. 704.—DIAGRAM OF LONGITUDINAL SECTION OF NUCLEUS OF OCULOMOTOR NE
(After Edinger.)



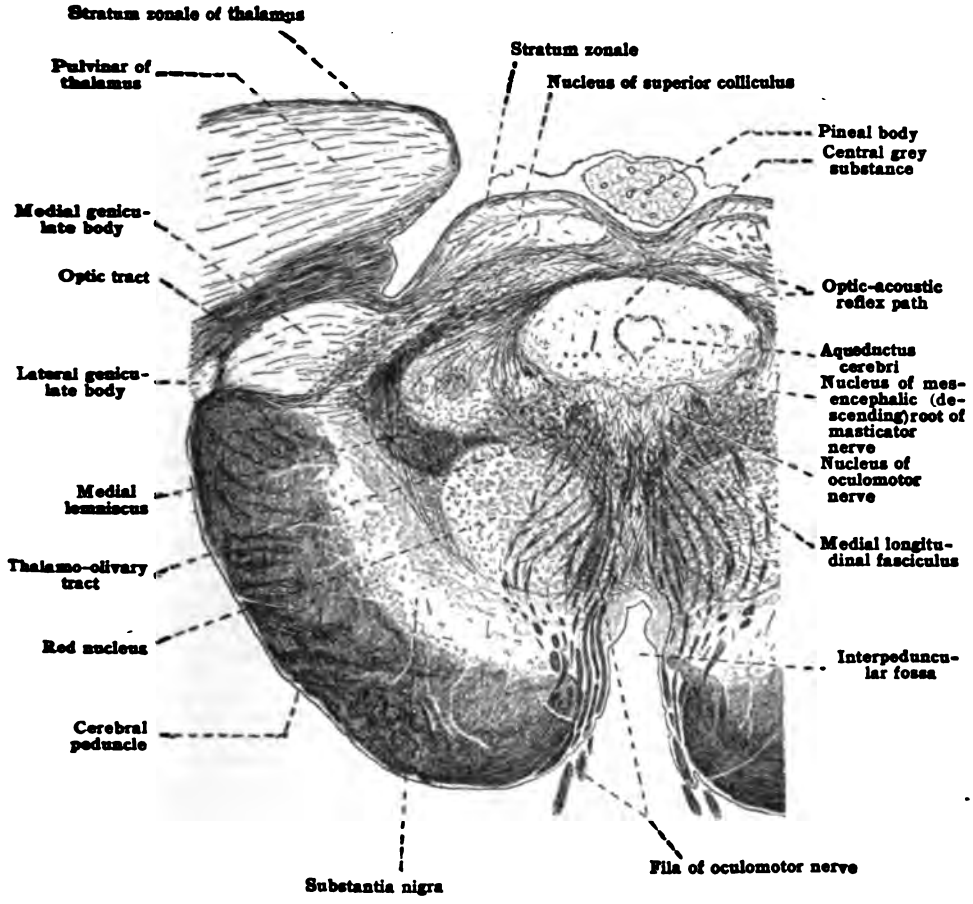
medial portion, situated in the medial plane and continuous across the midline with
of the opposite side. The superior medial group consists of cells of smaller size
inferior, and is known as the *nucleus of Edinger and Westphal*. It is believed to give
the fibers (visceral efferent fibers) which terminate in the ciliary ganglion, axones fr
supply the two intrinsic muscles concerned, viz., the ciliary muscle and the sphincte

The nucleus of the oculomotor is associated with the remainder of the optic appa
by way of the neurones of the superior quadrigeminate body with the optic tract (re
it receives impulses from the occipital part of the cerebral cortex of the same amd th
sides, and probably from the motor cortex of the frontal lobe; (2) by way of the medial
nal fasciculus with the nuclei of the trochlear and abducens (the latter making possit
ordinate action of the lateral and medial recti for the conjugate eye-movements pr
these muscles), and with the nucleus of the facial (associating the innervation of t
palpebræ with that of the orbicularis oculi); (3) with the nuclei of termination of th
nerves, especially the auditory, by way of the lateral lemniscus and medial lo
fasciculus. It is probably associated with the cerebellum by way of the brachia co
and red nuclei.

The eminence representing the **inferior quadrigeminate body proper** of an oval mass of gray substance, the *nucleus of the inferior colliculus*, co numerous nerve-cells, most of which are of small size. A thin superficia of white substance, the **stratum zonale**, forms its outermost bounda fibers from the lateral lemniscus enter it laterally and from below

Its nucleus of origin is situated beneath the inferior quadrigeminate bodies in the ventral margin of the central gray substance, quite close to the midline and to its fellow nucleus of the opposite side, and it is closely associated with the dorsomedial margin of the medial longitudinal fasciculus. Its root-fibers pass lateralward and dorsalward, curving around the margin of the central gray substance, medial to the mesencephalic root of the masticacor nerve. As the root curves toward the midline in the dorsal region just beneath the inferior quadrigeminate bodies, it turns sharply and courses inferiorly to approach the surface in the superior portion of the anterior medullary velum, the frenulum veli. In this it meets and undergoes a total decussation with the root of its fellow nerve, and then emerges at the medial margin of the superior cerebellar peduncle of the opposite side. Having emerged, it passes ventrally around the cerebral peduncle, and thence pursues its course to the superior oblique muscle of the eye. It receives optic impulses from the superior quadrigeminate bodies and impulses from the cerebral cortex of chiefly the same side, and it is associated with the nuclei of other cranial nerves by way of the medial longitudinal fasciculus.

FIG. 703.—TRANSVERSE SECTION THROUGH LEVEL OF SUPERIOR QUADRIGEMINATE BODIES.

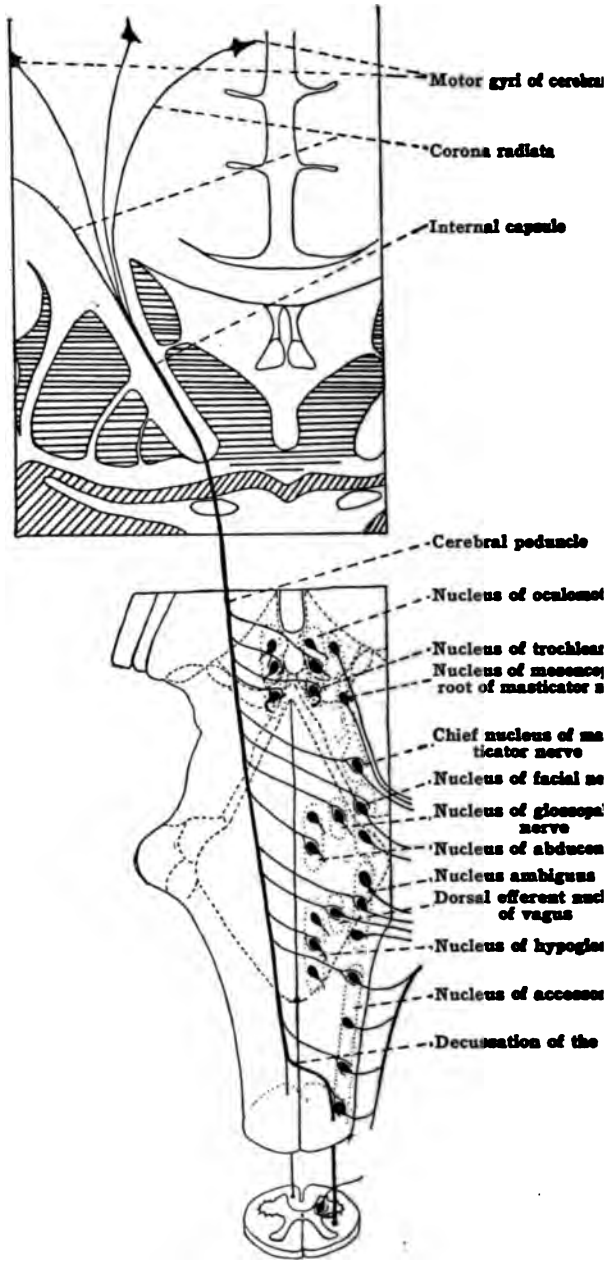


The **oculomotor** (or third) nerve, like the trochlear, is purely motor. It is the largest of the eye-muscle nerves. It supplies in all seven muscles of the optic apparatus:—two intrinsic, the sphincter iridis and the ciliary muscle (visceral efferent fibers), and five extrinsic (somatic efferent fibers). Of the latter, the levator palpebræ superioris is of the upper eyelid, while the remaining four, the superior, medial, and inferior recti and the obliquus inferior, are attached to the eyeball. As is to be expected, its nucleus of origin is larger and much more complicated than that of the trochlear nerve.

Practically continuous with that of the trochlear below, the nucleus is 5 or 6 mm. in length and extends anteriorly a short distance beyond the bounds of the mesencephalon into the gray substance by the side of the third ventricle. It lies in the ventral part of the central gray substance, and is very intimately associated with the medial longitudinal fasciculus. Its thickest portion is beneath the summit of the superior quadrigeminate body. The root-fibers leave the nucleus from its ventral side and collect into bundles which pass transversely through the medial longitudinal fasciculus and course ventrally to the medial portion of the substantia nigra,

hypothalamic region above. Its remarkable abundance begins at the s
border of the pons, and it conforms to the crescentic inner contour of the
the peduncle, sending numerous processes which occupy the interfascicular
of the latter. It contains numerous deeply pigmented nerve-cells, which
fresh specimen give the appearance suggesting its name.

FIG. 705.—SCHEME TO ILLUSTRATE THE PRINCIPAL OR CROSSED RELATIONS OF THE D
ING CORTICAL (PYRAMIDAL) FIBERS TO THE NUCLEI OF ORIGIN OF THE CRANIAL NI



Its anatomical significance is not well understood. It is known that some fib
medial lemniscus terminate about its cells instead of in the hypothalamus highe
Mellus has found in the monkey that a large portion of the pyraidal fibers arising in t
area of the cerebral cortex are interrupted in the substantia nigra. It is probable that o
of the peduncle also terminate here, its cells serving as relays in the descending cortic

The brachia conjunctiva or superior cerebellar peduncles, in passing fr
origin in the dentate nuclei, lose their flattened form and enter the mesen

lemnisci). Near the lateral margin of the central gray substance occurs the beginning of the *inferior brachium*, a bundle containing fibers chiefly from the lateral lemniscus to the medial geniculate body and from the cerebral cortex to the inferior quadrigeminate body.

The lemniscus in the mesencephalon is considered in three parts. The more lateral portion of the lemniscal plate occurring in the pons has here spread dorsolaterally, and occupies a position in the lateral margin of the section, and is known as the **lateral lemniscus**, while the medial portion which remains practically unchanged in the tegmentum is distinguished as the **medial lemniscus** (fig. 702). In the upper portion of the lateral lemniscus occurs a small, scattered mass of gray substance, *nucleus of the lateral lemniscus*, in which a few of its fibers are interrupted. The **trigeminal lemniscus** is described as being detatched from the medial lemniscus throughout the mesencephalon and as coursing in the gray substance, medial to the lateral lemniscus.

The greater portion of the **lateral lemniscus** with its nucleus belongs to the auditory apparatus, bearing impulses from the nuclei of termination of the cochlear nerve, chiefly of the opposite side (fig. 691). A large part of the fibers of this auditory portion terminate in the inferior quadrigeminate bodies. Many of the latter enter at once the nucleus of the body (nucleus of inferior colliculus) of the same side, and disappear among its cells; smaller numbers cross the midline to the quadrigeminate body of the opposite side. In crossing, some pass superficially and thus contribute to the stratum zonale, while others pass either through the nucleus or below it and cross beneath the floor of the median groove between the stratum zonale and the dorsal surface of the central gray substance, forming there an evident decussation with similar fibers crossing from the opposite side. Many fibers arising from the nucleus of the lateral lemniscus are said to pass into the reticular formation, serving in auditory reflexes. Most of the fibers arising from the cells of the nucleus of the inferior quadrigeminate body pass ventrally to terminate in the nucleus of origin of the trochlear nerve, but very few pass forward and laterally to terminate in the cortex of the superior gyrus of the temporal lobe, the cortial area of hearing. A large portion of the lateral lemniscus passes obliquely forward in the inferior brachium, and terminates in the medial geniculate body, the cells of which send fibers to the cortical area of hearing. Thus a large portion of the lateral lemnisci, the inferior quadrigeminate bodies with their brachia and the medial geniculate bodies are concerned with the sense of hearing. The nucleus of the inferior quadrigeminate body receives fibers which arise in the cortex of the superior temporal gyrus of chiefly the same side.

The remaining portions of the lateral lemniscus consist of (1) the spinothalamic part of the spinal lemniscus which, occupies the ventral edge of the lateral lemniscus and courses forward to terminate in the ventral part of the thalamus, and (2) the spinotectal part of the spinal lemniscus, which courses in the extreme dorsal edge of the lateral lemniscus and is dispersed to terminate in the nuclei of the quadrigeminate bodies. In terminating in the nucleus of the superior quadrigeminate body, these spinotectal fibers are joined by some fibers of the auditory portion of the lateral lemniscus of the same and opposite side. Together, the spinal and auditory fibers approach the nucleus from below, and contribute to the well-marked band of fibers coursing on the dorsolateral margin of the central gray substance, and known as the *'optic-acoustic reflex path'* or *stratum lemnisci* (fig. 703).

The **medial lemniscus** arises in the medulla oblongata from the nuclei (of termination) of the funiculus gracilis and funiculus cuneatus of the opposite side, and likewise from the nuclei of termination of the sensory roots of the cranial nerves of the opposite side. It is, therefore, a continuation of the central sensory pathway conveying the general bodily (including the head) sensations into the prosencephalon. Coursing still more laterally than in the pons below, it passes into the inferolateral gray substance of the thalamus, in which most of its fibers terminate. By axones given off from the cells of the inferolateral thalamic gray substance the impulses borne thither by the lemniscus are conveyed by way of the internal capsule and corona radiata to the gyri of the somesthetic area of the cerebral cortex. The trigeimnal lemniscus, here detached from the medial as noted above, arises from the nucleus of termination of the trigeminus of the opposite side and terminates as does the remainder of the medial lemniscus.

The basis (pes) pedunculi comprises the great descending pathway from the cerebral cortex, and thus is continuous with the internal capsule of the telencephalon.

The principal components of each basis pedunculi are as follows:—(1) The *pyramidal fibers*, which occupy the middle portion of the peduncle and comprise three-fifths of its bulk, and which are outgrowths of the giant pyramidal cells of the motor areas of the cerebral cortex, chiefly anterior central gyrus. These supply 'voluntary' impulses to the motor nuclei of the cranial nerves on the opposite side, form the pyramids of the medulla, and are distributed to the ventral horn cells of the spinal cord of the opposite side. (2) The *frontal pontile fibers*, which course in the mesial part of the peduncle from the cortex of the frontal lobe to their termination in the gray substance of the pons. (3) The *occipital and temporal pontile fibers* which run in the lateral portion of the peduncle from their origin in the occipital and temporal lobes to their termination in the gray substance of the pons.

The substantia nigra is continuous with the gray substance of the pons, the arcuate nuclei, and that of the reticular formation below, and with that of the

decussating the fibers turn in spray-like curves downward and soon join the medial longitudinal fasciculus. This is the **'fountain decussation'** of Forel. Decussating fibers which arise in the nucleus of the oculomotor nerve also cross in this decussation and it is said to be augmented by decussating fibers from the two red nuclei.

There is abundant evidence that fibers arising in the corpora quadrigemina descend into the spinal cord. Various studies make it appear that at least part of these are fibers from the fountain decussation, and that these course through the medulla oblongata in the ventral part of the medial longitudinal fasciculus, and thence descend into the cord as the sulcomarginal fasciculus and in the tectospinal path of the opposite side. The termination of some of these fibers about those ventral horn cells of the cervical and upper thoracic cord which send fibers through the rami communicantes probably establishes the pathway by which the superior quadrigeminate bodies are connected with the cervical sympathetic ganglia, and by which may be explained the disturbances in pupillary contraction induced by lesions of the cervical and upper thoracic spinal cord.

The medial geniculate body and the medial root of the optic tract, which runs into the former, probably have nothing to do with the functions of the optic apparatus. Both remain intact after extirpation of the eyes. The medial root of the optic tract is apparently nothing more than the beginning of the *inferior cerebral (Gudden's) commissure*, a bundle passing by way of the optic tract and chiasma, connecting the medial geniculate body of one side with that of the other side, and probably with the inferior colliculus.

The **medial longitudinal fasciculus** (posterior longitudinal fasciculus), continuous into the ventral fasciculus proprius and the sulcomarginal fasciculus of the spinal cord, extends throughout the rhombencephalon and mesencephalon, and is represented in the hypothalamic region of the prosencephalon. Deserted by the lemniscus at the inferior border of the pons, it maintains its closely medial position and courses throughout in the immediate ventral margin of the central gray substance of the medulla and floor of the fourth ventricle, and likewise in the ventral margin of the central gray substance of the mesencephalon.

The two fasciculi constitute the principal of the longer association pathways of the brain stem, and, true to their nature as such, they are among the first of its pathways to acquire medullation. In the mesencephalon they become two of its most conspicuous tracts, and their course in most intimate association with the nuclei of origin of the nerves supplying the eye-muscles suggests what is probably one of their most important functions, viz., that of associating these nuclei with each other and of bearing to them fibers from the nuclei of the other cranial nerves necessary for the co-ordinate action of the muscles of the optic apparatus associated with the functions of these other nerves.

Fibers from each medial longitudinal fasciculus terminate either by collaterals or terminal arborizations about the cells of the motor nuclei of all the cranial nerves, and each nucleus probably contributes fibers to it. It also receives fibers from the nuclei of termination of the sensory nerves especially the vestibular and cochlear. Thus it contains fibers coursing in both directions, and, while it is continually losing fibers by termination, it is being continually recruited and so maintains a practically uniform bulk. Thus, a given lesion never results in its total degeneration. Many of the fibers coursing in it arise from the opposite side of the midline. A special contribution of fibers of this kind is received by way of the fountain decussation from the nucleus of the superior colliculus of the opposite side. As noted above, it is in part continuous into the spinal cord as the ventral fasciculus proprius. It receives some fibers by way of the posterior commissure of the prosencephalon from a small nucleus, common to it and the posterior commissure, situated in the superior extension of the central gray substance of the mesencephalon. Van Gehuchten and Edinger describe for it a special *nucleus of the medial longitudinal fasciculus* situated beyond this commissure in the hypothalamic region. This nucleus may be explained as an accumulation of the gray substance of the reticular formation below and as receiving impulses from the structures of the prosencephalon which are distributed by its axones to the structures below by way of the medial longitudinal fasciculus.

Scattered in the posterior part of the posterior perforated substance, near the superior border of the pons, is a small group of cell-bodies forming the interpeduncular nucleus (interpeduncular ganglion of von Gudden). Fibers arising in the habenular nucleus of the diencephalon curve posteriorly, forming the *fasciculus retroflexus of Meynert*, and terminate about its cells. Fibers arising from its cells course dorsalward and terminate about association neurones in the ventral periphery of the central gray substance. It is concerned with olfactory impulses.

SUMMARY OF THE MESENCEPHALON

1. Quadrigeminate bodies:
   (*a*) Inferior colliculi, their nuclei and brachia.
   (*b*) Superior colliculi, their nuclei and brachia.
2. Peduncles of the cerebrum.
3. Aqueduct of the cerebrum.
4. Central gray substance.
5. Substantia nigra.
6. Decussation of superior cerebellar peduncles; the red nuclei.
7. Medial lemniscus, lateral lemniscus and nucleus of lateral lemniscus.
8. Mesencephalic nucleus and root of masticator nerve, and mesencephalic tract of the trigeminus with its nucleus.
9. Trochlear nerve and its nucleus.

as rounded bundles. In the tegmentum, under the inferior colliculi, the two brachia come together and undergo a sudden and complete decussation. Through this decussation the fibers of the brachium of one side pass forward to terminate, most of them, in the red nucleus [nucleus ruber] of the tegmentum of the opposite side (fig. 703). Some fibers are said to pass the red nucleus and terminate in the inferolateral part of the thalamus.

The red nuclei are two large, globular masses of nerve-cells situated in the tegmentum under the superior quadrigeminate bodies. At all levels they are considerably mixed with the entering bundles of the brachia conjunctiva, and they contain a pigment which in the fresh condition gives them a reddish color, suggesting their name.

They receive in addition descending fibers from the cerebral cortex (frontal operculum) and from the nuclei of the corpus striatum. From the cells of each red nucleus arise fibers which pass—(1) into the thalamus and to the telencephalon (prosencephalic continuation of the cerebellar path), and (2) fibers which descend as the 'rubroreticular' and the 'rubrospinal, tracts, in the lateral funiculus (fig. 661). The latter cross from the red nucleus of the opposite side and descend in the tegmentum. The red nuclei are also in relation with the *fasciculus retroflexus* of Meynert, which belongs to the interbrain.

The thalamo-olivary tract courses in the mesencephalon more dorsally than in the pons region. It runs in the ventrolateral boundary of central gray substance just lateral to the nuclei of the trochlear and oculomotor nerves.

A small *quadrigeminopontile* strand of fibers has been described as arising in the quadrigemina, especially the inferior pair, and terminating in the nuclei of the pons. Impulses carried by these fibers are probably destined for the cerebellar hemisphere of the opposite side.

The superior quadrigeminate bodies (superior colliculi) are phylogenetically more important than the inferior. In certain of the lower vertebrates they are enormously developed and in most of the mammals they are relatively larger and appear more complicated in structure than in man. They are concerned almost wholly with the visual apparatus mediating most of the reflexes with which it is concerned.

The *nucleus* of the superior colliculus is of somewhat greater bulk than that of the inferior. It is capped by a strong *stratum zonale* (fig. 703), which has been described as composed chiefly of retinal fibers, passing to it from the optic tract by way of the superior brachium; but, since Cajal found in the rabbit that extirpation of the eye is followed by very slight degeneration of the stratum zonale, it is probable that it is composed of other than retinal fibers—possibly fibers from the occipital cortex and fibers arising within the nucleus itself. The nucleus is separated from the central gray substance by a well marked band of fibers, the *stratum album profundum*. This contains fibers from two sources:—(1) fibers from the lateral lemniscus which approach the nucleus from the under side, some to terminate within it, others to cross to the nucleus of the opposite side; (2) fibers which arise within the nucleus and course ventrally around the central gray substance, both to terminate in the nucleus of the oculomotor nerve and to join the medial longitudinal fasciculus and pass probably to the nuclei of the trochlear and abducens. The lemniscus fibers often course less deeply than (2) and give the *stratum lemnisci*. The optic fibers proper approach the nucleus by way of the *superior brachium*, and are dispersed directly among its cells; only a small proportion of them cross over to terminate in the nucleus of the opposite side. They consist of two varieties:—(1) retinal fibers which arise in the ganglion-cell layer of the retina and enter the superior brachium at its junction with the lateral root of the optic tract, and (2) fibers from the visual area of the occipital lobe of the cerebral hemisphere. Sometimes the optic fibers in their course within the nucleus of the superior colliculus form a more or less evident stratum near the stratum zonale This is known as the *stratum opticum* (stratum album medium). The portion of the nucleus between this stratum and the stratum zonale is then called the *stratum cinereum*.

The fibers entering the nucleus from the lateral lemniscus probably all represent auditory connections. The stratum album profundum, composed of the lemniscus fibers and fibers from cells of the nucleus, and the stratum opticum together, form the so-called **'optic-acoustic reflex path'** (fig. 703).

The **tectospinal** and the **spinotectal** (spinomesencephalic) paths course together ventrolateral to the nuclei of the colliculi. In the superior quadrigeminate bodies they course in the dorsal edge of the medial lemniscus, between the stratum opticum and stratum album profundum.

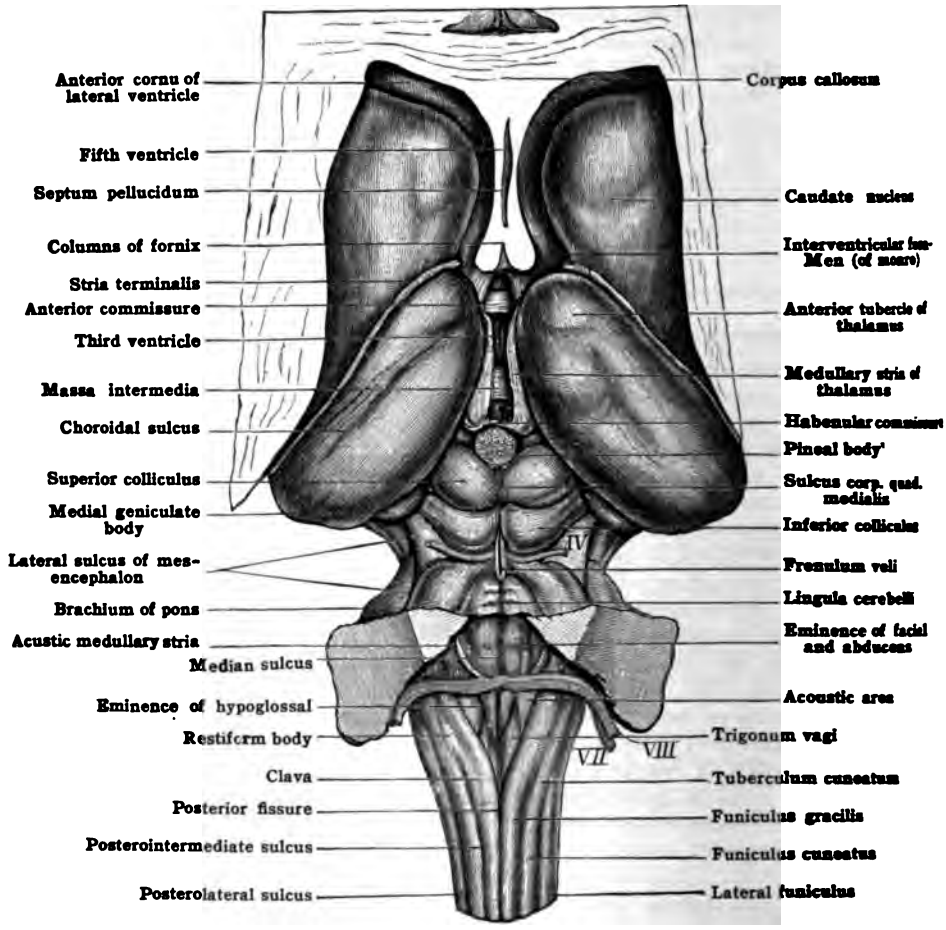
From the various studies that have been made it appears that the superior colliculus of the corpora quadrigemina is merely the central reflex organ concerned in the control of the eye muscles—eye muscle reflexes which result from retinal and cochlear stimulation, and from some general body sensations by way of the spinal cord and trigeminus. Fibers from its nucleus to the visual area of the occipital cortex have been claimed for certain mammals, but in man the superior colliculus may be entirely destroyed without disturbance of the perception of light or color and fibers arising from its nucleus to terminate in the cerebral cortex are denied.

In the level of the anterior part of the superior colliculus the fibers which arise from the cells of its nucleus and course ventrally in the stratum album profundum collect into a strong bundle. This bundle passes ventral to the medial longitudinal fasciculus and, in the space between the two red nuclei, it forms a dense decussation with the similar bundle from the opposite side. In

inferiorly and slightly overhang the level of the quadrigeminate bodies. The projecting portion assumes relations with the optic tract and the metathalamus.

Both the structures of the **metathalamus,** the lateral and medial geniculate bodies, are connected with the optic tract, but it is thought that actual visual axones terminate only in the lateral geniculate body. As the optic tract curves around the cerebral peduncle it divides into two main roots. The *lateral geniculate body* receives a small portion of the fibers of the lateral root of the optic tract; the remainder pass under this body and enter the pulvinar of the thalamus. The *medial geniculate body* is connected with the medial root of the optic tract,

FIG. 706.—DORSAL SURFACE OF DIENCEPHALON WITH ADJACENT STRUCTURES. (After Obersteiner.)



which root consists partly, not of retinal fibers, as does the lateral root, but of the fibers forming Gudden's commissure (the inferior cerebral commissure). The retinal fibers contained in the medial root pass to terminate in the superior quadrigeminate bodies.

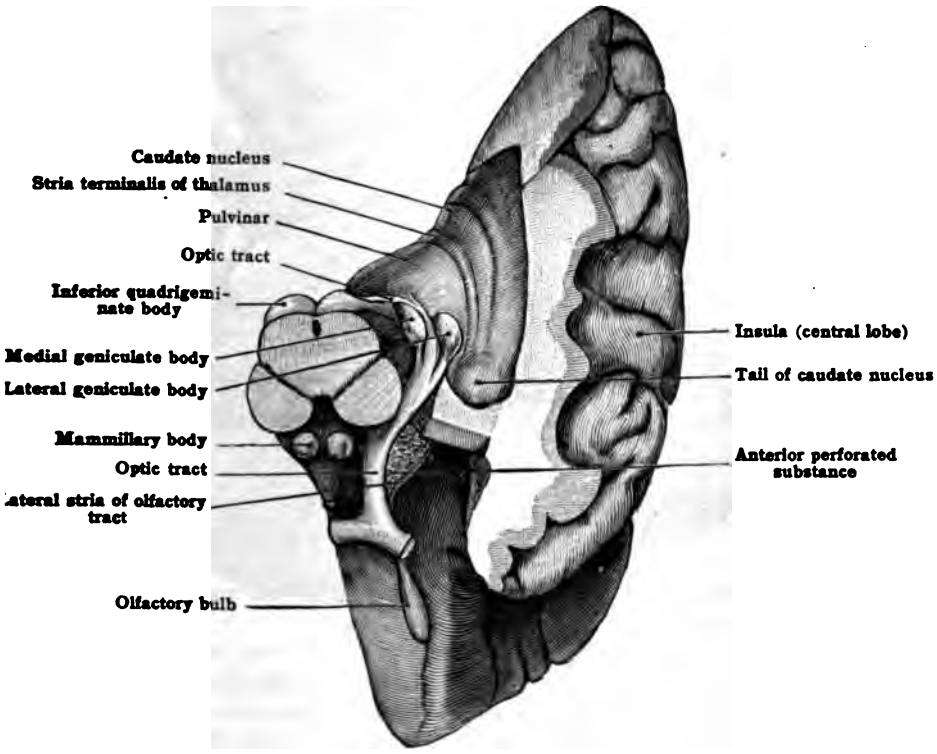
Of the **epithalamus,** the *pineal body* (epiphysis, conarium) is the most conspicuous external feature. This is an unpaired, cone-shaped structure, about 8 mm. long and 4 mm. broad, which also projects upon the mesencephalon so that its body rests in the groove between the superior quadrigeminate bodies. Its stem is attached in the midline at the posterior extremity of the third ventricle and therefore just above the posterior commissure of the cerebrum (fig. 706). It is covered by pia mater, and is involved in a continuation of the tela chorioidea of the third ventricle. Though it develops as a diverticulum of that portion of the anterior primary vesicle which gives origin to the thalamencephalon, it

holly a non-nervous structure, aside from the sympathetic fibers which enter it or the supply of its blood-vessels. (For further details, see p. 1327.)

Apparently arising from the base of the pineal dody, but having practically nothing to do with it, are the **striæ medullares of the thalamus** (striæ pineales, pedunculi conarii, tenia thalami, habenulæ). These are two thin bands of white substance which extend from under the pineal body anteriorly upon the thalamus, along the superior border of each lateral wall of the third ventricle, forming the boundaries between the superior and medial surfac of each thalamus.

They have been called the *habenulæ*, and the habenular nuclei, situated in the habenular trigone, are so called because related to them. They are continuous across the midline in the *habenular commissure*, the dorsal part of the posterior cerebral commissure, just below the neck of the pineal body (figs. 706, 735). It will be seen below that each habenula contains olfactory fibers from the fornix, the anterior perforated substance and the septum pellucidum, as well as fibers out of the thalamus, and that some of its fibers terminate in the habenular nucleus. Most of the thalamic fibers contained cross in the posterior commissure to the thalamus of the opposite side.

FIG. 707.—DIAGRAM OF DISSECTION OF BRAIN SHOWING METATHALAMUS AND PULVINAR WITH ADJACENT STRUCTURES.



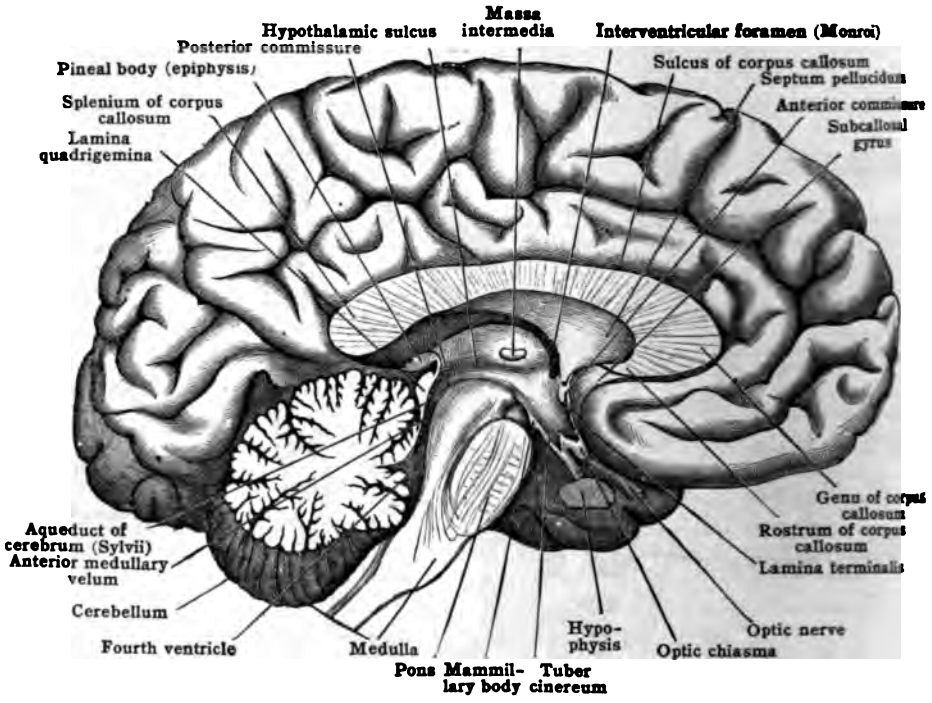
The inferolateral surface of the thalamencephalon is continuous into the hypothalamic tegmental region, the upward continuation of the tegmental gray substance of the mesencephalon. It is also adjacent to a portion of the internal capsule. Both these relationships, as well as the fiber connections of the diencephalon with the structures above and below it, are deferred until the discussion of the internal structure of the prosencephalon.

The **medial surface** of the diencephalon (fig. 708), allows a better view of the shape and relations of the **third ventricle.** Below the line of the massa intermedia the ventricle is usually somewhat wider than it is along the upper margins of the thalami. This greater width is occasioned by a groove in the inferomedial surface of each thalamus, known as the **hypothalamic sulcus** (sulcus of Monro). It is along the line of this sulcus that the third ventricle is continuous with the aqueduct of the cerebrum, and thus with the fourth ventricle below, and, likewise, with the two lateral ventricles of the cerebral hemispheres at its anterior end. The latter junction occurs through a small oblique aperture, the **interventricular**

foramen (foramen of Monro), one into each lateral ventricle. The upper portion of the third ventricle extends posteriorly beneath its choroid tela (velum interpositum) to form a small posterior recess about the pineal body. This is known as the **suprapineal recess.** The anteroinferior extremity of the third ventricle involves the pars optica hypothalami, which belongs to the telencephalon.

B. THE TELENCEPHALON.—External features.—The optic portion of the hypothalamus consists of that small central area of the basal surface of the brain which includes and surrounds the **optic chiasma,** and comprises the structures of the floor of the anterior and inferior portion of the third ventricle. The area belonging to the telencephalon extends anteriorly from the mammillary bodies in the interpeduncular fossa, and includes the **tuber cinereum** and **hypophysis** behind the optic chiasma, and some of the **anterior perforated substance** in front of it.

FIG. 708.—MIDSAGITTAL SECTION OF ENTIRE BRAIN, SHOWING MEDIAL SURFACE OF DIENCEPHALON AND TELENCEPHALON. (After Henle.)



The most anterior portion of the third ventricle is in the form of an inferior extension. The wall of this portion is almost wholly non-nervous and quite thin, and thus the cavity of the ventricle is but thinly separated from the exterior of the brain. The front portion of this wall is the **lamina terminalis** and in the ventricular side of the upper part of this lamina the **anterior commissure** of the cerebrum is apparent.

The **optic chiasma** lies across and presses into the lower portion of the lamina terminalis, and in so doing produces an anterior recess in the cavity of the ventricle known as the **optic recess** (fig. 708). Behind the optic chiasma the floor of the third ventricle bulges slightly, giving the outward appearance known as the **tuber cinereum,** and the cavity bounded by this terminates in the **infundibular recess.**

The **tuber cinereum** then is a hollow, conical projection of the floor of the third ventricle, between the corpora mammillaria and the optic chiasma. Its wall is continuous anteriorly with the lamina terminalis and laterally with the anterior perforated substance.

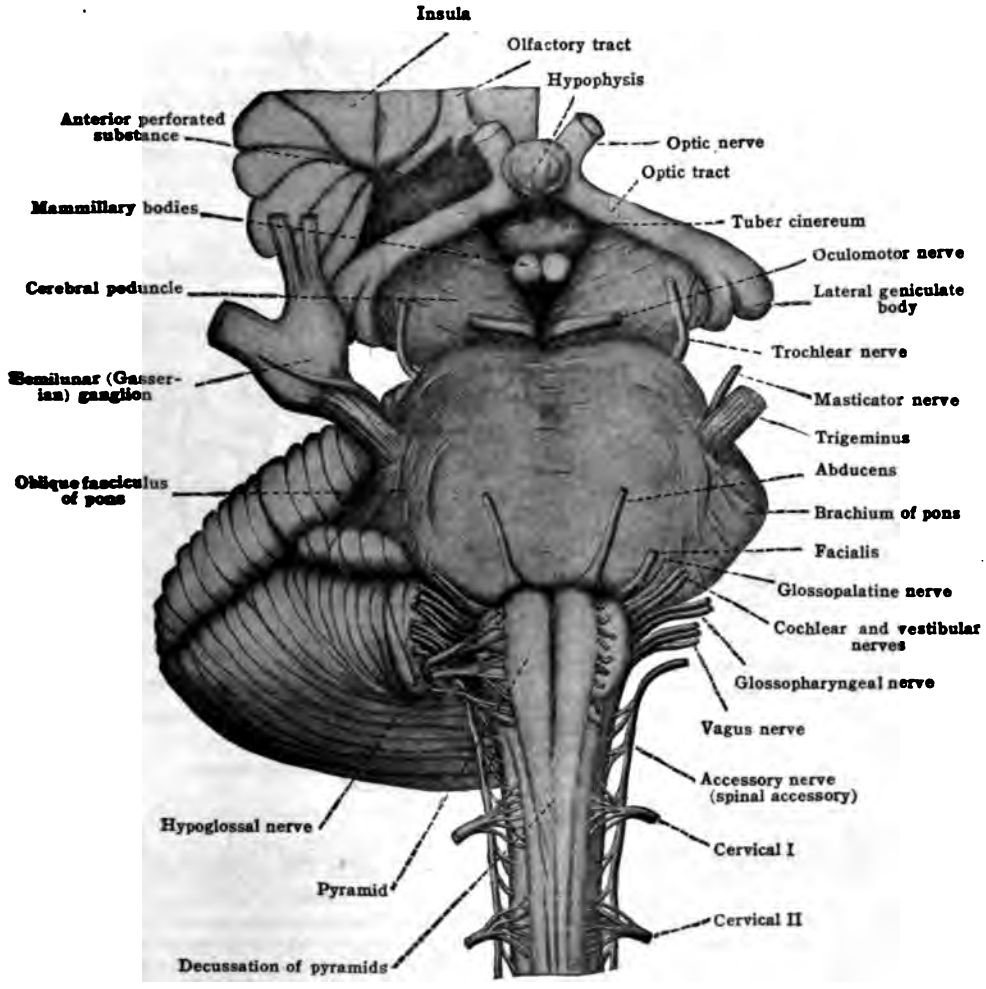
The **infundibulum** is but the attenuated apex of the conical tuber cinereum, and forms the neck connecting it with the hypophysis. It is so drawn out that it is referred to as the stalk of the hypophysis. The cavity of the tuber cinereum (*finundibular* recess) is sometimes maintained throughout the greater part of the

[illegible]gth of the infundibulum, giving it the form of a long-necked funnel. Near the [illegible]ophysis the cavity is always occluded in man.

The **hypophysis cerebri** (pituitary body or gland) (figs. 708, 709) is an ovoid [illegible]s terminating the infundibulum. It lies in the sella turcica of the sphenoid [illegible]e, and consists of two lobes, a large *anterior lobe*, the glandular or buccal lobe, [illegible]d a smaller *posterior* or *neural lobe*. For further details, see GLANDS OF INTER-[illegible]AL SECRETION, p. 1326.

The fundaments of the **optic nerve** are derived from this portion of the telen-[illegible]phalon, though the nuclei of termination of its fibers are located in the thalam-

[illegible]G. 709.—INFERIOR ASPECT OF BRAIN-STEM INCLUDING MAMMILLARY AND OPTIC PORTIONS OF THE HYPOTHALAMUS.



encephalon and mesencephalon. The optic apparatus consists of the retinæ and optic nerves, the optic chiasma, the optic tracts, the superior quadrigeminate bodies with their relations with the nuclei of the eye-moving nerves, the metathalamus, the pulvinar of the thalamus, and the visual area of the cerebral cortex of the occipital lobe. The fibers of the optic nerves arise from the cells of the ganglion-cell layer of the retinæ. The fibers which arise in the mesial or nasal halves of each retina cross in the chiasma to find their nuclei of termination in the gray substance of the opposite side, while those from the outer or lateral halves terminate on the same side (figs. 710, 744).

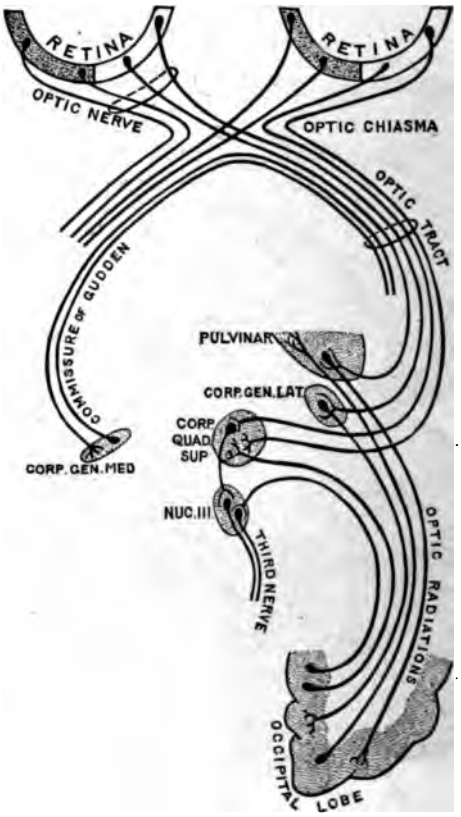
The **optic chiasma** (optic commissure) is adherent upon the structures of the optic portion of the hypothalamus adjacent to it. It is formed by the approach and fusion of the two optic nerves, and is knit together by the decussating fibers

from the nasal halves of each retina, and, in addition, by the fibers of Gud commissure which is contained in it.

Beyond the chiasma the optic fibers continue as the **optic tracts** which c posteriorly around the cerebral peduncles to attain their entrance into the th encephalon and mesencephalon. Upon reaching the pulvinar of the thal each optic tract divides into two roots, a lateral and medial (figs. 707, 709,

The *lateral root* contains practically all of the true visual fibers—fibers arising from the half of the retina of the same side and the nasal half of the retina of the opposite side. fibers are distributed to three localities:—(1) part of them terminate in the lateral geni body; (2) the greater portion pass over and around the lateral geniculate body and ent

FIG. 710.—DIAGRAM OF THE PRINCIPAL COMPONENTS OF THE OPTIC APPARATUS. Cunningham.)



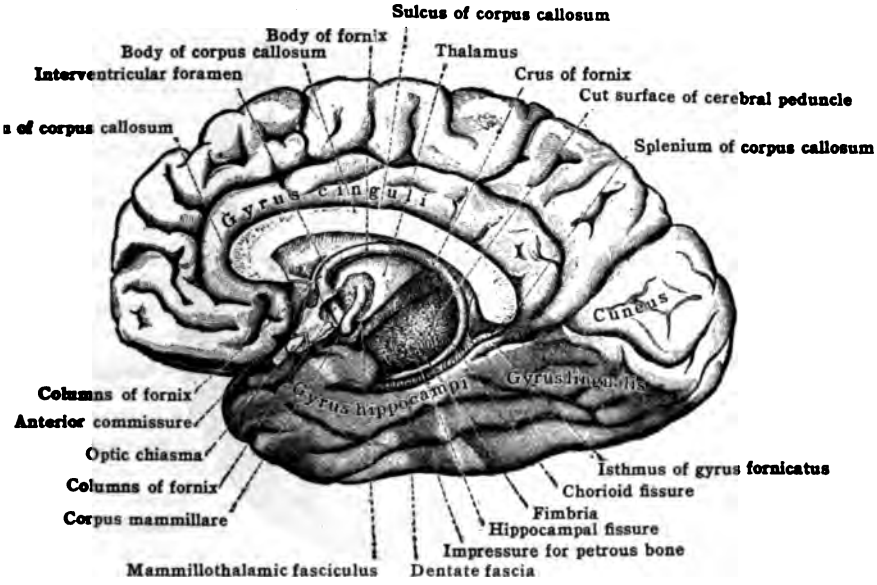
pulvinar; (3) a considerable portion enter the superior quadrigeminal brachium and c it to terminate in the nucleus of the superior quadrigeminate body. The most evident f of this latter portion is to bear impulses which, by way of the neurones of the quadrig body, are distributed to the nuclei of the oculomotor, trochlear, and abducent nerves, s mediate eye-moving reflexes. The cells of the lateral geniculate body and the pulvina which the retinal fibers terminate, give off axones which terminate in the cortex of th area, chiefly the gyri about the calcarine fissure of the occipital lobe. In reaching this a curve upward and backward, coursing in a compact band of white substance known as t radiation (radiatio occipitothalamica, fig. 736). This band also is in part composed arising from the cells of the visual area, which pass from the cortex to the pulvinar, quadrigeminate bodies, and possibly some to the medulla oblongata and spinal cor superior quadrigeminate bodies probably send no fibers to the visual cortex, althou receive fibers from it.

The *medial root* of the optic tract contains few true visual fibers. It runs into th geniculate body, and neither it nor this body are appreciably affected after extirpation eyes. It may be considered as largely representing the fibers of Gudden's commissu rior cerebral commissure). This commissure consists of fibers which correlate the med iculate bodies of the two sides with each other, and which, instead of crossing the through the mesencephalon, course in the optic tracts and cross by way of the posterior of the optic chiasma. It consists of fibers which both arise and terminate in each of th and, therefore, of fibers coursing in both directions. It is also claimed that the fibers of G commissure connect the medial geniculate body of each side with the inferior colliculu opposite side.

THE CEREBRAL HEMISPHERES

he cerebral hemispheres in man form by far the largest part of the central ous system. Together, when viewed from above (fig. 718), they present an d surface, markedly convex upward, which corresponds to the inner surface of vault of the cranium. The greater transverse diameter of this surface lies eriorly in the vicinity of the parietal eminences of the cranium. The outline he superior aspect varies according to the form of the cranium, being more oidal in the brachycephalic and more ellipsoidal in the dolichocephalic. hemispheres are separated from each other superiorly by a deep median slit, **ngitudinal fissure,** into which fits a duplication of the inner layer of the dura er known as the falx cerebri. The posterior or occipital extremities of the ispheres overlap the cerebellum, and thus entirely conceal the mesencephalon thalamencephalon. They are separated from the superior surface of the ellum and the corpora quadrigemina by the deep **transverse fissure.** This upied by the tentorium cerebelli, which is continuous with the falx cerebri also with the tela chorioidea of the third ventricle (figs. 666, 727).

711.—MEDIAL AND TENTORIAL SURFACES OF RIGHT CEREBRAL HEMISPHERE, VIEWED FROM E LEFT. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



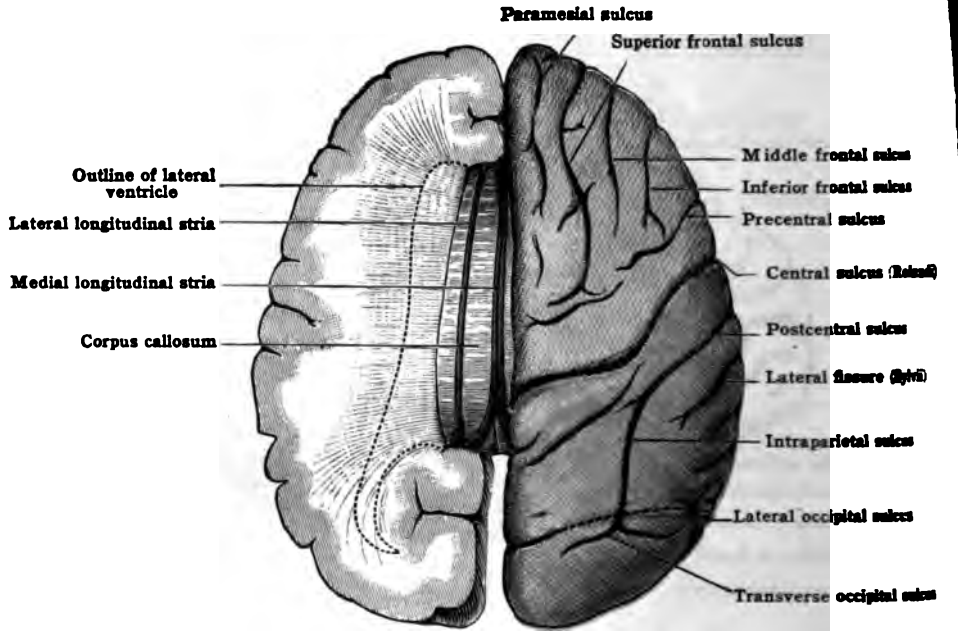
ach of the hemispheres is usually described as having three poles or projecting mities, and three surfaces bounded by intervening borders. The most ior projection is the **frontal pole.** This is near the midline, and with its v of the other hemisphere, forms the frontal end of the ovoid contour of the rum. The **occipital pole** is the most projecting portion of the posterior and ior end, and is more pointed than the frontal pole. The inferolateral por- of the hemisphere is separated anteriorly by the deep **lateral fissure** (fissure lvius) into a distinct division, the temporal lobe, and the anterior portion is lobe projects prominently forward and is known as the **temporal pole.**

he **surfaces** of the hemisphere are—(1) the lateral or *convex surface;* (2) the *al surface;* and (3) the *basal surface.* The convex surface comprises the e rounded aspect of the hemisphere visible previous to manipulation or ction, and is the surface subjacent to the vault of the cranium. The medial ce is perpendicular, flat, and parallel with that of the other hemisphere, the bounding the longitudinal fissure and for the most part in contact with the erebri. The **superomedial border** intervenes between the convex and medial ces, and is thus convex and extends from the frontal to the occipital pole.

he more complex *basal surface* fits into the anterior and middle cranial , and posteriorly rests upon the tentorium cerebelli. Thus it is subdivided —(*a*) an *orbital area,* which is slightly concave, since it is adapted to the

orbital plate of the frontal bone, and is separated from the convex surface by the necessarily arched **superciliary border** and from the medial surface by the medial **orbital border,** the latter being straight and extending from the frontal pole medial to the olfactory bulb and tract; (*b*) a *tentorial area* or surface, which is arched in conformity with the dorsal surface of the cerebellum. This is separated from the convex surface by the **inferolateral border,** which runs from the occipital to the temporal pole; and from the medial surface by the **medial occipital border,** which is a more or less rounded ridge extending from the occipital pole obliquely upward in the angle formed by the junction of the perpendicular falx cerebri and the horizontal tentorium cerebelli. This border is best seen in brains which have been hardened with the membranes *in situ*. The remainder of the basal surface includes the optic portion of the hypothalamus already considered, and the small depressed and punctate area, the anterior perforated substance, which is penetrated by the anterolateral group of the central branches of the anterior and

FIG. 712.—DIAGRAM OF CONVEX SURFACE OF RIGHT CEREBRAL HEMISPHERE AND UPPER SURFACE OF CORPUS CALLOSUM. (Temporal and occipital lobes red, parietal green.)



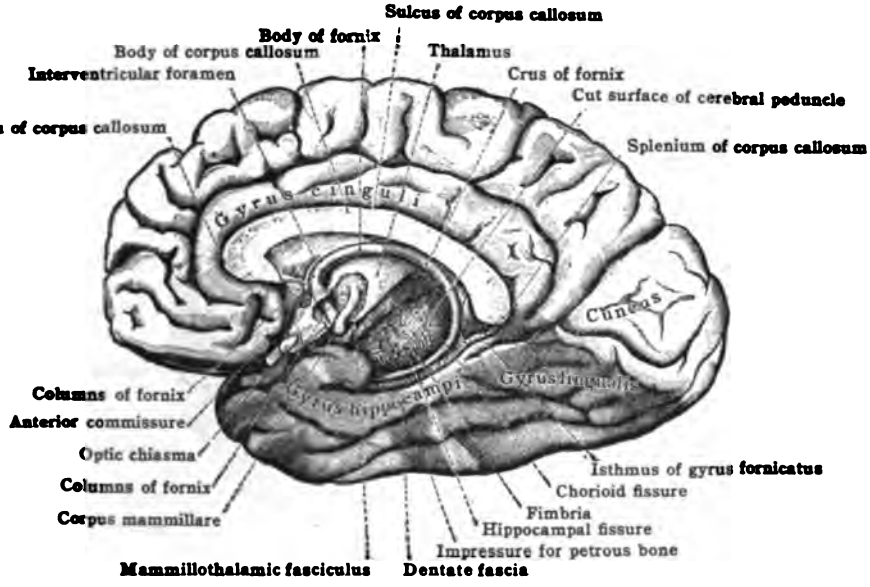
middle cerebral arteries and into which the striæ of the olfactory trigone disappear. In addition to the orbital area, the basal surface of the hemisphere shows signs of the impress of the petrous portion of the temporal bone and of the great wing of the sphenoid.

The corpus callosum.—In their early development as lateral dilations of the anterior primary brain-vesicles, the hemispheres are connected with each other only at the anterior end of the thalamencephalon, where they are both continuous with the unpaired lamina terminalis. As development proceeds and the hemispheres extend upward, backward, forward, and laterally to completely conceal the base, and as the pallium, or cortex, thickens and its folds begin to appear, the two hemispheres become united across the midline above the thalamencephalon and the third ventricle by the intergrowth of the great cerebral commissure, the corpus callosum. After removal of the falx cerebri from the longitudinal fissure, the dorsal surface of the corpus callosum may be exposed by drawing apart the contiguous medial surfaces of the hemispheres (fig. 712). It consists of a dense mass of pure white substance coursing transversely, and arises as outgrowth from the cortical cells of both hemispheres. Thus it is the great pathway which correlates the cortex of the two sides of the telencephalon. Only the smaller middle portion of the body lies free in the floor of the longitudinal fissure, by far the greater part being concealed in the substance of the hemispheres, where its fibers

THE CEREBRAL HEMISPHERES

The cerebral hemispheres in man form by far the largest part of the central **nervous** system. Together, when viewed from above (fig. 718), they present an **ovoid surface**, markedly convex upward, which corresponds to the inner surface of **the vault** of the cranium. The greater transverse diameter of this surface lies **posteriorly** in the vicinity of the parietal eminences of the cranium. The outline **of the superior aspect** varies according to the form of the cranium, being more **spheroidal** in the brachycephalic and more ellipsoidal in the dolichocephalic. **The hemispheres** are separated from each other superiorly by a deep median slit, **the longitudinal fissure,** into which fits a duplication of the inner layer of the dura **mater** known as the falx cerebri. The posterior or occipital extremities of the **hemispheres** overlap the cerebellum, and thus entirely conceal the mesencephalon **and thalamencephalon.** They are separated from the superior surface of the **cerebellum** and the corpora quadrigemina by the deep **transverse fissure.** This **is occupied** by the tentorium cerebelli, which is continuous with the falx cerebri **and also** with the tela chorioidea of the third ventricle (figs. 666, 727).

FIG. 711.—MEDIAL AND TENTORIAL SURFACES OF RIGHT CEREBRAL HEMISPHERE, VIEWED FROM THE LEFT. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



Each of the hemispheres is usually described as having three poles or projecting extremities, and three surfaces bounded by intervening borders. The most anterior projection is the **frontal pole.** This is near the midline, and with its fellow of the other hemisphere, forms the frontal end of the ovoid contour of the cerebrum. The **occipital pole** is the most projecting portion of the posterior and inferior end, and is more pointed than the frontal pole. The inferolateral portion of the hemisphere is separated anteriorly by the deep **lateral fissure** (fissure of Sylvius) into a distinct division, the temporal lobe, and the anterior portion of this lobe projects prominently forward and is known as the **temporal pole.**

The **surfaces** of the hemisphere are—(1) the lateral or *convex surface;* (2) the *medial surface;* and (3) the *basal surface.* The convex surface comprises the entire rounded aspect of the hemisphere visible previous to manipulation or dissection, and is the surface subjacent to the vault of the cranium. The medial surface is perpendicular, flat, and parallel with that of the other hemisphere, the two bounding the longitudinal fissure and for the most part in contact with the falx cerebri. The **superomedial border** intervenes between the convex and medial surfaces, and is thus convex and extends from the frontal to the occipital pole.

The more complex *basal surface* fits into the anterior and middle cranial fossæ, and posteriorly rests upon the tentorium cerebelli. Thus it is subdivided into—(*a*) an *orbital area,* which is slightly concave, since it is adapted to the

the cranium begins to grow more rapidly than the encephalon, and a space is formed b the cerebrum and the inner surface of the cranium. This space allows further expansion pallium, and at the time the space is relatively greatest (during the sixth month) the for direction of the principal gyri and sulci begin to be indicated. As growth proceeds the stricted expansion of the pallium results in the gyri again approaching the wall of the cr and during the eighth month of fetal life they again come in contact with it. Finally, th relative growth of the cranium results in the space found between it and the cortex in the It is obvious that the relation of the cranium may be a factor in the causation of the g the increase of surface area necessitated by the increased amount of cortical gray sul might be limited by a cranial cavity of small size. It is probable that the second contac cortex with the cranium (during the eighth month) may at least cause a deepening and ac tion of the sulci already begun. Evidently the form of the cranium modifies the gyri. a certain extent probably determines their direction, for in long, dolichocephalic crania teroposterior gyri are most accentuated, and in the wide, brachycephalic crania the tra gyri are most marked. At birth all the main fissures and sulci are present, but some smaller sulci appear later. In the growing pallium both the bottoms of the sulci as we summits of the gyri move away from the geometrical center of the hemisphere, the s more rapidly, and hence the sulci or fissures first formed grow gradually deeper as growth continues.

The mechanical factors in the growth processes which result in the more or less arrangement of the gyri of the hemispheres of a given group of animals have not be factorily determined. It has been suggested that the differences in arrangement of the different groups of animals may be in part dependent upon the functional importanc various regions—the amount of gray substance of a region varying with the function tance, and the consequent local increases being accompanied by resultant local folding idea is supported by the fact that while the somesthetic (sensory-motor) area of th varies with the bulk of the body, the frontal gyri, so much developed in man and w one of the chief regions of the associational phenomena, are relatively independent of an vary with the weight of either the body or the brain.

Surface area.—The total surface area of the adult human telencephalon is about cm. Of this area almost exactly one-third is contained on the outer or exposed surfac gyri, while the other two-thirds is found in the walls of the sulci and fissures.

Lobes of the Telencephalon and the Gyri and Sulci

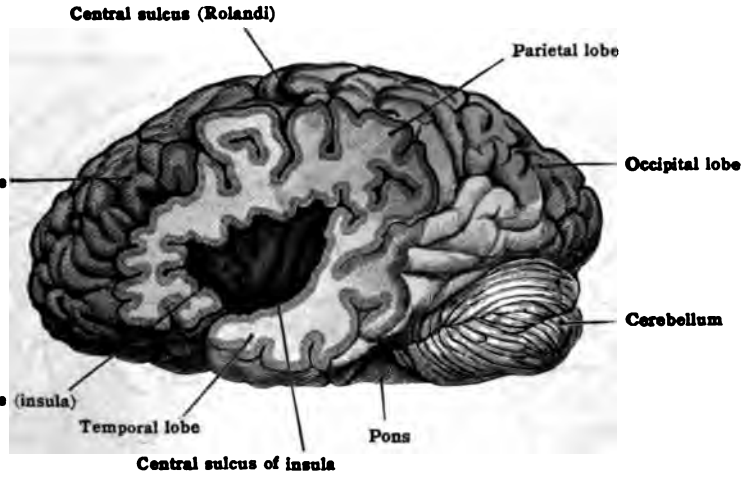
The folded pallium of each hemisphere is arbitrarily divided into lobes by the use of certain of the main fissures and sulci as boundaries and partly use of imaginary lines (figs. 712–714). These divisions are six in number selves subdivided into their component gyri:

(1) Temporal lobe.
(2) Insula (Central lobe or Island of Reil).
(3) Frontal lobe.
(4) Parietal lobe.

ward, the folds which form the margins of the Sylvian fossa increase in size height and begin to overlap and conceal its broad floor, which is the beginning e insula. The overlapping folds thus become the **opercula,** and as their lips roach each other, there results the deep fissure of Sylvius, which marks off riorly an inferolateral limb of the pallium, termed by position the temporal e. As growth proceeds further, the temporal lobe thickens, the temporal pole nds further forward and becomes a free projection, thus lengthening the ure of Sylvius and resulting in the inferior extension or stem of this fissure, ch runs between the temporal pole and the frontal lobe and curves under so as appear on the basal surface of the hemisphere. Finally the cortex of the poral lobe itself is thrown into folds or gyri. Its posterior end is never marked from the lobes above and behind, except by arbitrary lines which will be mened in connection with those lobes.

. 713.—Diagram of the Convex Surface of the Left Cerebral Hemisphere Showing the Five Principal Lobes of the Pallium.

e opercular regions of the frontal, parietal, and temporal lobes are removed to show the central lobe or island of Reil.



The temporal lobe forms part of the lateral convex and tentorial surfaces of the hemisphere, and its anterior portion is adapted to the surface of the middle cranial fossa. It thus has a lateral surface and a basal and tentorial surface. In these surfaces are the following gyri with their intervening and bounding sulci (fig. 714):

The **superior temporal gyrus** is bounded by the posterior ramus of the lateral fissure, and extends from the temporal pole backward into the supramarginal region belonging to the parietal lobe above. The upper margin of this gyrus constitutes the **temporal operculum,** in that it aids in overlapping and enclosing the insula in the floor of the lateral fissure. This margin is for the most part smooth, being occasionally interrupted by a few weak twigs of the lateral fissure. It is separated from the gyrus below by the **superior temporal sulcus,** which is parallel with the posterior ramus of the lateral fissure and is frequently called the ***parallel sulcus.*** The posterior extremity of this sulcus divides the angular gyrus of the parietal lobe, and its anterior end disappears in the temporal pole, sometimes as a continuous groove, sometimes in isolated pieces.

The **middle temporal gyrus** likewise begins in the temporal pole and is continuous backward into the angular gyrus of the parietal lobe.

The **inferior temporal gyrus** forms the inferolateral border of the temporal lobe, and is usually more broken up than the two gyri above it. It usually begins continuous with them in the frontal pole, and extends horizontally backward into the lateral gyri of the occipital lobe. It is separated from the middle gyrus by the **middle temporal sulcus,** which likewise is never so continuous a furrow as the superior temporal sulcus. Frequently this sulcus occurs in detached portions and often terminates within the temporal lobe.

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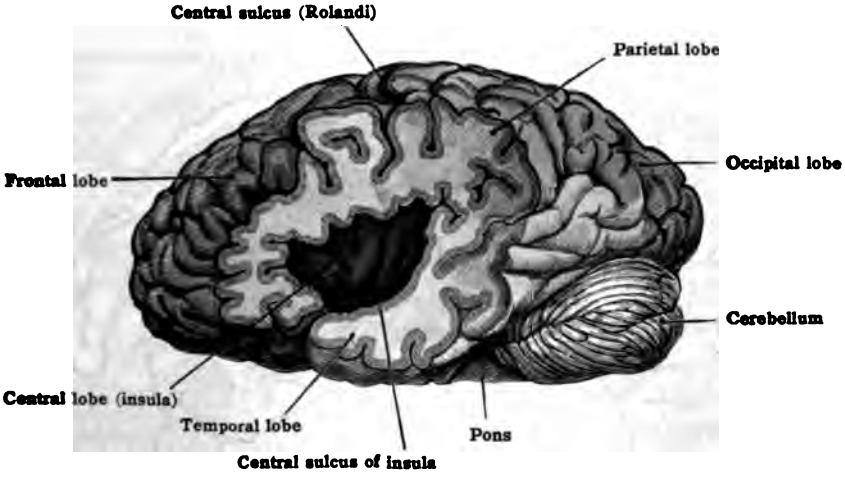

The temporal lobe forms part of the lateral convex and tentorial surfaces of the hemisphere, and its anterior portion is adapted to the surface of the middle cranial fossa. It thus has a lateral surface and a basal and tentorial surface. In these surfaces are the following gyri with their intervening and bounding sulci (fig. 714):

The **superior temporal gyrus** is bounded by the posterior ramus of the lateral fissure, and extends from the temporal pole backward into the supramarginal region belonging to the parietal lobe above. The upper margin of this gyrus constitutes the **temporal operculum,** in that it aids in overlapping and enclosing the insula in the floor of the lateral fissure. This margin is for the most part smooth, being occasionally interrupted by a few weak twigs of the lateral fissure. It is separated from the gyrus below by the **superior temporal sulcus,** which is parallel with the posterior ramus of the lateral fissure and is frequently called the ***parallel sulcus.*** The posterior extremity of this sulcus divides the angular gyrus of the parietal lobe, and its anterior end disappears in the temporal pole, sometimes as a continuous groove, sometimes in isolated pieces.

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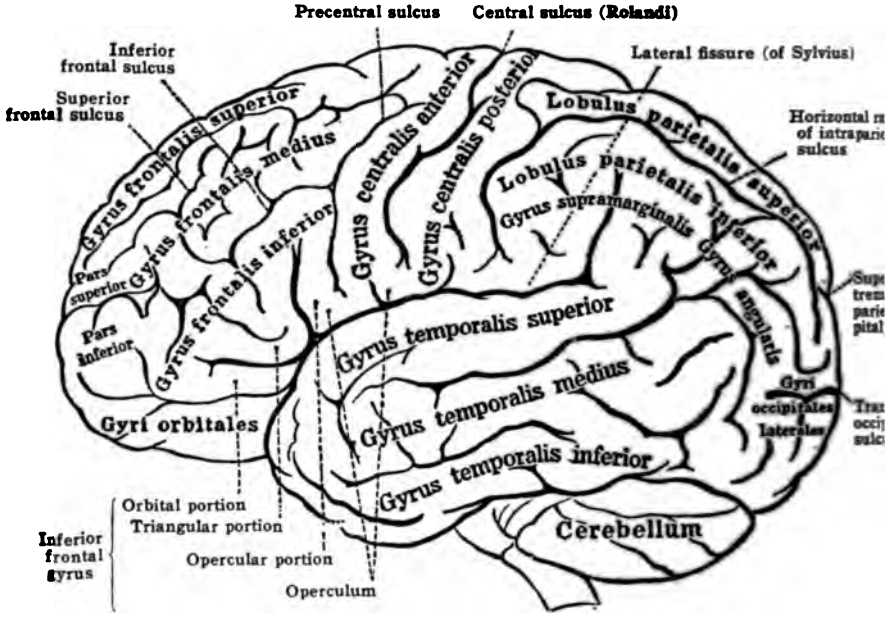
The **fusiform gyrus** is in the basal and tentorial surface of the temporal (fig. 716). Its usual somewhat spindle-shape suggests its name, and it is tinuous backward into the occipital gyri, or its posterior end may be compl isolated by a union of the *inferior temporal sulcus* and the **collateral fis** which two furrows separate it from its neighbors on either side. Anteriorly fusiform gyrus runs into the common substance of the other three gyri at temporal pole.

The **lingual gyrus** (fig. 716) is usually included in the tentorial surface o temporal lobe, though some regard it as a part of the occipital lobe. Its la posterior portion lies within the boundaries of the occipital lobe. Bou laterally by the collateral fissure, it is continuous anteriorly into the hippoca gyrus of the rhinencephalon.

All of the sulci give off occasional lateral twigs (*transverse temporal sulci*) w themselves may or may not branch, and which tend to divide the main gyri **transverse temporal gyri.**

FIG. 714.—OUTLINE DRAWING OF CONVEX SURFACE OF LEFT CEREBRAL HEMISPHER (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



The lateral fissure (fissure of Sylvius).—On account of its origin by th lapping and enclosing of the broad floor of the Sylvian fossa by the adjace of the pallium, the lateral fissure is the deepest and most conspicuous fis the cerebral hemisphere (figs. 714–716). Its main divisions are a short st three main branches. The stem lies in the basal surface of the hemisphere it begins in a depression in the anterior perforated substance, the *vallecula* and passes forward and upward between and separating the temporal pole superciliary border of the frontal lobe. It corresponds in direction w posterior border of the lesser wing of the sphenoid bone, which projects ba into it, and it contains the middle cerebral artery, the Sylvian vein, and th alæ parvæ. It appears on the lateral surface at a point known in cranial raphy as the *Sylvian point*, where it divides into its three main branches (fi

(1) The **posterior ramus** is the linear continuation of the fissure, a horizontally backward and upward to terminate in the supramarginal g the parietal lobe.

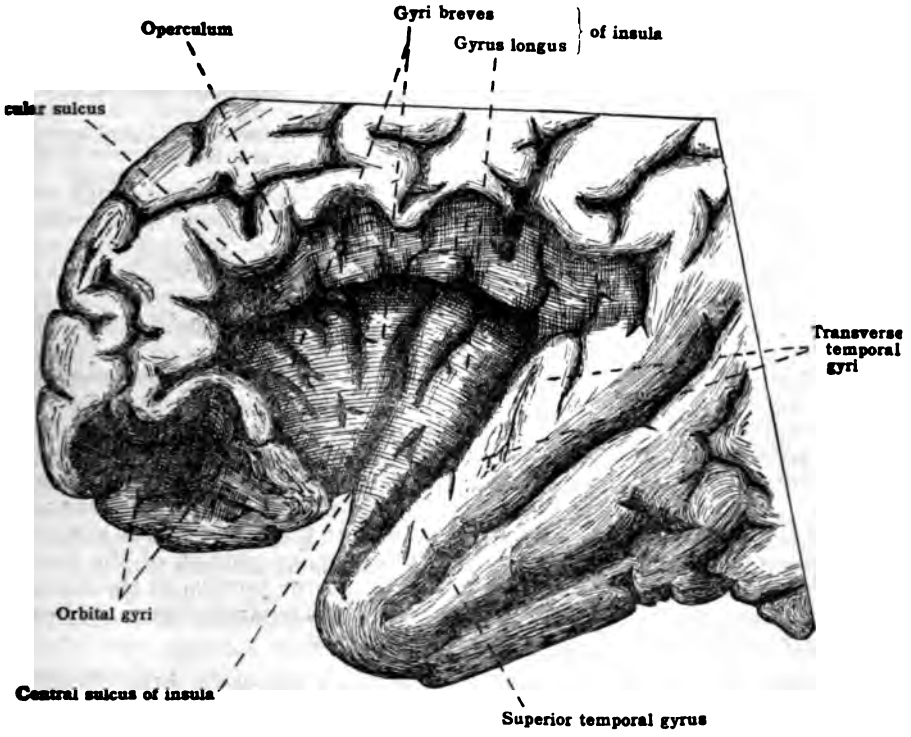
(2) The **anterior ascending ramus** passes upward for about 10 mm dividing the inferior gyrus of the frontal lobe.

(3) The **anterior horizontal ramus** passes forward from the stem of the about 10 mm., and likewise into the inferior frontal gyrus, but parallel w superciliary border.

hese branches, together with certain smaller collateral twigs, divide the over- ng or opercular portions of the adjacent pallium into (*a*) the *temporal opercu-* which lies below the posterior ramus; (*b*) the frontoparietal operculum, or *ulum proper*, which lies above and behind the anterior ascending ramus; (*c*) *rontal operculum*, between the latter and the anterior horizontal ramus; (*d*) he *orbital operculum*, below the anterior horizontal ramus. Collectively the ula are known as the *opercula of the insula*.

he insula (central lobe).—The insula or island of Reil (figs. 713, 715) is a gular area of the cerebral cortex lying in the floor of the lateral fissure, and aled by the opercula. Of these, the temporal operculum overlaps the insula greater extent than either the frontal or parietal. More than half of it may, fore, be exposed, by gently pressing away the temporal lobe. The insula sponds to the broad floor of the Sylvian fossa of the embryonic brain. In leveloped condition its surface is convex lateralward and is itself folded into

15.—THE INSULA WITH ITS GYRI AND SULCI. (Shown by widely separating the opercula.)



The apex of the triangle appears upon the basal surface of the hemisphere 716), and is the only portion which may be seen without disturbing the men. The apex appears as the end of a small gyrus under the temporal pole, in close relation with the anterior perforated substance and the vallecula i, and is known as the **limen of the insula**. In the folding process by which percula accomplish the overlapping and enclosing of the island, there results p sulcus which surrounds its entire area except at the limen insula. This is n as the **circular sulcus**, or limiting sulcus of Reil. The gyri (and sulci) of nsula radiate from the apex of the triangle. The **central sulcus** of the insula e deepest. It runs from below backward and upward, parallel with the al sulcus (of Rolando) above and divides the insula into a larger anterior and aller posterior portion. The anterior portion consists of from three to five irregular **gyri breves** or precentral gyri, separated by **sulci brevis**; the pos- r portion consists of a single, slightly furrowed gyrus, which is long and arched xtends from the apex to the base of the triangle, the **gyrus longus**.

In a thorough study of the insula of more than 200 human brains, including a few of id and paralytics and a series of young fetuses, Nelidoff finds that the left island is more de marked by sulci and averages 11 mm. longer than the right; that, of the sulci in the island, central sulcus is the first to appear, is the most persistent sulcus in defective brains, tho occasionally absent in microcephalic idiots, and that on the average it is more pron in males than in females.

The frontal lobe (figs. 712–719).—This is the most anterior of the lobes of hemisphere, and like the two lobes behind, it has a convex or lateral, a basal, and medial surface. The convex surface begins with the frontal pole, and is boun posteriorly by the *central sulcus* (*Rolandi*). The basal surface extends backw to the stem of the lateral fissure, covered by the frontal pole. The medial surfa is separated from the gyrus cinguli of the rhinencephalon (limbic lobe) by the s frontal part of the **sulcus cinguli** (callosomarginal fissure), and from the pariet lobe by a line drawn perpendicular from the upper extremity of the centr sulcus (Rolandi) to the sulcus cinguli. These surfaces include the following gy and sulci:—

	Gyri.		Sulci.
Convex surface	Anterior central gyrus.		
	Superior frontal gyrus.		Precentral sulcus (Superior. / Inferior.)
	Middle frontal gyrus	Superior portion.	Superior frontal sulcus.
		Inferior portion.	Middle frontal sulcus.
	Inferior frontal gyrus	Opercular portion.	Inferior frontal sulcus.
		Triangular portion.	Anterior ascending ramus of lateral fissure.
		Orbital portion.	Anterior horizontal ramus of lateral fissure.
Basal surface	Orbital gyri	Lateral.	Orbital sulci (Lateral / Medial. / Transverse.)
		Anterior.	
		Posterior.	
		Medial.	
	Gyrus rectus		Olfactory sulcus.
Medial surface	Superior frontal gyrus.		
	Marginal gyrus.		
	Paracentral lobule (anterior part).		Rostral sulci.

Many of the sulci, especially the superior frontal and the rostral sulci, often give off twigs or are broken into short furrows which give rise to small folds [gyri transitivi], too inconstant to be given special names.

The **anterior central gyrus** (ascending frontal convolution) is the only gyrus of the frontal lobe having a vertical direction. It lies parallel to the central sulcus (Rolandi), and thus extends obliquely across the convex surface from the posterior ramus of the lateral fissure (frontal operculum) to the superomedial border, and is continuous on the medial surface with the anterior portion of the *paracentral lobule*. It comprises the larger part of the motor portion of the somesthetic (sensory-motor) area of the cerebral cortex. It is separated from the horizontal frontal gyri in front of it by the **precentral sulcus**.

This sulcus is developed in three parts, but the upper and middle parts in the fetal brain usually fuse together, so that in the later condition it consists of a superior and an inferior segment. The superior cuts the superomedial border of the hemisphere and appears on the medial surface in the paracentral lobule. On the convex surface it is usually connected with the posterior end of the superior frontal sulcus (fig. 714).

The **superior frontal gyrus** is a relatively broad, uneven convolution, comprising the anterior portion of the superomedial border of the hemisphere and therefore extends horizontally from the precentral sulcus to the frontal pole. It is sometimes imperfectly divided into a superior and an inferior part by a series of detached, irregular furrows, spoken of collectively as the *paramedial sulcus*. The resulting transitory gyri are of considerable interest in that they are peculiar to the human brain, and are said to be more marked in the higher than in the lower types.

The **middle frontal gyrus** is likewise a broad strip of pallium extending from the precentral sulcus to the temporal pole. It is separated from the superior frontal gyrus by the **superior frontal sulcus**, which is usually continuous into the superior section of the precentral sulcus and thence extends horizontally to the frontal pole. The middle frontal gyrus is in most cases subdivided anteriorly into a *superior* and an *inferior portion* by a **middle frontal sulcus**. This sulcus begins above and runs into the frontal pole, where, upon reaching the superciliary

border, it frequently bifurcates into a transverse furrow, known as the *fronto-marginal sulcus*.

The **inferior frontal gyrus** forms the superior wall of the lateral fissure, and is separated from the middle frontal gyrus by the **inferior frontal sulcus.** This sulcus usually begins continuous with the inferior section of the precentral sulcus, and extends, very irregularly and frequently interrupted, toward the frontal pole. The gyrus abuts upon the anterior central gyrus, and its posterior portion is divided into three parts (the frontal opercula) by the anterior ascending and horizontal rami of the lateral fissure. The part behind the anterior ascending ramus is the **opercular portion** (a part of the frontoparietal operculum or operculum proper), sometimes referred to as the *basilar portion*. In most brains this part is traversed by a short oblique furrow, the **diagonal sulcus.** The part between the two anterior rami of the lateral fissure is the cone-shaped **triangular portion.** This portion frequently involves one and sometimes two descending twigs of the inferior frontal sulcus. The part below the anterior horizontal ramus is by position the **orbital portion.**

It is seen that the inferior frontal gyrus gives rise to the whole of the frontal operculum and the anterior half of the frontoparietal operculum. The opercular portion is of special interest in that in the left hemisphere it constitutes the celebrated convolution of Broca, the motor area for the function of speech. The area controlling speech, however, involves that part of the triangular portion bounding the anterior ascending ramus of the lateral fissure as well, and both these parts often appear more developed on the left hemisphere. The development of the opercula of the inferior frontal gyrus is a distinctive characteristic of the human brain. This gyrus does not develop opercula even in the highest varieties of apes. The development of the function of speech in man no doubt influences the development of the frontal opercula.

On the *basal surface* (fig. 716) of the frontal lobe is the orbital area and the gyrus rectus. The more pronounced of the **orbital sulci** are often so joined with each other as to form an H-shaped figure standing parallel to the medial plane, and thus they comprise a *medial*, a *lateral* and a *transverse orbital sulcus*. This figure naturally divides the orbital area into four gyri:—(1) The **lateral orbital gyrus** is the basal continuation of the inferior frontal gyrus, and is thus related to the orbital portion of the frontal operculum; (2) the **anterior orbital gyrus** is continuous at the pole with the middle frontal gyrus; (3) the **posterior orbital gyrus** is closely related to the limen insulæ and the stem of the lateral fissure, and its outer part is in relation with the orbital portion of the operculum; (4) the **medial orbital gyrus** is continuous over the superciliary border with the superior frontal gyrus. It frequently contains one or two short, isolated sulci. Its medial boundary is the straight **olfactory sulcus,** in which lies the olfactory bulb and tract of the rhinencephalon. This sulcus marks off a narrow straight strip of cortex between it and the medial border of the lobe known as the **gyrus rectus.** The posterior portion of the gyrus rectus comprises a part of the **parolfactory area** or Broca's area, which functionally belongs to the rhinencephalon. As an area or field, this appears mesially lying between the anterior and posterior parolfactory sulci.

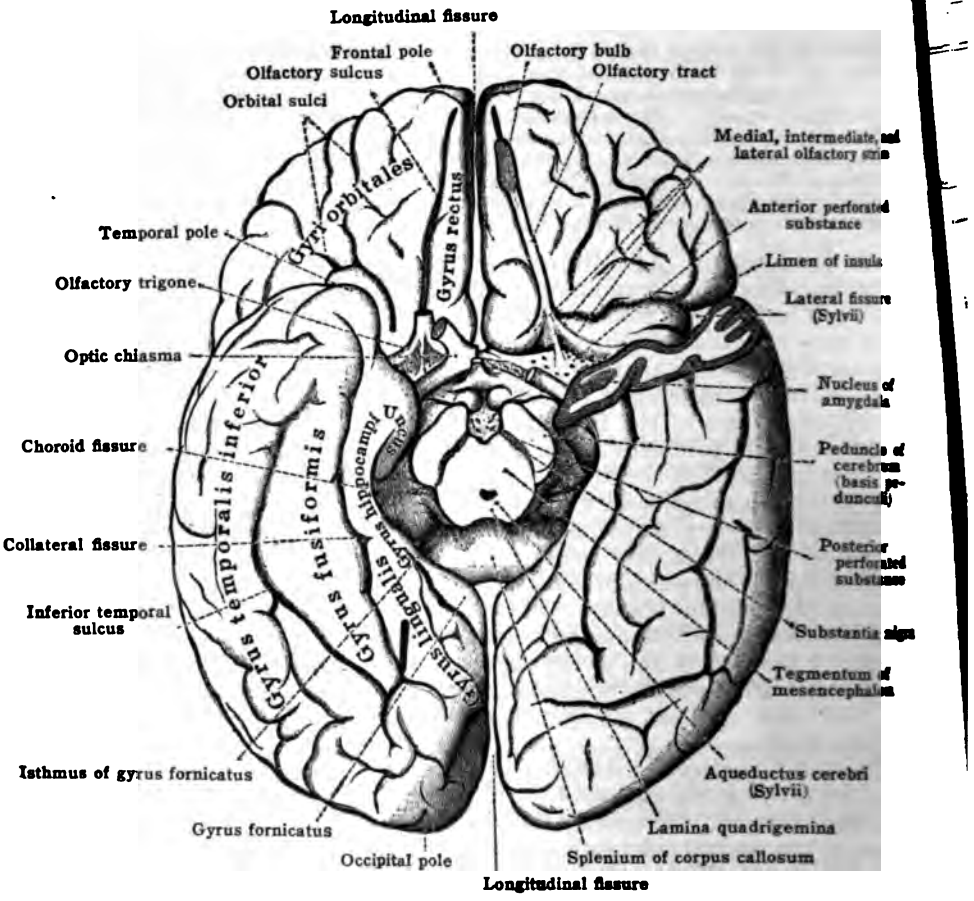
On the *medial surface* (fig. 719) of the frontal lobe the superior frontal gyrus is separated from the gyrus cinguli of the rhinencephalon (limbic lobe) by the well-marked **sulcus cinguli.** Anteriorly the superior frontal gyrus is subdivided by the main stem of the **rostral sulci** into a **marginal gyrus,** and what may be termed a **submarginal gyrus.** The marginal gyrus is usually broken into smaller parts by twigs of the rostral sulci, most of which are perpendicular to the main stem, while the submarginal gyrus is less frequently interrupted. Posteriorly the superior frontal gyrus constitutes the anterior portion of the *paracentral lobule*, a part of the somesthetic area of the medial surface of the hemisphere. This lobule is usually marked off anteriorly by a vertical twig from the sulcus cinguli.

The **sulcus cinguli** (callosomarginal fissure) is the longest and one of the most prominent sulci on the medial surface of the hemisphere. It divides the anrerior portion of the medial surface into a marginal part above and a callosal part below —in other words, it separates the superior frontal gyrus from the gyrus cinguli. Its **subfrontal portion** begins below the rostrum of the corpus callosum and curves forward and upward around the genu, and then turns backward above the body of the corpus callosum. Before it reaches the level of the splenium, it turns upward and cuts and terminates in the superomedial border of the hemisphere, as the next sulcus behind the upper termination of the central sulcus. This upward

turn is the **marginal portion** of the sulcus cinguli. It is sometimes an ab... curve and sometimes curves gradually, but its marginal relation to the upper... of the central sulcus is so constant that it serves as a means by which either of... sulci may be identified. The marginal portion separates the paracentral lo... from the precuneus (quadrate lobule), and is wholly within the parietal l... One of the most constant twigs of the sulcus cinguli is that which marks off... paracentral lobule from the superior frontal gyrus. Another sometimes divi... the paracentral lobule into its frontal and parietal portions.

The sulcus cinguli is developed from two and sometimes three (anterior, middle, and p... terior) separate furrows, which later extend and fuse into continuity. This method of... development may explain the irregularities frequently met with and the fact that sometim... in the adult the sulcus occurs in separate pieces.

FIG. 716.—BASAL SURFACE OF THE CEREBRAL HEMISPHERES. TIP OF LEFT TEMPORAL LOBE REMOVED. (After Toldt, 'Atlas of Human Antomy,' Rebman, London and New York.)

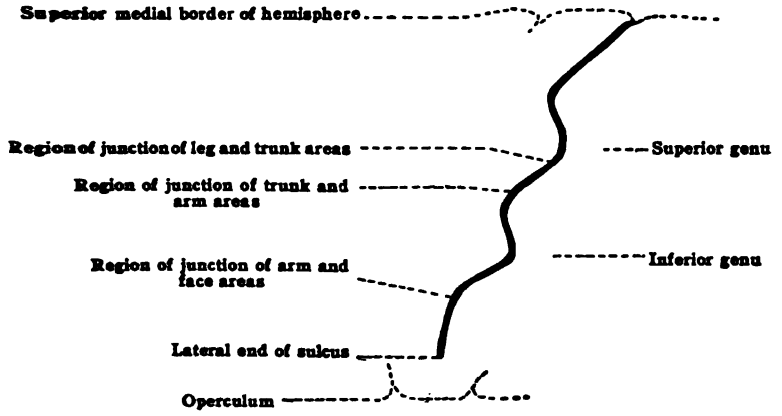


The **central sulcus** (fissure of Rolando) (figs. 714, 717, 718) **is one of the principal** landmarks of the convex surface of the hemisphere. **It separates the frontal** from the parietal lobe, and likewise divides the **somesthetic area of the pallium.** Its upper end terminates in and usually cuts the **superomedial border of the hemisphere** immediately in front of the termination of the **marginal portion of the sulcus** cinguli. Thence it pursues an oblique though sinuous **course forward across the** convex surface of the hemisphere, forming on the **average an angle of about 72°** with the superomedial border (**Rolandic angle**), **and terminates in the fronto**parietal operculum immediately above the posterior **ramus, and about 2.5 cm. be**hind the point of origin of the anterior rami of the **lateral fissure. It rarely cuts** through the frontoparietal operculum. In its **sinuous course, varying from the** line of its superomedial end, two bends are marked (**fig. 717**):—(1) **The superior genu** occurs at about the junction of the upper and **middle thirds of the sulcus and**

is concave forward. It accommodates the greater part of that portion of the cortex which is the motor area for the muscles of the leg and trunk, and the development of this area in man probably aids in producing it. (2) The inferior genu occurs below, is concave forward and is commonly a little more marked than the superior genu. It is probably in part a result of the superior genu—the turn of the sulcus in resuming its general course, but it may further result from the development of the shoulder and arm area of the cortex which occupies its concavity.

The central sulcus (Rolandi) appears in the pallium of the fetus during the latter part of the fifth month. It then consists of a lower longer and an upper shorter part. Usually these two parts become continuous before birth; very rarely do they remain separate in the adult. The point of their fusion is sometimes manifest within the depth of the sulcus. If the lips of the sulcus be pressed widely apart at about the region of the junction of its middle and upper thirds, it will be found that the opposing walls give off a number of protuberances or lateral gyri, which dovetail into each other when the sulcus is closed. Sometimes two of these lateral gyri

FIG. 717.—DIAGRAM REPRESENTING THE MOST COMMON FORM OF THE CENTRAL SULCUS AND INDICATING THE REGIONS OF JUNCTION UPON IT OF THE AREAS OF THE PRECENTRAL GYRUS DEVOTED TO THE DIFFERENT REGIONS OF THE BODY (SYMINGTON AND CRYMBLE).


Superior medial border of hemisphere
Region of junction of leg and trunk areas
Superior genu
Region of junction of trunk and arm areas
Region of junction of arm and face areas
Inferior genu
Lateral end of sulcus
Operculum

appear fused across the floor of the sulcus, so as to form a bridge of gray substance known as the deep annectant gyrus. This interruption of the continuity of the sulcus, when present, represents the point at which the two parts of the sulcus in the fetal brain joined each other without the continuity becoming wholly completed in the adult. The genua of the adult sulcus may often be due to the precedent parts not being in line at the time of their fusion.

From a special study of the central sulcus of 237 normal adult hemispheres, Symington and Crymble (1913) give the following details: (1) that the most common course of the sulcus is that illustrated in fig. 717, above; (2) that it varies in depth both in a given specimen and in different specimens—the greatest variations in depth reported for a given sulcus being from 22 to 12 millimeters, the shallowest part being in the region of the deep annectant gyrus; (3) that the average length from the superomedial border of the hemisphere to the opercular end of the sulcus is about 9 cm. in direct line and 10.4 cm. following the curves of the sulcus. The average length of the curved floor is 7.9 cm. (4) From the superomedial end of the sulcus to the points of junction of the general areas of the precentral gyrus, direct line measurements give averages, (a) to the junction of leg and trunk areas, 3.5 cm.; (b) to junction of trunk and arm areas, 4.5 cm.; (c) junction of arm and face areas, 7.5 cm.

The parietal lobe.—The parietal lobe (figs. 711–714, 718, 719) occupies a somewhat smaller area of the human telencephalon than either the frontal or the temporal lobe. It has a lateral convex and a medial surface, but no basal surface. It is separated from the frontal lobe in front by the central sulcus; from the occipital lobe behind, on the medial surface by the *parietooccipital fissure*, and, on the convex surface, by an arbitrary line drawn transversely around the convex surface of the hemisphere from the superior extremity of this fissure to the inferolateral border, and it is separated from the temporal lobe below by the horizontal part of the posterior ramus of the lateral fissure, and by a line drawn in continuity with this horizontal part to intersect the transverse line drawn to limit it from the occipital lobe.

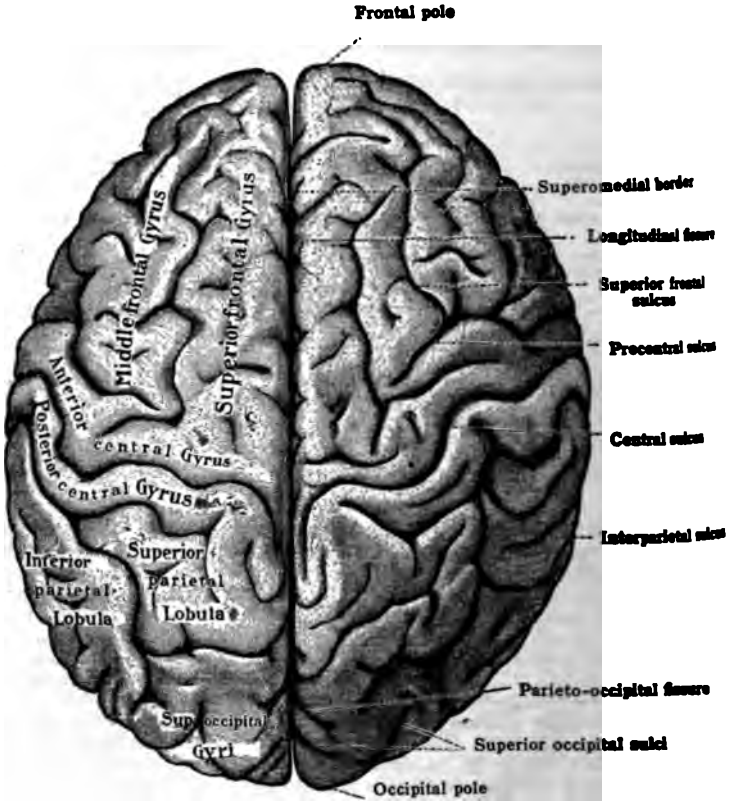
The preoccipital notch.—*In situ*, the inferolateral border of the posterior portion of the hemisphere rests over a small portion of the parietomastoid suture of the cranium, and upon this suture occurs a fold or vertical thickening of the dura mater, which slightly indents the inferolateral border of the hemisphere. This indentation occurs about 4 cm. from the

occipital pole, and is considered one of the points of limitation of the parietal from the occipital lobe, and is therefore called the preoccipital notch. While during late fetal life and early childhood it is well marked, it is usually very slight in the adult brain, and is, as a rule, evident only in brains hardened *in situ*. When it is visible, the arbitrary transverse line from the superior extremity of the parietooccipital fissure, used as a boundary between the convex surfaces of the parietal and occipital lobes, should be so drawn as to bisect the preoccipital notch.

The *convex surface* of the parietal lobe comprises the following gyri and sulci:—

The **posterior central gyrus** (ascending parietal) extends obliquely across the hemisphere parallel with the anterior central gyrus of the frontal lobe, from which it is separated by the central sulcus. Its inferior end is bounded by the posterior ramus of the lateral fissure, and constitutes the posterior or parietal portion of the frontoparietal operculum. Its upper end takes part in the superomedial border

FIG. 718.—CONVEX SURFACE OF THE CEREBRAL HEMISPHERES AS VIEWED FROM ABOVE. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

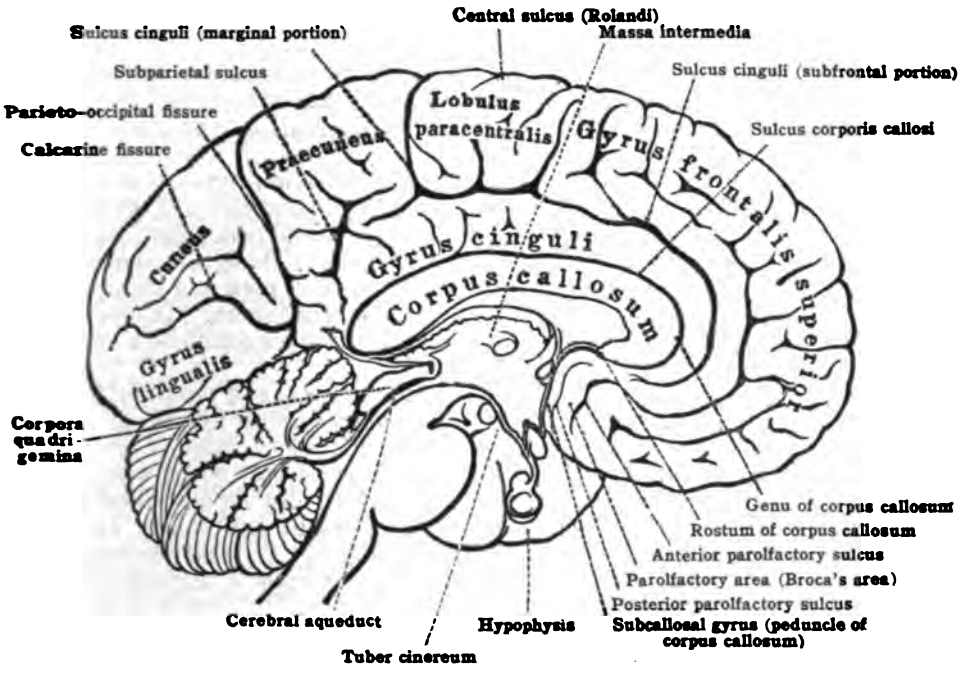


of the hemisphere, and is bounded posteriorly by the tip end of the marginal portion of the sulcus cinguli. Its posterolateral boundary consists of the two more or less vertical rami or factors of the interparietal sulcus, viz., the inferior and superior portions of the *postcentral sulcus*, either continuous with each other or detached.

The **interparietal sulcus** (intraparietal) is often the most complicated sulcus of the pallium. Its development usually begins as four different furrows in the fetal brain, and the difficulty with which it is traced in the adult brain depends upon the extent to which these four factors become continuous in the later development. When continuity of the furrows is well established, the entire sulcus may be described as consisting of an anterior end and a convex ***horizontal ramus***, which gives off a few short collateral twigs and whose either end is in the form of an irregular, reclining ⊣. The transverse bar of the anterior end arises from two of the four factors of the entire sulcus:—(1) an inferior furrow, the ***inferior postcentral sulcus***, commencing above the posterior ramus of the lateral fissure and ascending as the boundary of the lower half of the posterior central gyrus, and (2) a superior furrow, the *superior postcentral sulcus*, lying behind the upper portion

of the posterior central gyrus, and which, upon approaching the superomedial border, may turn backward a short distance parallel with the horizontal ramus, as in fig. 714. When confluent, these two factors form together a continuous **postcentral sulcus.** In the adult the superior of the two is always continuous with the horizontal ramus; when confluent, the two join so as to form the transverse bar of the anterior end of this ramus. The horizontal ramus, which represents the third of the primary furrows, is continued backward past the superior extremity of the parietooccipital fissure into the occipital lobe, where it usually joins the *occipital ramus*, the fourth of the primary furrows. This ramus divides shortly into two branches which run at right angles to the stem, forming the *transverse occipital sulcus*, and thus arises the transverse bar of the posterior end of the interparietal sulcus.

FIG. 719.—OUTLINE DRAWING OF MEDIAL SURFACE OF LEFT CEREBRAL HEMISPHERE. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



The occipital ramus may, however, consist of little more than the transverse bar, which may or may not be joined by the horizontal ramus. The occipital ramus is more frequently separate from the horizontal than is the postcentral sulcus. In their development the inferior postcentral sulcus appears first (during the latter part of the sixth month), the occipital ramus second, the horizontal ramus third, and last, the superior postcentral sulcus.

The superior parietal lobule (*gyrus*) is the area of the superomedial border of the parietal lobe (fig. 714). It is limited in front by the superior postcentral sulcus, below by the horizontal ramus of the interparietal sulcus, and posteriorly it is continuous around the superior end of the parietooccipital fissure into the cortex of the occipital lobe. It is a relatively wide area (lobule), always invaded by collateral twigs of its limiting sulci, and usually contains a few short, isolated furrows. When the parieto-occpital fissure is considerably prolonged over the superomedial border (*external parietooccipital fissure*), the continuation of the lobule about the end of this fissure presents the appearance described as the **parietooccipital arch.**

The inferior parietal lobule is limited in front by the inferior postcentral sulcus, and above by the horizontal ramus of the interparietal sulcus (fig. 714). It is continuous with the cortex of the temporal lobe, and with that of the occipital lobe behind, and is therefore invaded by the ends of the sulci belonging to these lobes. Its anterior portion is separated from the temporal lobe by the horizontal portion of the posterior ramus of the lateral fissure. The upturned end of this

ramus invades the anterior portion of the lobule and the broad fold, arched around this end and continuous behind it into the superior temporal gyrus, is known as the **supramarginal gyrus**—an area to which auditory word- and tone-images are attributed. The **angular gyrus** is the portion which embraces the posterior end of the superior temporal sulcus, and is continuous behind this into the middle temporal gyrus and in front usually with the superior temporal gyrus. It is the area for visual word images. Its shape is usually such as to suggest its name. The most posterior part of the inferior parietal lobule, when arching about the end of the middle temporal sulcus and continuous with the temporal gyri on its either side, is known as the **postparietal gyrus.** This is a smaller area than either of the other two, and, owing to the variability of the end of the middle temporal sulcus, is not always evident.

The *medial surface* of the parietal lobe is divided into two parts by the marginal portion of the sulcus cinguli. The anterior and smaller part is the medial continuation of the posterior central gyrus, and comprises the posterior portion of the **paracentral lobule** (fig. 719). It is limited from the part of this lobule belonging to the frontal lobe by a vertical line drawn from the marginal extremity of the central sulcus. The **precuneus** (*quadrate lobule*) is the posterior and larger part of the medial surface of the parietal lobe. It is separated from the cuneus of the occipital lobe by the parietooccipital fissure, and is imperfectly separated from the gyrus cinguli (limbic lobe) below by the *subparietal sulcus* (postlimbic fissure), branches of which invade it extensively.

The occipital lobe.—This is a relatively small, trifacial, pyramidal segment, comprising the posterior extremity of the hemisphere, its apex being the occipital pole. Though one of the natural divisions of the cerebral hemisphere, it is very indefinitely marked off from the lobes anterior to it. Though it contains the cortical area of the visual apparatus, only in the brains of man and the apes does it occur as a well-defined posterior projection of the hemisphere. In most of the mammalia it is not differentiated at all. Its three surfaces comprise a convex, a medial, and a tentorial surface.

Its *convex surface* is separated from that of the parietal and temporal lobes by the superior and external extremity of the parietooccipital fissure, and by an arbitrary line drawn transversely from this extremity to the inferolateral border of the hemisphere, or so drawn as to bisect the preoccipital notch when this is evident. The sulci which occur on the convex surface may be described as two, though both of these are very variable in their extent and shape, and their branches are inconstant both as to number and length. (1) The **transverse occipital sulcus** is the most constant in shape. It extends a variable distance transversely across the superior portion of the lobe, and, as noted above, it is frequently continuous with the interparietal sulcus through its occipital ramus, and when so, it appears as the posterior terminal bifurcation of this sulcus (fig. 714). When detached, it often occurs merely as a definite furrow with few rami, and sometimes the ramus by which it otherwise would join the interparietal sulcus is entirely absent. (2) The **lateral occipital sulcus** is always short, and has its deepest portion below the transverse sulcus. It usually has a somewhat oblique course toward the superomedial border. Sometimes it occurs in several detached pieces, then known collectively as the *lateral occipital sulci.*

Therefore, the gyri of the convex surface of the lobe are also variable. They are not sufficiently constant to merit individual names. The lateral occipital sulcus or sulci roughly divide them into an inferior and lateral area, known as the **lateral occipital gyri,** and into a superior area, the **superior occipital gyri.** The lateral area is continuous into the gyri of the temporal lobe, while the superior area is continuous into the gyri of the parietal lobe.

The *medial surface* of the occipital lobe is separated from that of the parietal lobe (precuneus) and from the gyrus cinguli of the limbic lobe by the well-marked parietooccipital fissure. It comprises the constantly defined, wedge-shaped lobule known as the **cuneus,** and the posterior and medial extremity of the **lingual gyrus.** Since the greater portion of the length of the lingual gyrus is involved in the basal surface of the temporal lobe, this gyrus as a whole has been considered as belonging to the temporal lobe (see figs. 711, 716). The cuneus is separated from the lingual gyrus by the posterior portion of the **calcarine fissure,** which always terminates in a bifurcation, one limb of which invades the cuneus near the superomedial border. In addition the cuneus may contain

[illegible]er twigs from both the fissures bounding it, and also, when wide, may contain [illegible] or more short, detached **sulci cunei.**

The **calcarine fissure** and the **parietooccipital fissure** are almost invariably joined in the human brain, forming a Y-shaped figure, the prongs of which give the cuneus its shape. The calcarine fissure begins on the tentorial surface in the posterior portion of the hippocampal gyrus of the limbic lobe, below the splenium of the corpus callosum, and extends backward upon the medial occipital border of the hemisphere. It then bends downward and proceeds to its terminal bifurcation in the polar portion of the occipital lobe. The stem or hippocampal portion of the fissure is deeper than the posterior or occipital portion. It produces a well-marked eminence in the medial wall of the posterior cornu of the lateral ventricle, known as the *calcar avis* or *hippocampus minor*. It is developed separately from the posterior portion, which itself first appears as two grooves. All three parts are usually continuous with each other before birth.

The **parietooccipital fissure** usually appears from the first as a continuous groove. It begins in the superomedial border of the hemisphere, rarely extending into the convex surface more than 10 mm. (*external parietooccipital fissure*), thence it extends vertically downward across the mesial surface (*internal parietooccipital fissure*), and terminates by joining the calcarine fissure at the region of the downward bend of the latter, or at about the junction of its anterior and middle thirds. In certain of the lower apes and in the brain of the chimpanzee there is no junction between the two fissures, they being kept apart by a narrow neck of cortex, the **gyrus cunei.** Neither are they joined in the human fetus. If in the adult human brain the region of their junction be opened widely, there will be found a submerged transitory gyrus (**deep annectant gyrus**), which is the gyrus cunei, superficial in the fetus. In the higher apes and in microcephalic idiots this gyrus may be on the surface or partially submerged. Two other transitory gyri (annectant gyri) are to be found by pressing open the calcarine fissure, and they mark the points at which its three original grooves became continuous during its development into a boundary between the cuneus and the lingual gyrus. Of these, the **anterior cuneolingual gyrus** crosses the floor of the calcarine fissure on the posterior side of its junction with the parietooccipital fissure, and therefore near the gyrus cunei. The **posterior cuneolingual gyrus** occurs near the region of the terminal bifurcation of the fissure.

The *tentorial surface* of the occipital lobe is blended intimately with that of the temporal lobe, from which it is separated only by an arbitrary line drawn from the line of demarcation for the convex surface, at the region of the preoccipital notch, and thence to the isthmus of the gyrus fornicatus—the narrow neck of cortex connecting the gyrus cinguli with the hippocampal gyrus, just below the splenium of the corpus callosum (see fig. 711). The gyri blending the occipital and temporal lobes across this line are the *lingual gyrus*, already mentioned, and the **fusiform gyrus** (occipitotemporal convolution). In fact, the tentorial surface of the lobe may be considered as nothing more than the posterior extremity of the fusiform gyrus, and the inferior portion of the same extremity of the lingual gyrus. The former is often somewhat broken up and is then continuous into the lateral occipital gyri. These two gyri are separated by the *collateral fissure* the posterior end of which extends into the occipital lobe. The fusiform gyrus is bounded laterally by the inferior temporal sulcus, which sometimes is continuous by a lateral twig, across the posterior end of this gyrus, with the collateral fissure.

The Rhinencephalon

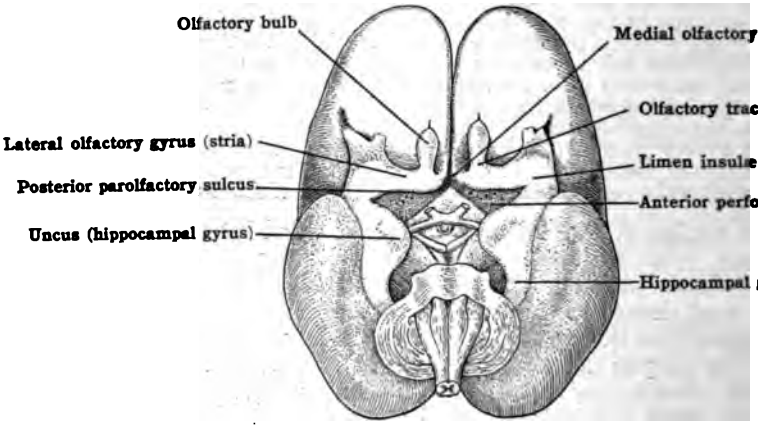
The rhinencephalon or *olfactory brain* includes those portions of the cerebral hemisphere which are chiefly concerned as the central components of the olfactory apparatus. Owing to the preponderant development of the other divisions of the hemisphere, the parts comprising this division appear relatively but feebly developed in the human brain. In most of the mammals the sense of smell is relatively much more highly developed, and in many of the larger mammals the parts comprising the rhinencephalon are of greater absolute size than in man, though their cerebral hemispheres may be considerably smaller. In the human fetus the parts of the rhinencephalon are relatively much more prominent than after the completed differentiations into the adult condition. In the broader sense of the term the rhinencephalon includes those parts of the hemisphere usually classed as comprising two lobes, viz., the **olfactory lobe** and the **limbic lobe.** Neither of these is a 'lobe' in the sense of comprising a definite segment of the hemisphere, as do the other lobes, and therefore the rhinencephalon cannot be called a distinct lobe. It is so strung out that by one or the other of its parts it is either in contact or continuity with each of the other lobes of the hemisphere. Morphologically, the olfactory lobe and adjacent structures form the *anterior division*, and the limbic lobe forms the *posterior division* of the rhinencephalon.

The anterior division.—The *olfactory lobe* proper belongs almost wholly to the base of the encephalon, and consists of the following parts:—

(1) The **olfactory bulb** is an elongated, oval enlargement of gray substance which lies upon the lamina cribrosa of the ethmoid bone, and, practically free, it is pressed into the anterior end of the olfactory sulcus in the basal surface of the frontal lobe. The numerous thin filaments of non-medullated axones of the *olfactory nerve* enter the cranium through the foramina of the lamina cribrosa and pass into the inferior surface of the bulb.

(2) The **olfactory tract** is a triangular band of white substance which arises in the olfactory bulb, and continues backward about 20 mm. to the region of the anterior perforated substance. It appears triangular in transverse section from the fact that its upper side fits into the olfactory sulcus. It becomes somewhat broader at its posterior end. In the human fetus and in the adult of many of the lower vertebrates the tract retains considerable gray substance.

FIG. 720.—BRAIN OF HUMAN FETUS OF 22.5 CM. (BEGINNING OF FIFTH MONTH), SHOWING THE PARTS OF THE DEVELOPING RHINENCEPHALON APPARENT ON THE BASAL SURFACE. (After Retzius.)



(3) The **olfactory trigone** (*olfactory tubercle*) is the small triangular ridge, the posterior continuation of the olfactory tract joining the anterior perforated substance. In it the olfactory tract breaks up into three roots, the *lateral, intermediate,* and *medial olfactory stria* (*gyri*). The lateral olfactory stria emphasizes the lateral portion of the trigone into the **lateral olfactory gyrus,** a portion of which is directly continuous into the *limen insulæ* (figs. 716, 720).

While a few of the fibers of the lateral stria penetrate this region, the greater mass of them pass obliquely lateralward over it and gradually disappear in the anterolateral portion of the anterior perforated substance, in which some of them terminate, but through which most of them pass to curve into the anterior end of the hippocampal gyrus and terminate there, chiefly in the uncus. In most of the mammals the lateral stria is so strong that it appears as a superficial white band passing directly into the uncus. In the early fetus it is seen to enter the uncus in two branches, forming the medial semilunar gyrus and the lateral gyrus ambiens upon the uncus. A portion of the *limen insulæ* belongs to the rhinencephalon.

(4) The **parolfactory area** (Broca's area) involves the mesial extension of the olfactory trigone, and is concerned with the *medial olfactory* stria. On the basal surface of the hemisphere this area involves the posterior extremity of the gyrus rectus—a portion of which is sometimes seperated from the remainder of the gyrus by a ventral prolongation of the *anterior parolfactory sulcus* of the medial surface (figs. 719, 724). This prolongation when present has been called the **fissura serotina.** On the medial surface the parolfactory area appears as a definite gyrus. In front this is separated from the superior frontal gyrus by the *anterior parolfactory sulcus*, and from the subcallosal gyrus behind by the deeper *posterior parolfactory sulcus* (fig. 719). It is continuous above into the gyrus cinguli of the limbic lobe, a portion of the posterior division of the rhinencephalon.

A large portion of the fibers of the medial stria are lost in the parolfactory area, and are known to terminate about the cells there. This stria or root of the olfactory tract forms a slight ridge on the ventral surface of the area, which is frequently prominent enough to retain the name medial olfactory gyrus applied to it in the fetal brain (fig. 720).

(5) The **subcallosal gyrus** (peduncle of the corpus callosum) is the narrow fold of the pallium which lies between the posterior parolfactory sulcus and the rostral lamina and the ventral continuation of the latter into the lamina terminalis. It begins above, in part fused to the rostrum of the corpus callosum, and in part continuous with the gyrus cinguli, and ventrally it goes over lateralward and posteriorly into that portion of the anterior perforated substance known as the *diagonal band* of Broca, and in this way it extends into the uncus. Medially, it approaches its fellow of the opposite side so closely that the groove separating the two is known as the *median subcallosal sulcus* of Retzius Some fibers of the medial olfactory stria disappear in the substance of the subcallosal gyrus.

(6) The **anterior perforated substance** must be considered with the rhinencephalon, but, like the limen insula, it can only be considered as belonging in part to this division of the brain. It comprises the basal region between the optic chiasma and tract and the olfactory trigone. Usually the posterior parolfactory sulcus (*fissura prima* of the embryo) is sufficiently evident to more or less distinctly separate it from the latter. Its posterolateral area is occupied by the *diagonal band* of Broca. A few fibers from the medial stria are known to disappear within its depths, and, as mentioned above, many fibers from the lateral stria also pass into it. The intermediate *olfactory stria* is always much the weakest of the three striæ, and in many specimens is apparently absent The fibers of this stria run almost straight backward and plunge directly into the anterior area of the anterior perforated substance, where some of them are known to terminate, while others continue into the uncus.

On embryological grounds, the subcallosal gyrus and the anterior perforated substance are classed with the posterior part of the 'olfactory' lobe or anterior division of the rhinencephalon. The olfactory bulb and tract arise as a hollow outgrowth from the lower and anterior part of the anterior of the three primary vesicles. It is tubular structure at first, and in many of the mammals the cavity maintains throughout life as the *olfactory ventricle*. In man the cavity becomes occluded and the ependyma and gelatinous substance which surround it become the gray core of the bulb and tract of the adult.

The gray substance persists and develops chiefly in the bulb, and in fact produces it as such. It is much thicker on the inferior surface of the bulb than on the superior surface, and in section shows definite layers. From within outward, the principal of these layers are—(1) the layer of large cells whose shape suggests their name, *mitral cells;* (2) large dendrites of the mitral cells project toward the inferior surface of the bulb and there break up into numerous telodendria which copiously form synapses with like telodendria of the entering fibers of the olfactory nerve, thus forming rounded, much tangled glomeruli and the layer containing these, the *glomerular layer;* (3) the superficial layer, or *olfactory layer*, consists of the fibers of the olfactory nerve which form a dense interlacement with each other on the inferior surface of the bulb before they pass into its interior. The superior surface of the bulb becomes formed almost wholly of the fibers which arise as axones of the mitral cells and pass backward to form the olfactory tract, and thence to their localities of termination, chiefly by way of the three striæ. Along the dorsal, covered, aspect of the olfactory tract the gelatinous substance of the core may show through as a gray ridge.

The posterior division of the rhinencephalon or the so-called **limbic lobe** (a name introduced by Broca in 1878) takes part in both the medial and tentorial surfaces of the hemisphere (fig. 721). Seen from the medial surface, it forms an irregular elliptical figure which encloses the corpus callosum and the extremities of which approach each other at the anterior perforated substance, where they are continous with the structures of the anterior division of the rhinencephalon. The figure is bounded externally by the sulcus cinguli above, by the subparietal sulcus (postlimbic sulcus) and the anterior limb of the calcarine fissure behind, and by the collateral fissure below. These respectively separate it from the frontal, parietal, occipital, and temporal lobes. It comprises the following structures which are either wholly or in part devoted to the functions of the olfactory apparatus:—

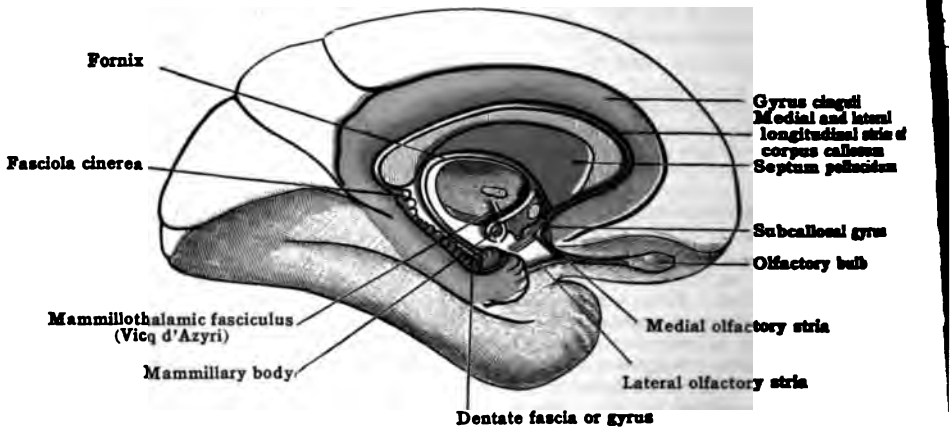
1. Gyrus fornicatus
   - Part of gyrus cinguli and cingulum.
   - Isthmus of the gyrus fornicatus.
   - Hippocampus
     - hippocampal gyrus.
     - uncus.
     - dentate gyrus (fascia).
     - fimbria.
2. The medial and lateral longitudinal striæ upon the corpus callosum.
3. The fornix.

4. The mammillary body, the mammillothalamic fasciculus to the anterior nucleus of the thalamus and the mammillopeduncular fasciculus.
5. Part of anterior cerebral commissure.
6. Part of septum pellucidum.
7. Part of medullary stria of thalamus.
8. Most of habenular nucleus.

The **gyrus fornicatus** comprises the greater mass of the limbic lobe. As seen above, it is a term used to collectively represent a number of conjoined structures. Being an incomplete ellipse in form, its two ends are united to form a closed ring by means of the connection of the parolfactory area with the gyrus cinguli and the connection of the anterior perforated substance with the uncus of the hippocampal gyrus. It is best described in terms of its three component parts indicated above:

The **gyrus cinguli** begins in junction with the area parolfactoria below the anterior end of the corpus callosum, and curves above so as to entirely embrace the upper surface of the latter. It is separated from the frontal lobe by the sulcus

FIG. 721.—DIAGRAM SHOWING POSITION OF STRUCTURES COMPRISING THE LIMBIC LOBE AS SEEN FROM THE MEDIAL ASPECT OF THE CEREBRAL HEMISPHERE.



cinguli (callosomarginal fissure), from the parietal lobe by the **subparietal sulcus**, and from the corpus callosum below by the **sulcus of the corpus callosum**. By the latter it is separated from the longitudinal stria of the upper surface of the corpus callosum.

The gyrus cinguli covers over, and its cells are closely associated with, the **cingulum**, a well-marked arcuate band of white substance, which follows the gyrus in its bend around the rostrum and backward to turn around the splenium of the corpus callosum in the isthmus of the gyrus fornicatus, and then to course forward into the hippocampal gyrus and the uncus. The cingulum is largely an association fasciculus between the gyri of the temporal lobe and those gyri on the medial surface of the cerebral hemisphere in which it runs, its fibers for the most part running short courses, being continually added to it and continually leaving it. However, it contains olfactory axones running in two directions: (1) fibers from the medial olfactory stria and fibers arising in the parolfactory area, the gyrus subcallosus and the anterior perforated substance which course posteriorly for distribution in the cortex of the gyrus cinguli and hippocampal gyrus; (2) fibers arising in the hippocampal gyrus, especially the uncus, to course dorsalward through the isthmus and forward as association fibers. Some fibers arising from the cortical cells of the gyrus cinguli pass inferiorly through the cingulum, through the corpus callosum and, anteriorly, through the septum pellucidum to join the fornix below (*perforating fibers of the fornix*).

The **isthmus of the gyrus fornicatus** is the constricted portion connecting the posterior end of the gyrus cinguli with that of the **hippocampal gyrus** (fig. 711, 716). It is bounded externally by the anterior end of the **calcarine fissure**, and incloses the posterior turn of the cingulum.

The **hippocampus** is the name applied to the curved appearances produced in the floor of the lateral ventricle by the peculiar foldings of this part of the cerebral cortex. The *hippocampal gyrus* (gyrus of the hippocampus) is the main gyrus of the tentorial surface of the limbic lobe. Externally it is separated from the fusi-

m gyrus by the collateral fissure, and it is bounded internally by the **hippo-mpal** or, more inclusive, the **choroid fissure.** Posteriorly it is partially divided the calcarine fissure into the lingual gyrus (of the temporal lobe) and the hmus of the gyrus fornicatus. Its anterior extremity is hooked backward and known as the **uncus** (*gyrus uncinatus*). This is almost entirely separated from e temporal lobe by a groove, the **temporal notch.** If the hippocampal fissure opened up, the **dentate gyrus** or fascia and the *fimbria* will be seen. These lie le by side, separated by the shallow **fimbriodentate sulcus** (fig. 728).

The free edge of the dentate gyrus presents a peculiarly notched appearance, produced by merous parallel grooves cutting it transversely. Its posterior end, sometimes called the *ziola cinerea*, continues backward over the splenium of the corpus callosum, and upon the per surface of the corpus callosum appears as a thin strip of gray substance which contains bedded in it the ends of the *medial* and *lateral longitudinal striæ*. This strip is called the **racallosal gyrus** (*gyrus epicallosus, induseum griseum*), and is thought to represent a ves-ial part of the hippocampal gyrus. Closely beneath the splenium of the corpus callosum, a the superomedial side of the hippocampal gyrus and medial to the dentate gyrus, there metimes occur suggestions of round or oval elevations of the gray substance which have been lled the **'callosal convolutions'** or *gyri Andreæ Retzii*. Rarely are they strongly developed, but hen so they often produce a spiral appearance.

The **fimbria** is but the fimbriated, free border of the posterior end or origin f the fornix, so folded as to project into the hippocampal fissure, parallel with the entate gyrus (fig. 728). It is a conspicuous band composed almost entirely of hite substance, continuous laterally with the thick stratum covering the ven-icular surface of the hippocampus. It begins anteriorly in the hook or recurved ctremity of the uncus. Traced backward, it is seen to curve upward, and within ie ventricle it becomes part of the general accumulation of the white substance *lveus*) of the ventricular surface of the hippocampus, which accumulation is the eginning of the fornix. The free border of the fimbria (seen in section) is known s the *tenia fimbriæ*, or better, *tenia fornicis*. The fimbria is separated from the erebral peduncles by the **choroid fissure,** the thin, non-nervous floor of which one intervenes between the exterior of the brain and the cavity of the lateral entricle within.

The hippocampal fissure attains its greatest depth between the dentate gyrus nd the hippocampal gyrus, and the resulting eminence produced in the floor of ie lateral ventricle is known as the **hippocampus major** (figs. 726, 727), as distin-uished from the lesser eminence produced posteriorly by the end of the calcarine ssure and known as the *hippocampus minor* [calcar avis]. The collateral fissure ay likewise produce a bulging in the wall of the ventricle, the *collateral eminence.* n transverse sections of the hippocampus major, the layers of gray and white sub-ance present a coiled appearance known as the **cornu ammonis.** Externally ie medial surface of the hippocampal gyrus adjoining the dentate gyrus has flected over it a delicate reticular layer of white substance known as the *sub-antia reticularis alba* (*Arnoldi*).

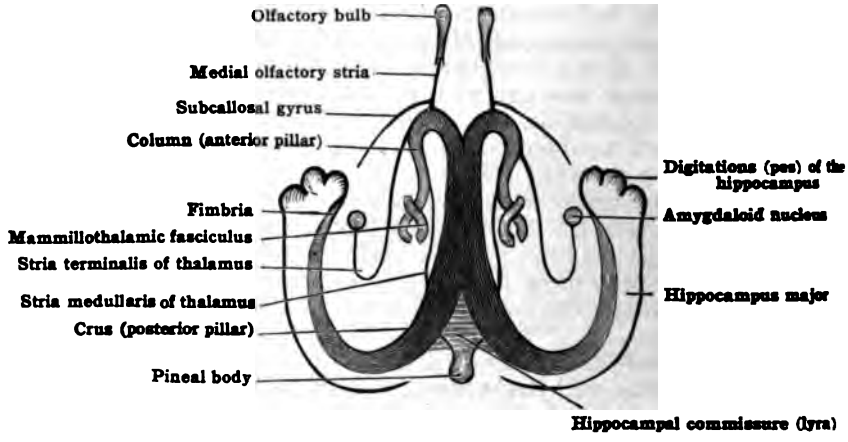
The fornix (figs. 722–724) is the great association pathway of the limbic lobe, nd appears to be wholly concerned in the apparatus of the rhinencephalon. It a bilateral structure arched beneath the corpus callosum, with which it is onnected anteriorly by the septum pellucidum. Posteriorly it passes in contact ith the splenium. It consists of two prominent strips of white substance, one r each hemisphere, the ends of which are separate from each other, while their in-rmediate parts are fused across the midline. These run above the choroid tela of ie third ventricle, and their lateral edges (*teniæ fornicis*) rest, on each side, along ie line of the tenia chorioidea. The posterior, separate ends are known as the osterior pillars or crura of the fornix; the fused, intermediate portion is the body, nd the separate, anterior ends are the anterior pillars or columns of the fornix.

The crura (posterior pillars) of the fornix.—When seen from the medial aspect f the hemisphere, the fused portion of the fornix, in the separation of the hemi-pheres, is split along the midline (fig. 711). The half under examination may be en to course obliquely lateralward under the splenium of the corpus callosum, nd then, continuous into the fimbria, to curve forward and ventralward toward ie uncus. The greater mass of the fibers coursing in the fornix arise as out-rowths of the cells of the uncus, hippocampal gyrus, and dentate gyrus. They ccumulate as a dense stratum on the ventricular surface of these gyri, termed the lveus, which crops outward as the fimbria and which passes backward and up-ard; upon reaching the region of the splenium it turns obliquely forward under

it and approaches the midline, to fuse with the like bundle from the gyri of the hippocampus of the opposite side. The bundles thus arising from the two sides are the crura (posterior pillars) of the fornix. They appear as two flattened bands of white substance which come in close contact with and even adhere to the splenium.

The angle formed by the mutual approach of the crura of the fornix is crossed by a lamina of commissural fibers connecting the hippocampal gyri of the two hemispheres (fig. 722). This lamina is the **hippocampal commissure** or *transverse fornix*. Like those of the fornix, its fibers arise from the cortex of the hippocampal gyri, but they serve as commissural fibers between the hippocampal gyri of the two hemispheres. Being of a different functional direction, it should not be considered a part of the fornix. The angle formed by the two crura of the fornix as traversed by the hippocampal commissure gives a picture named the **psalterium** or **lyra**. Usually the hippocampal commissure and the crura are in close contact with the under surface of the splenium. When occasionally they do not adhere, the space between is known as **Verga's ventricle**. According to recent studies of brains with degenerated corpus callosum (Shimazono), further commissural fibers between the limbic lobes course in the posterior angle of the septum pellucidum, transverse to the body of the fornix.

FIG. 722.—DIAGRAM SHOWING FORNIX AND ITS CONNECTIONS AS SEEN FROM ABOVE.



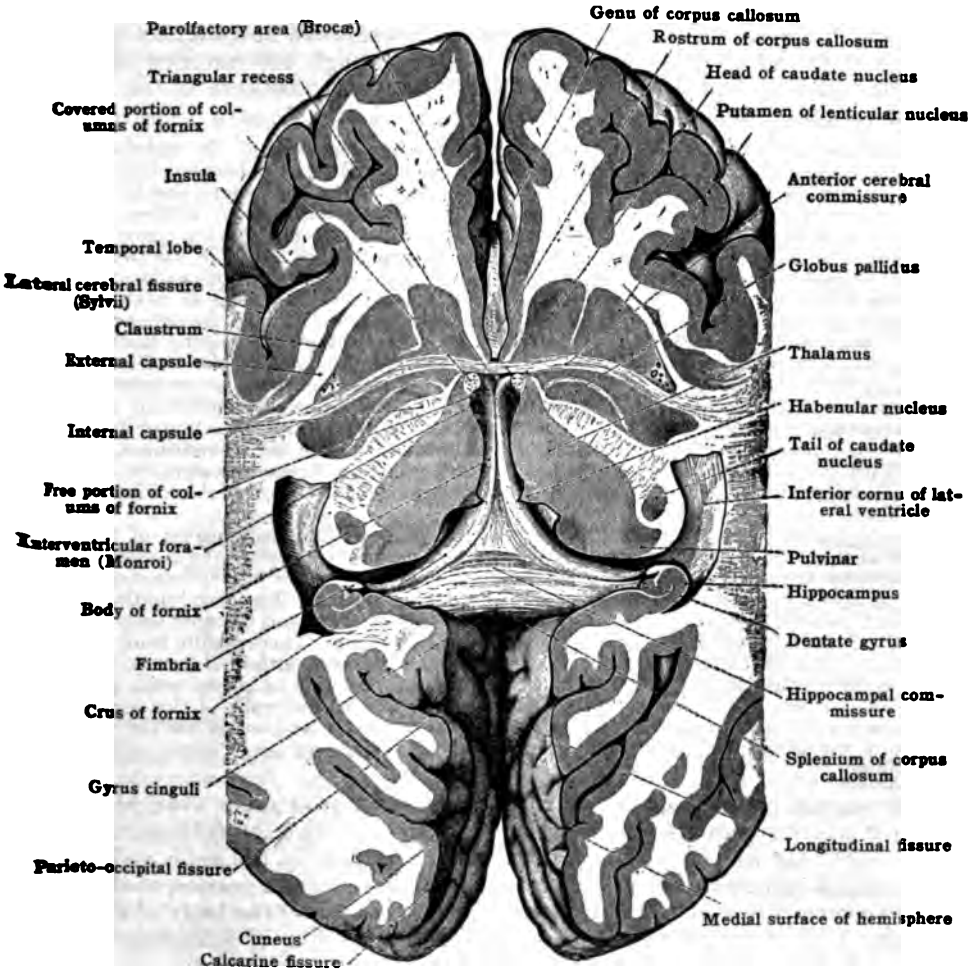
The body of the fornix [corpus fornicis] appears as a triangular plate of white substance produced by the fusion of the pillars. Its base or widest portion is behind. It is not always bilaterally symmetrical. Its upper surface is attached by the septum pellucidum to the lower surface of the corpus callosum. Below, it lies over the choroid tela of the third ventricle, which separates it medially from the cavity of the third ventricle and laterally from the upper surfaces of the thalami. Its sharp lateral edge or margin (tenia fornicis) projects into the lateral ventricle of either side in relation with the choroid plexus of that ventricle, and thus the lateral portion of its upper surface forms part of the floor of the lateral ventricle—an arrangement to be expected, since the crura arise from the floor of the ventricle, viz., the hippocampus. The ventricular portion is covered by a layer of ependyma in common with that lining the rest of the ventricle.

Along its body the fornix receives fibers arising from the cells of the cortex of the gyrus cinguli and fibers from the longitudinal stria upon the dorsal surface of the corpus callosum. These pass through the latter and are the **perforating fibers of the fornix (fig. 724)**. In their ventral course, they pass obliquely forward through the corpus callosum and, anteriorly, through the posterior angle of the septum pellucidum to join the fornix and course in its functional direction. The fibers arising in the cortex of the gyrus cinguli may course short distances in the cingulum before perforating the corpus callosum.

The columns (anterior pillars) of the fornix [columnæ fornicis] are two separate, cylindrical bundles which pass forward from the apex of the body of the fornix and then turn sharply downward along the anterior boundary of the third ventricle, just behind the anterior cerebral commissure. A part of each column, *free portion* [pars libera], forms the anterior boundary of the interventricular foramen (Monroi). Thence the *covered portion* [pars tecta] sinks into the gray substance of the lateral wall of the third ventricle, and passes downward to the base of the brain, where it appears on the exterior as the **mammillary body** [corpus mammillare] (fig. 711).

Some fornix fibers are interrupted in the nuclei of the mammillary body; probably most of them merely double back, forming the genu. From the mammillary body the fibers are disposed at least three ways: (1) The greater part perhaps pass directly upward and are lost in the *anterior nucleus of the thalamus*, where they ramify freely and terminate about its cells. These fibers form the bundle known as the **mammillothalamic fasciculus**, or bundle of Vicq d'Azyr; (2) a portion of the fibers go to form a **mammillomesencephalic fasciculus** (*tegmentomammillary fasciculus, mammillopeduncular fasciculus*). This begins in the mammillary body and passes caudalward into the mesencephalon to terminate about cell-bodies in, or in the region of, the so-called *nucleus of the medial longitudinal fasciculus and posterior commissure.* Fibers given by

FIG. 723.—HORIZONTAL SECTION OF TELENCEPHALON SHOWING BODY OF FORNIX AND HIPPOCAMPAL COMMISSURE AS SEEN FROM BELOW AND THE ANTERIOR COMMISSURE, IN SECTION. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



these cell-bodies may convey impulses by way of the medial longitudinal fasciculus or the general reticular formation to the nuclei in the mesencephalon, rhombencephalon and perhaps into the spinal cord. Some of this portion of the fibers from the mammillary body are said to pass caudalward through the mesencephalon without interruption there. (3) A portion of the fibers decussate in the superior parts of the mamillary bodies and are distributed to both the thalamus and the mesencephalon of the opposite side. This decussation is the **supramammillary commissure.**

As seen above, the fornix as a whole is composed of longitudinally directed fibers, some of which, however, cross the midline in the region of its body and course in the columns of the opposite side. For the greater part, its fibers rise from the cells of the hippocampal gyri, but it is known to contain some fibers which arise in the anterior perforated substance and subcallosal gyrus and course through the fornix to the hippocampal gyri.

The **medial and lateral longitudinal striæ** upon the corpus callosum consist of olfactory fibers coursing in both directions: (1) fibers arising in the parolfactory area, the subcallosal gyrus and the anterior perforated substance (diagonal band of Broca) course posteriorly and then inferiorly in them to the gray substance of the gyri of the hippocampus; (2) and chiefly, fibers from the hippocampal gyri course in them anteriorly and inferiorly around the rostrum of the corpus callosum, through the ventral part of the septum pellucidum, to join the fornix.

It is suggested that the stria, especially the medial, may be considered as a part of the fornix detached upon the dorsal surface of the corpus callosum during the projection of the latter between the cerebral hemispheres. The medial stria is often called the *stria Lancisii*. The two striæ are sometimes called the *dorsal fornix*.

The anterior cerebral commissure is largely concerned in the rhinencephalon; the remainder includes commissural fibers connecting the two temporal lobes. It forms one of the five commissures of the telencephalon, the other four being the corpus callosum, the hippocampal, inferior cerebral, and supramammillary commissures. It is a bundle of white substance with a slightly twisted appearance, which crosses the midline in the anterior boundary of the third ventricle between the lamina teminalis and the columns of the fornix (figs. 711 and 723), just below the interventricular foramen (foramen of Monro). In each hemisphere its main or temporal portion passes lateralward and slightly backward beneath the head of the caudate nucleus and through the anterior end of the lenticular nucleus, and thence is dispersed to the gray substance of the temporal lobe and hippocampal gyrus.

It contains fibers both to and from the temporal lobe of each side. In addition to these fibers the anterior commissure carries in its frontal side three sets of fibers belonging to the olfactory apparatus:—(1) fibers arising in the olfactory bulb of one side, which pass by way of the medial olfactory stria through to it the olfactory bulb of the opposite side; (2) fibers which pass through it from the medial stria (olfactory bulb) of one side to the uncus of the opposite side; 3 commissural fibers between the hippocampal cortex, especially the uncus, of the two sides.

The anterior commissure is a more primitive commissure than the corpus callosum, in that it is present in the lower forms when the latter is absent, and diminishes in relative size and importance as the corpus callosum appears and increases in size. In man the appearance of the anterior commissure precedes but little that of the corpus callosum. During the fifth month the lamina terminalis, which then alone unites the anterior ends of the two hemispheres, develops a thickening of its dorsal portion. In a part of this thickening, transverse fibers begin to appear and their increase in number results in the partial separation posteriorly of the part containing them from the rest of the lamina, and then follows the differentiation of this part into the anterior commissure. The remainder of the thickening of the lamina continues to increase in size with the increase of the hemispheres; its upper edge is directed posteriorly, and fibers begin to appear in it which arise in the cortex of one side and cross over to that of the other side. These fibers form the corpus callosum.

The corpus callosum, a growth of fibers in the upper, expanded portion of the lamina terminalis, thus bridges over a portion of the longitudinal fissure between the hemispheres. In the mean time, the *fornix* arises as two bundles of fibers, one from the hippocampus of each side. In the complex mechanics of the development of the cerebrum these two bundles approach each other under the corpus callosum, fuse for a certain distance, and together arch the cavity of the third ventricle and come to acquire their adult position. There results from these processes of growth a completely enclosed space, a portion of the longitudinal fissure, the roof of which is the corpus callosum, its floor, the body of the fornix, and its lateral walls, portions of the mesial surfaces of the two cerebral hemispheres. The lateral walls of this space do not thicken as do the other regions of the pallium, but remain thin and constitute the *septum pellucidum* of the adult, the space itself being the so-called *fifth ventricle* or cavity of the septum pellucidum.

The **septum pellucidum** is a thin, approximately triangular, vertically placed partition which separates the anterior portions of the two lateral ventricles from each other. Its widest portion lies in front, bounded by the genu and rostrum of the corpus callosum, the rostral lamina, and the anterior portion of the fornix, to all of which it is attached. Prolonged backward under the body of the corpus callosum, it narrows rapidly and terminates at the line of adherence between the posterior portion of the fornix and the splenium of the corpus callosum. It consists of two thin layers, the **laminæ of the septum pellucidum,** arrested developments of portions of the pallium of the hemispheres. The laminæ enclose a narrow median cavity known as the **fifth ventricle** [cavum septi pellucidi]. This cavity is of very variable size, is completely closed, and does not merit the term 'ventricle,' as applied to the other cavities of the brain, in that it has no communication with the ventricular system and has a different lining from the other ventricles.

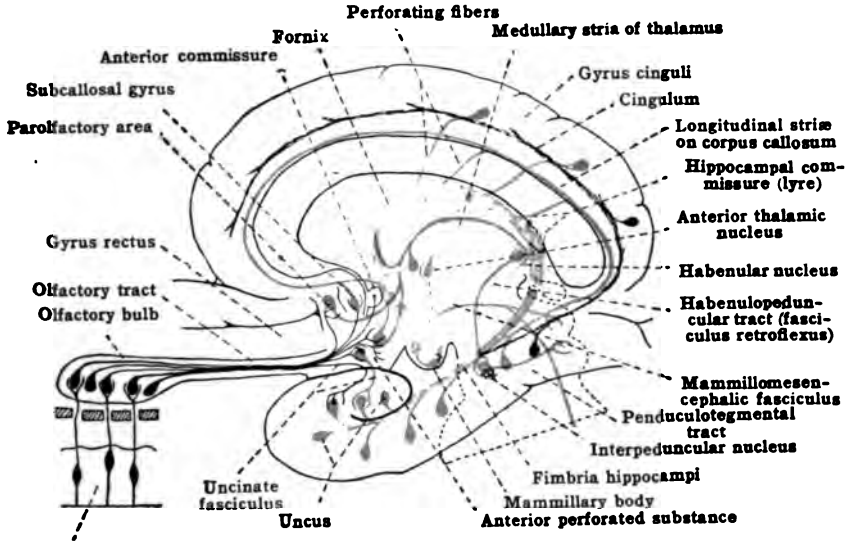
Each lamina of the septum pellucidum consists of a layer of undeveloped gray substance next to the fifth ventricle and a layer of white substance next to the lateral ventricle, the latter covered by a layer of ependyma common to that ventricle. The white substance consists in part of fibers belonging to the general association systems of the hemispheres, and in part of four varieties of fibers concerned with the rhinencephalon:—(1) fibers from each medial olfactory stria are known to reach the septum pellucidum and thence go by way of the fornix to the hippocampus major; (2) fibers are thought to be contributed by the fornix to the septum pellucidum, and through it reach the subcallosal gyrus and perhaps the parolfactory area and even the olfactory bulb; (3) the posterior angle of the septum pellucidum is perforated by some commis-

al fibers passing from the body of the fornix and by some perforating fibers of the fornix, pass- from above through it to the fornix below; (4) anteriorly, some fibers from the longitudinal a upon the corpus callosum pass through its inferior portion to join the fornix.

The medullary stria of the thalamus [stria medullaris thalami] (*stria pinealis, tenia thalami, enula*), already described as to position, receives fibers from three sources, the majority at t of which belong to the rhinencephalon: (1) fibers from the fornix nearby and thus from the rtex of hippocampal gyrus and gyrus cinguli (a corticohabenular tract); (2) fibers from the par- ctory area and the anterior perforated substance, through the septum pellucidum and mina terminalis (a more direct olfactohabenular tract); (3) fibers arising from the cell-bodies the thalamus, supposedly chiefly from its anterior (olfactory) nucleus. These latter fibers ke a thalamohabenular tract.

The majority of the fibers of the medullary stria terminate in the **habenular nuclei**, situated t the two sides of the stalk of the pineal body. Most terminate in the habenular nucles of the me side. Some cross in the *habenular commissure* (dorsal part of the posterior cerebral com- issure) and terminate in the nucleus of the opposite side. A few are claimed to pass to the uclei of the quadrigeminate bodies and a few others to join the association tracts of the mesen- ephalon. Axones given off by the cells of the habenular nucleus curve anteriorly, inferiorly,

FIG. 724.—DIAGRAM SHOWING SOME OF THE PRINCIPAL TRACTS AND SYNAPSES OF THE OLFACTORY APPARATUS.



and then course posteriorly (fasciculus retroflexus) to terminate in the *interpeduncular nucleus* (*habenulopeduncular tract*), and fibers arising in this latter nucleus pass to the cells about the central gray substance of the mesencephalon (an interpedunculotegmental tract). The two mesencephalic paths here noted and the mammillomesencephalic fasciculus noted above give three anatomical possibilities for olfactory reflex activities, visceral (or sympathetic) and somatic, involving the motor cranial nerves and possibly the spinal nerves. Fibers arising in the cortex of the hippocampal gyrus, uncus especially, may pass by way of the cingulum and thence by any suitable association fasciculus of the cerebral hemisphere to the motor area of the cerebral cortex; also fibers may arise from the anterior nucleus of the thalamus and pass to the motor cortex by way of the internal capsule. From the motor cortex, the descending pyramidal fibers give the possibilities for any higher cortical activities induced by smell.

A more direct mesencephalic path has been suggested by Wallenberg, namely, that cells in the olfactory trigone and anterior perforated substance, about which terminate fibers of the olfactory tract, send axones directly posteriorly, around the tuber cinereum, to terminate in the mammillary body and thence the impulses may go to the mesencephalon. Such fibers, if they exist, would form an *olfactomammillary tract*. A path is described in the hedge-hog which arises from cells in the olfactory trigone and passes directly posteriorly to terminate in the gray substance of the mesencephalon—an *olfactomesencephalic tract*.

To the complicated central connections of the sense of smell, Dejerine adds yet another path, namely, a portion at least of the terminal stria [stria terminalis] of the thalamus (tenia semicircularis). This contains fibers arising from cells in the anterior perforated substance and in the septum pellucidum and fibers from the opposite side by way of the anterior commissure. It runs a crescentic course posteriorly, bounding the thalamus from the caudate nucleus, turning downward and then anteriorly in the wall of the inferior cornu of the lateral ventricle to terminate in the amygdaloid nucleus, which latter is a more or less detached bit of the cortex of the extreme anterior portion of the hippocampal gyrus (uncus). The stria is said also to contain fibers which arise in the amygdaloid nucleus and course in it forward to be given off to the thalamus and probably to the internal capsule and thence to the cerebral cortex above. For a more detailed description of what may be called the fornix-system of fibers, the work of Shimazono may be consulted.

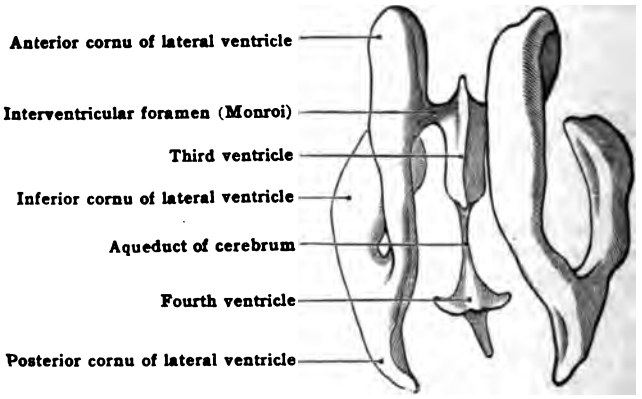
SUMMARY OF THE OLFACTORY APPARATUS

I. Peripheral part.
(1) Olfactory area of nasal epithelium containing the cell-bodies and peripheral p of olfactory neurones (*olfactory ganglion*).
(2) Non-medullated central processes of olfactory neurones, the *olfactory nerve*, pa numerous filaments through the cribriform plate of the ethmoid, to terminate in conta the dendrites of the 'mitral cells' (stratum glomerulosum) in the olfactory bulb.
II. The rhinencephalon.
A. The anterior division.
(1) Olfactory bulb, olfactory tract, olfactory trigone (tubercle), lateral olfact (gryus), medial and intermediate olfactory stria.
(2) The parolfactory area, subcallosal gyrus, anterior perforated substance inclu diagonal band of Broca.
B. The posterior division.
(1) Part of anterior commissure, septum pellucidum, uncinate fasciculus, hipp gyrus (uncus especially), dentate gyrus, gyrus cinguli and cingulum.
(2) Fimbria, hippocampal commissure, fornix, longitudinal striæ upon corpus c mammillary body, mammillothalamic fasciculus, mammillomesencephalic fasciculus.
(3) The anterior nucleus of the thalamus.
(4) The medullary stria of the thalamus, habenular nucleus, fasciculus retroflex peduncular nucleus, and interpeduncolotegmental tract.
(5) Probably an olfactomammillary and an olfactomesencephalic tract, and a pa terminal stria of the thalamus with the amygdaloid nucleus.

THE LATERAL VENTRICLES

Two of the four cavities of the ventricular system of the brain are in th cephalon. From their position, one in each cerebral hemisphere, they are as the **lateral ventricles** (figs. 725–728). They arise as lateral dilation cavity of the anterior of the primary vesicles; and, just as the fourth v remains in communication with the third by way of the aqueduct of the ce

FIG. 725.—A CAST OF THE FOUR VENTRICLES OF THE ENCEPHALON. (After Welc



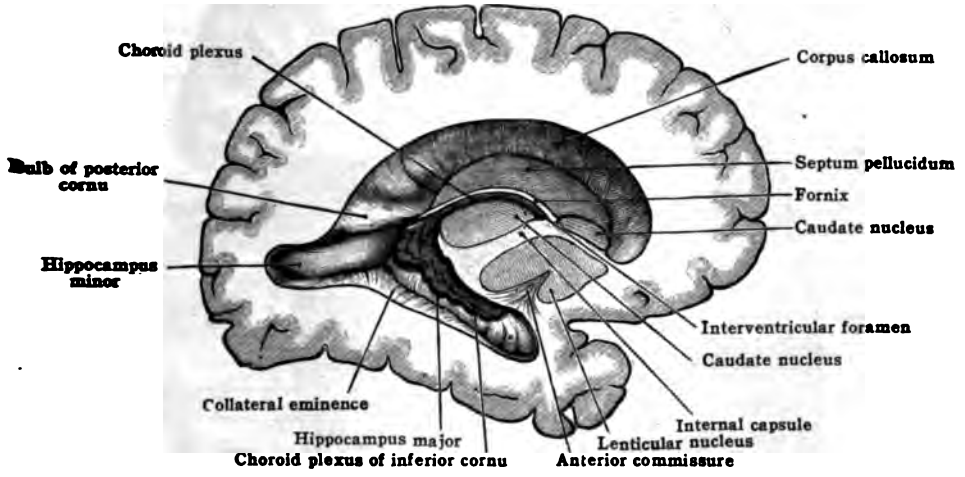
so the lateral are connected with the third by the two interventricular f (Monroi). The whole ventricular system, including the central canal of t cord, is lined by a continuous layer of ependyma and contains a small qu liquid known as the cerebrospinal fluid.

Each lateral ventricle is of an irregular, horseshoe shape. It cons *central portion* or body and three cornua, which correspond to the three the hemisphere. The portion projecting into the frontal lobe is know *anterior cornu*, that projecting into the occipital lobe is the *posterior co* the portion which sweeps anteriorly downward into the temporal lol *inferior cornu*. The ventricles of different individuals vary considerably ity, and the cavity of a given ventricle is not uniform throughout. localities the space may be quite appreciable, while in other places the w be approximate or even in apposition. Each lateral ventricle is a co closed cavity except at the interventricular foramen. However, a str floor of the inferior cornu is separated from the exterior of the brain by thin, non-nervous lamina forming the floor of the choroid fissure.

The interventricular foramen (foramen of Monro), by which the lateral ventricle is continuous with the cavity of the third ventricle, is a small, roundish channel, 2 to 4 mm. wide, which opens into the mesial side of the posterior end of the anterior cornu. It is bounded in front by the free portion of the columns (anterior pillars) of the fornix, and behind by the anterior tubercle of the thalamus. That the greater part of the lateral ventricle is posterior to it is due to the backward extension of the hemispheres during their growth and elaboration. Through the two foramina indirectly, the cavities of the two lateral ventricles are in communication with each other.

The walls of the lateral ventricle.—The **anterior cornu** is a bowl-like cavity, convex forward and extending downward and medialward into the frontal lobe. Above and anteriorly it is bounded by the lower surface of the corpus callosum and the radiations of its genu into the substance of the frontal lobe. Its medial boundary is the septum pellucidum; the head of the caudate nucleus (part of the corpus striatum) gives it a bulging, inferolateral wall, and the remainder of its floor is formed by the white substance of the orbital part of the frontal lobe.

FIG. 726.—DIAGRAM OF SAGITTAL SECTION THROUGH LATERAL PART OF RIGHT HEMISPHERE SHOWING LATERAL VENTRICLE FROM THE MESIAL SIDE OF THE SECTION.



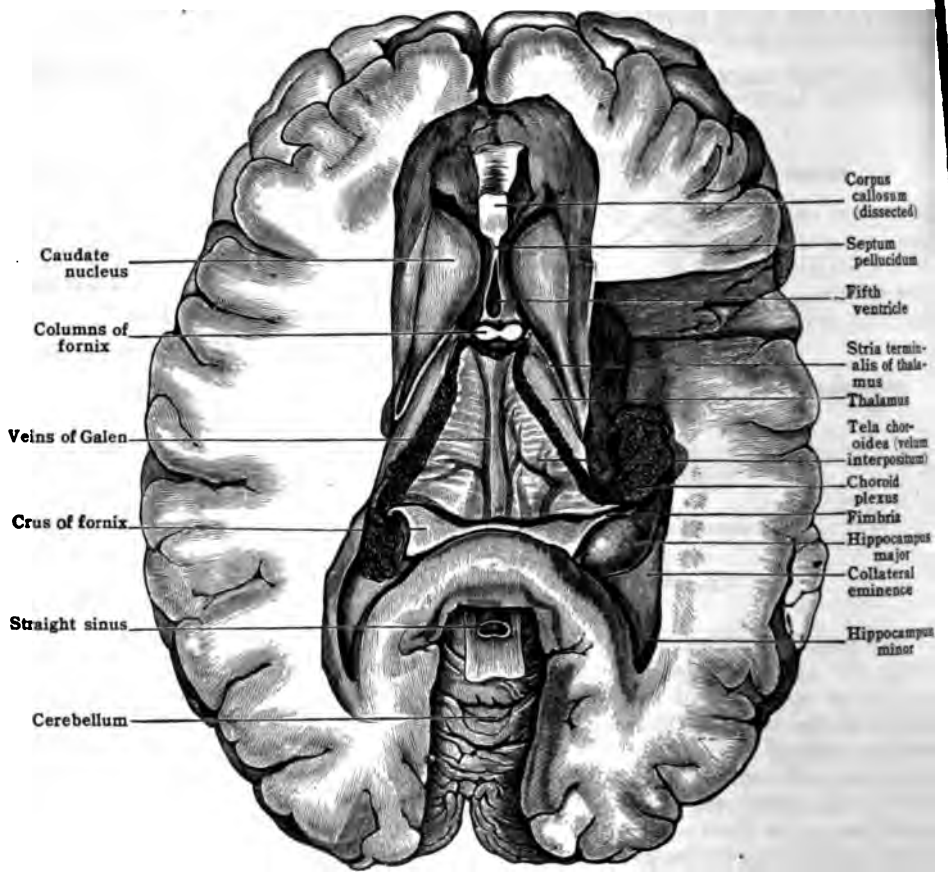
The **central portion** or body of the ventricle is more nearly horizontal. It lies within the parietal lobe and extends from the interventricular foramen to the level of the splenium of the corpus callosum. Its roof is formed by the inferior surface of the body of the corpus callosum, and its medial wall consists of the posterior part of the septum pellucidum, attaching the fornix to the lower surface of the corpus callosum. Like the anterior horn, it is given an oblique, inferolateral wall by the narrower, middle part of the caudate nucleus. Several structures contribute to its floor:—(1) the stria terminalis of the thalamus, a line of white substance conforming to the genu of the internal capsule within, and constituting the boundary between the caudate nucleus and the thalamus, and containing (2) the vena terminalis (vein of the corpus striatum); (3) the lamina affixa, a medial continuation of the stria terminalis upon the surface of (4) the lateral part of the thalamus; (5) the medial edge of the lamina affixa, the tenia chorioidea, and the choroid plexus continuing under (6) the edge (tenia) of the body and the beginning crura (posterior pillars) of the fornix (fig. 727).

The choroid plexus of the lateral ventricles (figs. 727, 760) is continuous with that of the third ventricle. The choroid tela of the third ventricle (velum interpositum) continues under the tenia of the fornix into the lateral ventricle, and there, along the line of the tenia chorioidea, becomes elaborated into a varicose, convoluted, villus-like fringe, rich in venous capillaries and lymphatics. This fringe is the choroid plexus. It is continuous anteriorly, at the interventricular foramen, with the corresponding plexus of the opposite lateral ventricle and with the choroid plexus of the third ventricle. The latter consists of two similar but smaller fringes, which project close together into the cavity of the third ventricle

from the medial portion of the ventral surface of the choroid tela. Behind, the choroid plexus of the lateral ventricle curves posteriorly and inferiorly into the inferior cornu, being especially well developed at the region of its entrance into the latter, into what is called the **choroid glomus.** It extends into neither posterior nor anterior cornu.

Though apparently lying free in the ventricle, the choroid plexus is invested throughout by a layer of ependyma, the **epithelial choroid lamina,** which is adapted to all its unevenness of surface and which is a continuation of the ependymal lining of the remainder of the ventricle —continuous, on the one hand, with that of the lamina affixa and thalamus, and, on the other, with the epitheloid covering upon the upper surface of the tenia of the fornix and fimbria.

FIG. 727.—HORIZONTAL DISSECTION OF THE CEREBRAL HEMISPHERES.
The fornix has been removed to show the relation of the tela chorioidea of the third ventricle to the choroid plexus of the lateral ventricles. (From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)

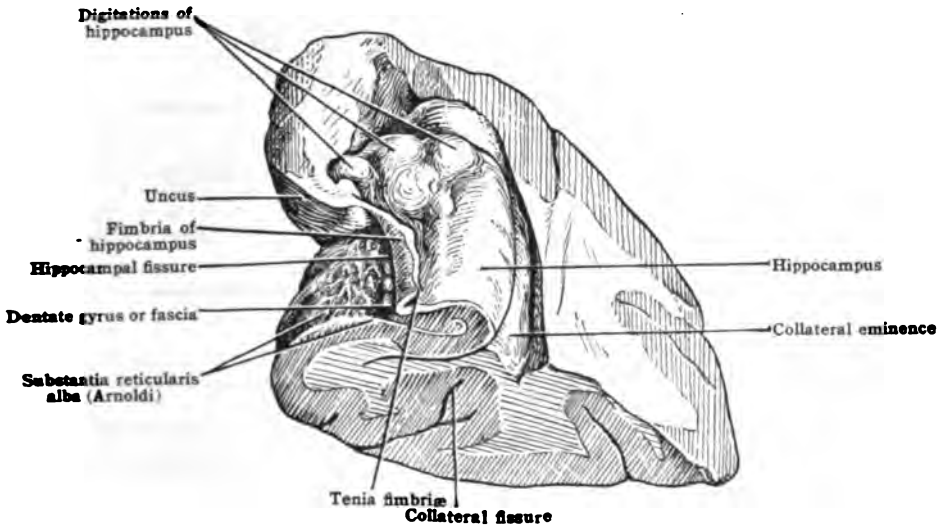


The **posterior cornu** of the lateral ventricle is a crescentic cleft of variable length, convex lateralward, which is carried backward from the posterior end of the body of the ventricle and, curving medialward, comes to a point in the occipital lobe. Its *roof* and *lateral wall* are formed by a portion of the posterior radiation of the corpus callosum, which forms a layer, from its appearance known as the **tapetum.** In transverse sections of the occipital lobe (fig. 736) the tapetum appears as a thin lamina of obliquely cut white substance immediately bounding the cavity, while lateral to the tapetum occurs a thicker layer of more transversely cut fibers, the occipitothalamic radiation. In the medial or *inner wall* of the posterior cornu run two variable longitudinal eminences:—(1) The superior of these is the **bulb of the posterior cornu,** and is formed by the occipital portion of the radiation of the corpus callosum (splenium), which bends around the impression of the deep parieto-occipital fissure, and, hook-like, sweeps into the occipital lobe. In horizontal sections these fibers, together with the splenium and the

similar fibers into the opposite occipital lobe, form the figure known as the **forceps major.** (2) The inferior and thicker of the eminences is the **hippocampus minor** [**calcar avis**] (cock's spur), and is due to the anterior part of the calcarine fissure, by which the wall of the hemisphere is projected into the ventricle. The posterior cornu, like the anterior, is not entered by the choroid plexus.

The inferior cornu.—In its inferior and slightly lateral origin from the region of junction between the body of the ventricle and the posterior cornu, the inferior cornu aids in producing a somewhat triangular dilation of the cavity known as the **collateral trigone.** Beginning as a part of the trigone, the cavity of this cornu at first passes posteriorly and lateralward, but then suddenly curves anteriorly and inferiorly into the medial part of the temporal lobe nearly parallel with the superior temporal sulcus. Above, it follows the curved crura (posterior pillars) of the fornix and fimbria; below, it does not extend to the temporal pole by from 2 to 3 cm. The *roof* and *lateral wall* are, for the most part, like those of the posterior cornu, being formed by the tapetum, but medialward a strip of the roof is formed by the attenuated, inferior prolongation, or tail, of the caudate nucleus, together with the inferior extension of the stria terminalis of the thalamus.

FIG. 728.—DISSECTION OF RIGHT TEMPORAL LOBE SHOWING THE MEDIAL WALL OF THE END OF THE INFERIOR HORN OF THE LATERAL VENTRICLE. (From Spalteholz.)



At the end of the inferior cornu the roof shows a bulging, the **amygdaloid tubercle,** situated at the termination of the tail of the caudate nucleus. This bulging is produced by the *amygdaloid nucleus,* an accumulation of gray substance continuous with that of the cortex of the hippocampal gyrus, and which gives origin to part of the longitudinal fibers coursing in the stria terminalis of the thalamus.

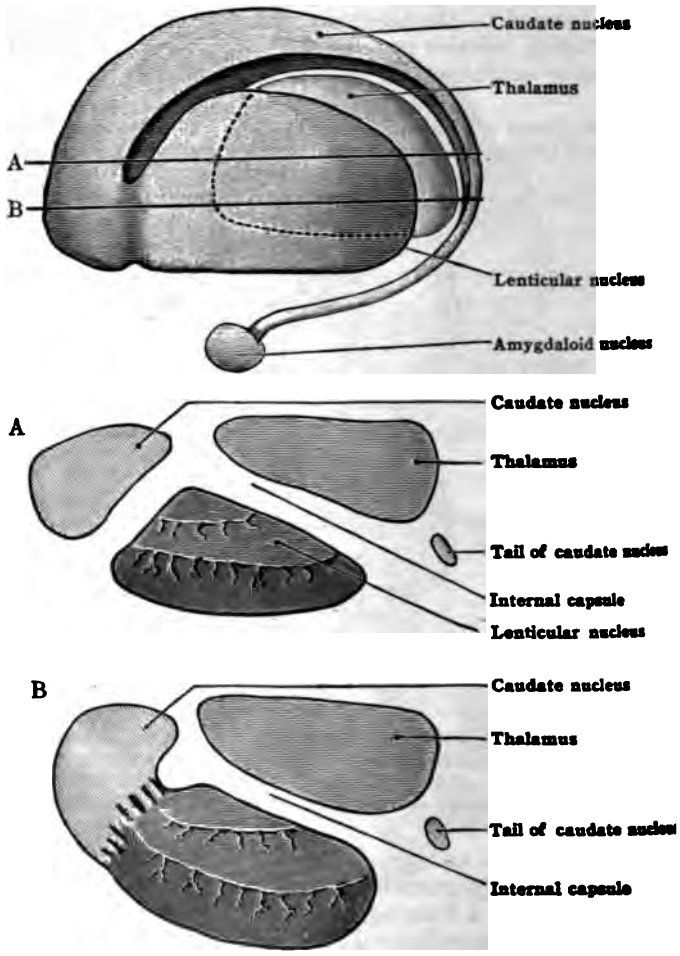
In the *medial wall* and floor of the inferior cornu the following structures are shown:—(1) In the posterior or trigonal part of the floor is the longitudinal **collateral eminence,** a bulging, very variable in development in different specimens, produced by the collateral fissure. This is often pronouncedly in two parts, a posterior prominence corresponding to the middle portion of the collateral fissure and an anterior prominence (less frequent) produced by the anterior part of the fissure. (2) Medial to this eminence lies the inferior extension of the **choroid plexus,** usually more voluminous than the part in the body of the ventricle. (3) Partly covered by the choroid plexus is the **hippocampus major,** a prominent, sickle-like ridge corresponding to the indentation of the hippocampal fissure. It begins as a narrow ridge posteriorly, at the end of the body of the ventricle, as the extension of the crus of the fornix, and expands anteriorly as the ventricular surface of the uncus. Its surface is not regular, but shows a concave medial margin as distinguished from a wider, convex, lateral surface. Its termination in front (*pes hippocampi*) is divided by two or three flat, radial grooves into a corresponding number of short elevations known as the *hippocampal digitations.* It is covered by a thick stratum of white substance, the *alveus,* arising from its

depths and continued mesially into the fimbria. (4) The **fimbria** is so fol that its margin, *tenia fimbriæ*, lies in the cavity of the inferior cornu attac to the choroid plexus and the thin, non-nervous floor of the choroid fissure.

The caudate nucleus (fig. 729).—As realized in the study of the lateral v tricle, the caudate nucleus is a comma-shaped mass of gray substance wit long, much-curved, and attenuated tail. Its *head* forms the bulging lateral w of the anterior cornu; thence it proceeds posteriorly in the lateral wall of the b of the ventricle and, at the collateral trigone, curves downward and its *tail* comes a medial portion of the roof of the inferior cornu. It is separated from

FIG. 729.—DIAGRAMS OF LATERAL VIEW AND SECTIONS OF THE CORPUS STRIATUM WI THE INTERNAL CAPSULE.

A and B below represent horizontal sections along the lines A and B in the figure above. figure also shows the relative position of the thalamus and the amygdaloid nucleus.



thalamus adjacent to it by the stria terminalis of the thalamus (tenia se cularis). The end of its tail extends anteriorly below to the level of the an horn of the ventricle above. Owing to its much curved shape, both hori and vertical sections of the hemisphere passing through the inferior cornu contain the nucleus cut at two places (figs. 731, 735).

The caudate nucleus is the intraventricular of the two masses of gray sub which together are sometimes referred to as the **basal ganglia.** The ext tricular of these masses is the *lenticular nucleus*, which is buried in the sub of the hemisphere, laterally and inferior to the caudate nucleus. The two a are separated by the *internal capsule*, a thick band of nerve-fibers continuou the cerebral peduncles, and connecting the gray cortex of the hemisphere w structures inferior to it. Anteriorly and below, the two nuclei become conti

hite substance of the internal capsule, in separating them posteriorly, butes to the striated appearance in sections, known collectively as the *corpus m* (figs. 730–735). The corpus striatum as such is described below.

INTERNAL STRUCTURE OF THE PROSENCEPHALON

om the above examinations of their external and ventricular surfaces, it is nt that the cerebral hemispheres consist of a folded, external mantle of bstance, the cortex cerebri, spread more or less evenly over an internal mass te substance which contains embedded within it certain masses of gray sub-, the chief of which are known as the caudate and lenticular nuclei of the striatum. In addition, the hemispheres of the telencephalon overlie and functional connection with the structures of the diencephalon below, the f which are the thalamencephalon and the bases of the cerebral peduncles.

e gray substance of the telencephalon.—The gray substance is in intimate n with the white substance, and in fact its cells give origin to the greater f the fibers composing the white substance. The accumulations of gray nce to be considered are the cerebral cortex, with its variations in thickness rrangement, the corpus striatum, the claustrum, and the amygdaloid s.

e cerebral cortex [substantia corticalis] is distributed over the entire surface hemisphere except the peduncular region of the base and the region of the callosum and fornix of the medial surface. Numerous measurements een made to determine its average thickness. These have shown that the e is not uniformly distributed:—(1) that it is thicker on the convex surface n the basal and medial surfaces; (2) that on the convex surface it is thicker central region of the hemisphere, somesthetic area, than at the poles; (3) the average normal specimen it averages somewhat thicker on the left than right hemisphere; (4) that its average thickness varies greatly in different luals, and that the thickness decreases with old age; (5) that it is probably hat thicker in males than in females, and (6) that in a given specimen it es thicker on the summits of the gyri than in the floor of the corresponding

he normal adult conditions it averages about 4 mm. thick on the anterior and posterior gyri, in the somesthetic area, while it attains its mimimum thickness of about 2.5 mm. basal surface of the occipital and frontal lobes. Its total average thickness is about 2.9 The lamina of the septum pellucidum and the practically non-nervous floor of the third le and that of the choroid fissure are very much thinner. The cortex of the (more) rhinencephalon is termed the *archipallium;* while the remaining cortex of the telence- is the *neopallium.*

cerebral cortex consists of layers of the cell-bodies of neurones, chiefly of the pyramidal g. 647), which receive impulses from the structures below and from other regions of the by way of fibers reaching them through the internal mass of white substance, and which contribute fibers to the white substance. Certain fibers of shorter course and numerous al branches of fibers passing out of the cortex are devoted to the association of the region origin with the cortex of the immediate vicinity of their origin, and most of these course the gray cortex itself. In certain gyri, such as the anterior central gyri and those of the surface of the occipital lobe, these short association fibers accumulate into strata, and cal sections give the cortex a stratified appearance. Two such strata of white substance noted in the above localities, one lying about midway in the thickness of the cortex and htly internal to this. They are known as the inner and outer **stripes of Baillarger.** In n, a thin, superficial or *tangential layer* of fibers may often be distinguished lying in the of the cortex. Transverse sections through the anterior end of the hippocampus show l arrangement of the layers of white substance, to which has been given the name *cornu is.* The peculiar structure and appearance of the olfactory bulb and tract, parts of tex, have already been mentioned.

e corpus striatum is so called on account of the appearance in section of nponent parts, the caudate and lenticular nuclei (basal ganglia) and the al capsule between them. The two nuclei are directly continuous with ther at their anterior ends (fig. 729), and in addition they are connected by ous small bands of gray substance which pass from one to the other through ternal capsule, especially its anterior part. Also each nucleus contributes ous fibers to, and receives fibers from, the internal capsule. These bundles rs both arising and terminating within the nuclei, together with the gray nce among the fibers of the capsule, produce the ribbed and striped appear- uggesting the name, corpus striatum. The **caudate nucleus**—the intra-

ventricular part of the corpus striatum—lies with its thicker anterior part (he... closely related to the internal capsule, but its tail passes posteriorly around t... posterior border of the capsule and curves downward and anteriorly into the ro... of the inferior cornu of the lateral ventricle.

The lenticular nucleus [nucleus lentiformis]—the extraventricular part o... the corpus striatum—is embedded in the white substance of the cerebral hemi... sphere. It is somewhat pyriform in shape, not being so long as the caudate... nucleus, and neither having a tail nor extending so far anteriorly. Its lower sur... face is separated from the inferior cornu of the lateral ventricle by the white sub... stance of the roof of that cornu and by the tail of the caudate nucleus, and, fur... ther forward, the anterior commissure passes through its base. Its lateral sur... face is rounded and conforms both in extent and curvature with the surface of the insula, from which it is separated by the fibers of the external capsule and the intervening claustrum. Its oblique superior and medial surface is adapted to the lateral surface of the internal capsule, and it comes to a rounded apex in the angle formed by the internal capsule and a plane parallel with the base of the hemi... sphere. In both horizontal and coronal (transverse) sections through its middle it resembles a compound biconvex lens. Internally this appearance is produced by two vertically curving lamina of white substance, an **external** and an **internal medullary lamina,** which divide its substance into three zones:—the two medial zones together form an area, triangular in section, known as the **globus pallidus;** the lateral, larger and more gray, concavoconvex zone is the **putamen** (figs. 730–732). Radiating fibers from the medullary lamina extend into the zones, especially those of the globus pallidus. These zones disappear in transverse sections of the anterior portion of the lenticular nucleus on account of the fact that the larger putamen alone comprises this portion and alone becomes continuous with the caudate nucleus. (See figs. 729, 733.)

Connections.—Both nuclei of the corpus striatum become continuous with the cortex in the region of the anterior perforated substance, and the putamen of the lenticular nucleus may blend with the anterior part of the base of the claustrum. The following are the principal fiber connections:—(1) Fibers arising in the nuclei which join the internal capsule to reach the cerebral cortex, and fibers arising in the cortex which descend by the same course to the cells of the nuclei. (2) Fibers which pass in both directions between the thalamus and the corpus striatum (caudate nucleus especially). These are more abundant anteriorly, and necessarily pass in the internal capsule. (3) The **ansa lenticularis,** or striosubthalamic radiation, a usually distinct lamina, composed largely of fibers passing inferiorly between the thalamus and lenticular nucleus. It passes from the basal aspect of the anterior tubercle of the thalamus and curves below through the internal capsule to the basal surface of the lenticular nucleus, and there its fibers are distributed upward through its medullary lamina to the globus pallidus and putamen. Some enter the internal capsule and reach the cortex, chiefly that of the temporal lobe. The ansa lenticularis also contains fibers from the cortex of the temporal lobe to terminate in the inferior and medial parts of the thalamus. The fibers associating the thalamus with the temporal lobe belong to the so-called *inferior peduncle of the thalamus.* (4) Fibers connecting both nuclei (chiefly the lenticular) with the red nucleus and substantia nigra of the mesencephalon. These pass through the hypothalamic region and along the cerebral peduncle.

No definitely localized functions have been with certainty ascribed to either nucleus of the corpus striatum. They serve as relays in the pathways associating the cortical gray substance with the structures below. It is held that some of the descending motor fibers arising from the cells of the cortex give off collaterals, in passing, to the cells of the nuclei and these give fibers which join the internal capsule and cerebral peduncles, increasing the number of fibers bearing impulses from the cortex to the mesencephalon, rhombencephalon and spinal cord. This would make the functions of the nuclei subsidiary to those of the cerebral cortex. In lower vertebrates, the corpus striatum is an important reflex center. Phylogenetically, the globus pallidus is the most primitive portion, and in mammals fibers arising therein may descend to exert control over skeletal muscular activity (S. A. K. Wilson), via the red nucleus (striorubral tract).

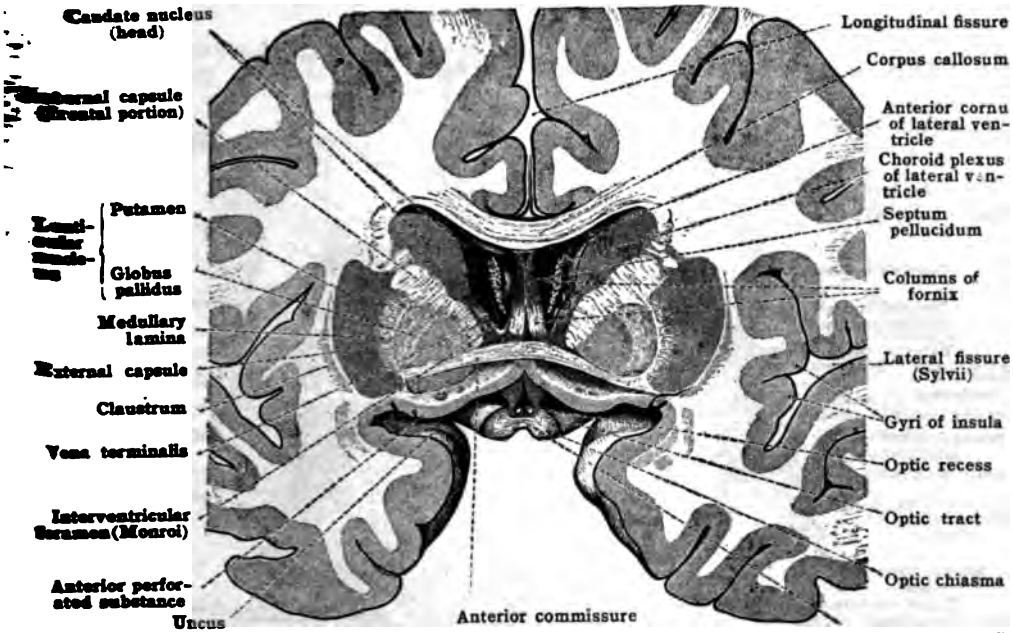
The claustrum is a triangular plate of gray substance which is embedded in the white substance between the lenticular nucleus and the cortex of the insula. Its medial surface is concave, conforming to the convexity of the putamen. The sheet of white substance intervening between it and the putamen is known as the **external capsule.**

The lateral surface of the claustrum shows ridges in section which conform to the neighboring gyri of the insula, and it is spread through a region which quite closely coincides with the area of the insula. Below and anteriorly it becomes continuous with the cortex of the anterior perforated substance and with the lenticular nucleus at the region of the junction of these. Above and posteriorly it gradually becomes thinner, and finally disappears in the white substance about it. In origin it is thought to be a detached portion of the cortical gray substance of the insula.

The amygdaloid nucleus [nucleus amygdalæ] is represented by the amygdaloid tubercle, which has already been described in the extremity of the inferior horn of the lateral ventricle (figs. 707 and 729). It is an almond-shaped mass of gray joined to the tail of the caudate nucleus, continuous above with the putamen and anteriorly continuous with the cortex of the hippocampal gyrus.

The chief connections of the amygdaloid nucleus by way of the *stria terminalis of the thalamus* are noted above under the description of the posterior division of the rhinencephalon. The amygdaloid nucleus, like the claustrum, is thought to represent a detached portion of the cortex, having detached from the uncus. Considering this and its chief connections, it, with the stria terminalis of the thalamus, are concerned in the central portion of the olfactory apparatus.

FIG. 730.—CORONAL SECTION OF TELENCEPHALON THROUGH THE ANTERIOR COMMISSURE, OPTIC CHIASMA AND BODY OF CORPUS CALLOSUM. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



The thalamus and hypothalamus.—The external features of these portions of the prosencephalon have been described previously, but inasmuch as they contain the chief relays between the telencephalon and the divisions of the nervous system caudal to the prosencephalon, the consideration of their internal structure has been deferred until now. The principal gray masses to be considered are the thalamus and the hypothalamic nucleus. The structures comprising the metathalamus and epithalamus have already been mentioned in their relations with the mesencephalon and the optic and auditory apparatus.

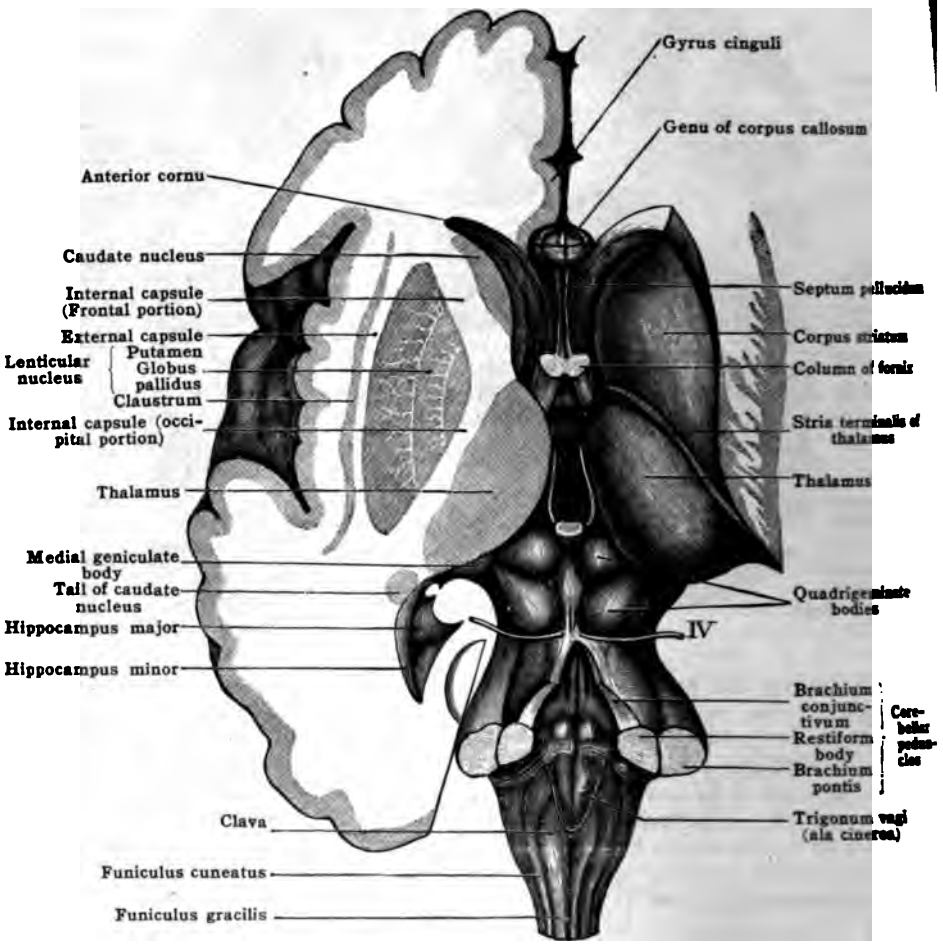
The thalamus has upon its upper surface, under its ependyma, a thin **stratum zonale** of white substance, derived in part from the incoming fibers but chiefly from its own cells. Its oblique lateral surface conforms to the medial surface of the internal capsule; its vertical medial surface forms the lateral wall of the third ventricle, and below it is continuous into the hypothalamic (tegmental) region and the hypothalamic nucleus. Its upper surface shows a middle, an anterior, and a posterior prominence or tubercle. The **anterior tubercle** (nucleus) forms the posterior boundary of the interventricular foramen; the posterior tubercle is the cushion-like **pulvinar** which projects backward over the lateral geniculate body and the brachium of the superior quadrigeminate body.

A horizontal section through the superomedial edge, splitting the stria medullaris of the thalamus and thus passing above the massa intermedia, shows the gray mass of the thalamus divided into segments or nuclei by a more or less distinct **internal medullary lamina.** This extends the whole length of the thalamus, dividing its middle and posterior portion into the medial and the **lateral nucleus.**

Anteriorly the lamina bifurcates into a medial limb, extending to the medial face of the thalamus, and a lateral limb, extending forward to join the genu of the internal capsule (figs. 732, 733). This bifurcation results in a cup-like sheet of white substance which encloses the **anterior nucleus.** On the lateral surface of the section, next to the internal capsule, there may usually be distinguished the **external medullary lamina,** separated from the white substance of the capsule by a *reticular layer* of mixed white and gray substance.

The anterior nucleus, lying partially encapsulated in the bifurcation of the internal medullary lamina, is somewhat wedge-shaped and points backward between the anterior portions of the lateral and medial nuclei.

FIG. 731.—HORIZONTAL DISSECTION SHOWING THE GRAY AND WHITE SUBSTANCE OF THE TELENCEPHALON BELOW THE CORPUS CALLOSUM AND THE RELATIVE POSITION OF THE THALAMENCEPHALON. (After Landois and Stirling.)



It is composed chiefly of large cells, and constitutes the anterior tubercle of the superi aspect. Its principal connection from below is with the nuclei of the mammillary body of t same and opposite sides, and chiefly with uninterrupted fibers derived from the form The fibers from both sources enter it by way of the *mammillothalamic fasciculus* (figs. 711 a 732). The significance of this connection is mentioned in the description of the limbic lob

The lateral nucleus, lying between the external and internal medullary lam inæ, extends posteriorly to include the **pulvinar, which latter, however, is oft** called the posterior nucleus of the thalamus.

The neurones of the anterior portion of the lateral nucleus (**lateral nucleus proper**), togeth with the entire inferolateral gray substance of the thalamus, receive the terminations of t spinal, medial and trigeminal lemnisci and thus serve as the third links in the neurone cha bearing sensory impulses from the general body to the cerebral cortex. The lateral nucle also especially receives fibers inferiorly from the red nucleus and from the brachium conju

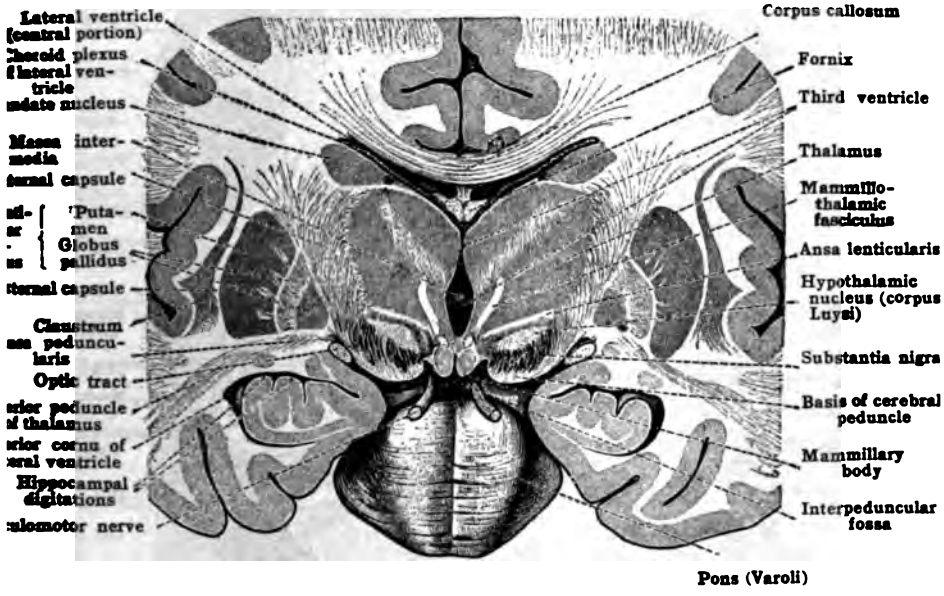
direct. The pulvinar, as already noted, together with the lateral geniculate body, con- the prosencephalic nucleus of termination of the optic tract, and the stratum zonale the surface of this nucleus might be called the stratum opticum.

The medial nucleus lies medial to the internal medullary lamina and forms the erior portion of the lateral wall of the third ventricle. It is shorter than the ral nucleus, and is less extensively pervaded by fibers.

s inferior part is thought to receive fibers from the three lemnisci, trigeminal especial y, to send fibers to the cortex. Its dorsal part receives fibers from the olfactory areas of the x and contributes fibers to the medullary stria of the thalamus and probably some to the x. It is usually continuous across the third ventricle with the opposite medial nucleus by massa intermedia.

In comparative anatomy, the nuclei of the thalamus have been variously subdivided by different investigators. All the nuclei are connected with the lenticular nucleus by fibers ing between the two through the internal capsule directly, and by fibers curving from below, fly from the anterior, lateral and medial nuclei, and passing in the ansa lenticularis.

. 732.—Coronal Section of Prosencephalon through Thalamencephalon at Region of Corpora Mammillaria. (Seen from in front.) (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



The cortical connections of the thalamus are abundant. They consist of fibers th to and from the cortex of the different lobes of the hemisphere, the greater rt arising in the thalamus and terminating in the cortex. These fibers collect the internal and external medullary lamina and the stratum zonale; most of em enter the internal capsule and thence radiate to the different parts of the rtex. Carrying sensory impulses to the cortex received from sensory neurones low, these thalamocortical fibers are the *sensory projection fibers* of the brain.

They form the so-called peduncles of the thalamus, which have been distinguished both by Flechsig method of investigation and by the degeneration method. The anterior or **frontal luncle** passes from the lateral and anterior part of the thalamus through the frontal portion the internal capsule, and radiates to the cortex of the frontal lobe (fig. 737). The idle or **parietal peduncle** passes from the lateral surface of the thalamus through the inter- diate part of the internal capsule, and upward to the cortex of the parietal lobe. The pos- ior or **occipital peduncle** passes chiefly from the pulvinar, through the occipital portion of the ernal capsule, and radiates backward to the occipital lobe by way of the occipitothalamic otic) radiation (fig. 736). The **inferior peduncle** passes from the medial and basal surface the thalamus (from the anterior and medial nuclei chiefly), turns outward to course beneath lenticular nucleus, and radiates to the cortex of the temporal lobe and insula. The fibers this peduncle course chiefly in the ansa lenticularis (fig. 732). Some turn upward in the ernal capsule to reach the cortex above the insula; others pass upward through the medullary ainæ of the lenticular nucleus.

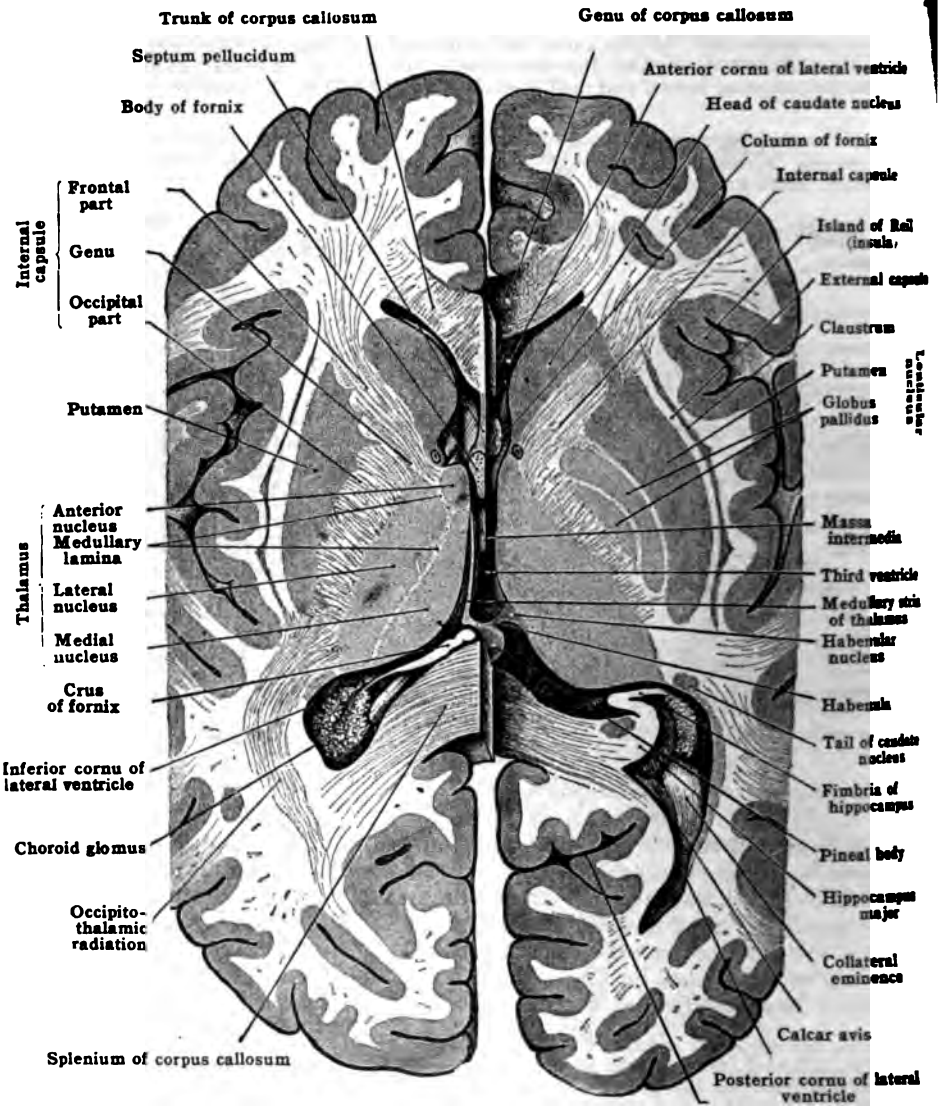
The nuclei of the thalamus without doubt serve chiefly as relays in the sensory paths, both neral and special, from the periphery of the body to the cerebral cortex. By the several minal branches of each of the visiting fibers making synapses with the thalamic neurones,

the sensory impulses are not only reinforced by the transfer but also the number of neuro bearing them to the cortex is increased in the thalamus.

From the viewpoint of comparative anatomy, the larger, lateral portion of the thalam or *neothalamus*, including the pulvinar and the lateral and medial geniculate bodies (detach portions of the thalamus), is considered especially concerned in such relays. In the lower fo having little or no cerebral cortex, the medial portion of the thalamus persists and serves for t mediation of primitive reflex activities. In man, clinical evidence collected by Head a

FIG. 733.—HORIZONTAL SECTIONS OF THE PROSENCEPHALON THROUGH THE THALAMUS AN CORPUS STRIATUM.

The plane of the section of the left hemisphere splits the medullary stria of the thalamus abo 15 mm. above the plane through which the right hemisphere is cut (After Toldt.)



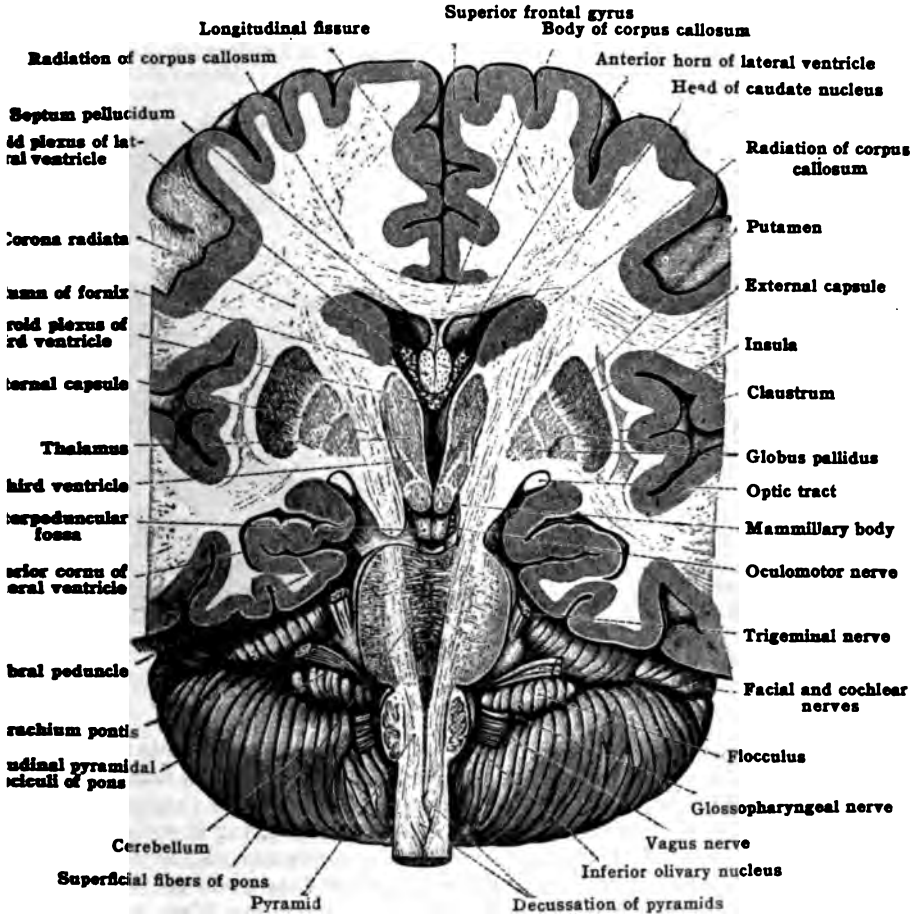
Holmes and others seem to suggest that some of these primitive reflex functions may be r tained in the medial portion; but further, the interesting inference is possible that some acti ities usually classed as conscious may be mediated by the thalamus, the cerebral cortex b being essential for them. In other words, the thalamus divorced from the cerebral cortex b destructive lesions, seems able to mediate activities in response to sensations of pleasure a pain. The participation of the cerebral cortex, however, seems especially necessary for analytical, or so-called intellectual and voluntary activities. Such functions of the thalam give the thalamospinal fasciculus greater functional significance than is usually attributed to

The hypothalamic nucleus (body of Luys, subthalamus) **(fig. 732) is a biconv** plate of gray substance situated on the basal aspect of the lateral and anteri

ei of the thalamus, and between these and the basis of the cerebral peduncle. the anterior continuation of the substantia nigra, which is spread upon the al surface of the peduncle, and which, though greatly diminished, extends into hypothalamic region. It is referred to as the hypothalamic nucleus as far eriorly as the posterior commissure. It presents a brownish-pink color esh material, due to pigment in its cells and to its abundant blood-capillaries.

is enclosed by a thin capsule of white substance, some of the fibers of which seem to decuss- ith those of the opposite side in the floor of the third ventricle, above and just behind the of the corpora mammillaria. It is said to receive fibers descending from the cortex and from the thalamus and nuclei of the corpus striatum. Most of the fibers arising from

734.—Oblique Frontal Section through the Brain in the Direction of the Cerebral Peduncles and the Pyramids. (Seen from in front.) (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



n the cerebral peduncle. Such relations would suggest that the hypothalamic nucleus s as a relay in certain paths from the cortex and striate body to the structures below. On ther hand, until recently it was considered the chief nucleus of termination of the medial iscus.

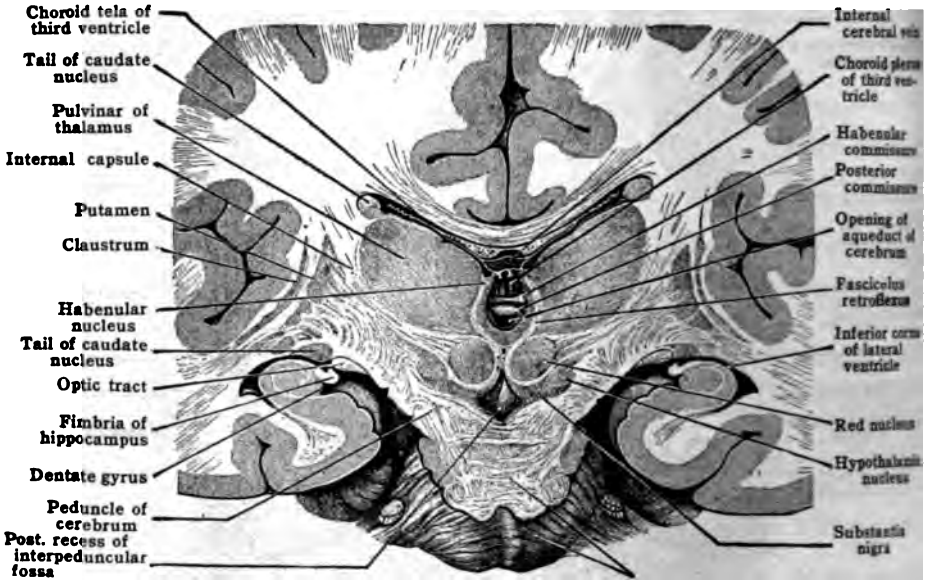
he *habenular nucleus* and the *fasciculus retroflexus* of Meynert have been noted in the de- tion of the rhinencephalon. The **habencular nucleus**, a part of the epithalamus, is a small of nerve cells situated in the habenular trigone just inferolateral to the pineal body. Some of the medullary stria of the thalamus (habenula) terminate about its cells. A small le of fibers crossing the midline under the pineal body in the superior aspect of the posterior ral commissure is called the *commissure of the habenulæ*, from the fact that it contains fibers lating the habenular nuclei of the two sides.

he **fasciculus retroflexus** (**Meynerti**) (tractus habenulopeduncularis) is a relatively strong le of fibers which runs downward and then turns caudalward from the habenular nucleus rd the inferior portion of the interpeduncular fossa. It has been shown that many, at of the fibers of this bundle arise from the cells of the habenular nucleus. In its slightly al course, the bundle passes obliquely through the red nucleus, entering the medial superior t and making its exit from the medial side of the inferior extremity of this nucleus. In the

animals in which it has been studied, the bundle ends in the *interpeduncular nucleus* (ganglion), a group of nerve cells lying in the floor of the interpeduncular fossa at the level of the inferior quadrigemina. In man, the interpeduncular nucleus is not definitely assembled and the bundle seems to disappear in the posterior perforated substance. However, the microscope shows nerve cells dispersed among the fibers of the bundle and these cells probably represent the nucleus. Impulses borne by the fasciculus are presumably transmitted to the cranial and spinal nerves.

The white substance of the telencephalon.—A horizontal section through the upper part of the body of the corpus callosum will pass above the basal gray substance of the corpus striatum, and, aided by the corpus callosum, each hemisphere in such a section will appear as if consisting of a solid, half-oval mass of white substance, bounded without by the gray layer of the cortex (fig. 712). As seen at this level, the white substance of each hemisphere is known as the **centrum semiovale.** Horizontal sections passing below the body of the corpus callosum involve the corpus striatum and thalamus, and the appearance of the white substance is modified accordingly (fig. 731).

FIG. 735.—CORONAL SECTION OF BRAIN PASSING THROUGH THE PULVINAR OF THE THALAMUS AND THE UNCUS OF THE HIPPOCAMPAL GYRUS. (After Toldt.)



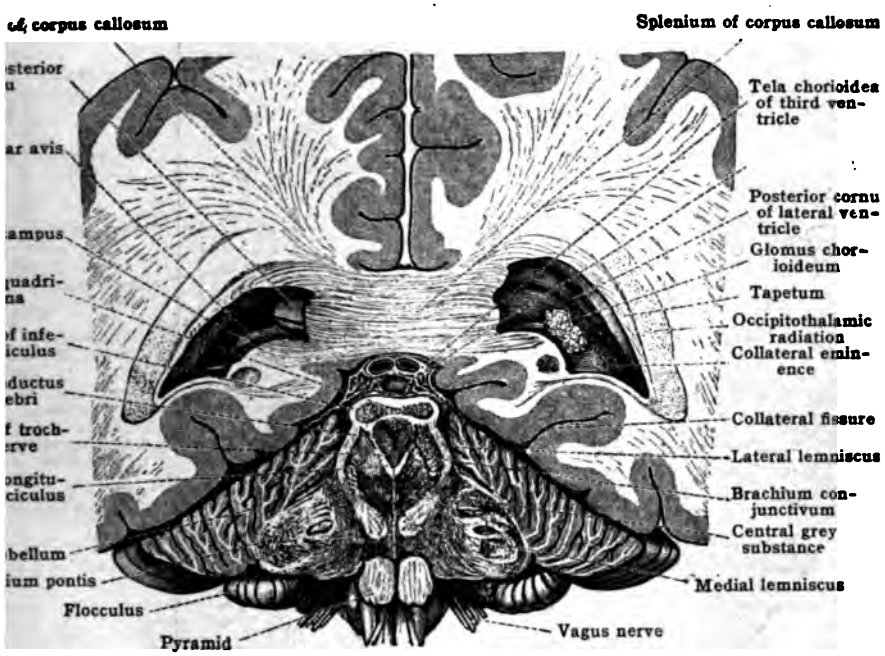
In the white substance of the cerebral hemispheres as a whole three main systems of fibers are recognized:—projection fibers, commissural fibers, and association fibers. The *projection fibers* are those of a more or less vertical course, which pass to and from the cortex of the hemisphere, associating it with the structures below the confines of the hemisphere. The *commissural fibers* are those of transverse or horizontal course, which cross the midline and functionally correlate the two hemispheres with each other. The *association fibers* are those which neither cross the midline nor pass beyond the bounds of the hemisphere in which they arise, but instead associate the different parts of the same hemisphere—lobe with lobes and gyri with gyri. The fibers which associate the cortex with the nuclei of the corpus striatum must also be classed as association fibers, since the masses of gray substance are a part of the telencephalon, while by definition those which associate the thalamus and hypothalamus with the cortex belong to the projection system. Some of the fiber bundles of the above systems have already been described in connection with the parts with which they are concerned.

The projection fibers of the hemisphere comprise both ascending and descending fibers between the cerebral cortex and structures below the bounds of the hemisphere proper, i.e., some arise in the structures below and terminate in the cortex, others arise from the cortical cells and terminate in the structures below, including the gray substance of the thalamencephalon, mesencephalon, rhombencephalon and spinal cord. The projection fibers are given different names in the hemi-

according to their arrangement and the appearances to which they con- in the dissections. Beginning with the pyramidal fasciculi and the basis peduncle, they contribute fibers (both sensory and motor)—(1) to the *l capsule* and some to the *external capsule* and (2) to the *corona radiata.*

internal capsule [capsula interna] is a band of white substance, consisting scending fibers from the nuclei of the thalamus, hypothalamus, and corpus n, reinforced by the descending fibers from the cortex to these nuclei and e descending in the cerebral peduncle to terminate in the mesencephalon, ncephalon and spinal cord. It is a broad, fan-like mass of fibers, which es in width from the base of the hemisphere upward, and which is spread n the lenticular nucleus on its lateral aspect and the caudate nucleus and us on its medial side. To reach the cortex above, the course of its fibers rily intersects that of the radiations of the corpus callosum, and thus,

5.—Coronal Section through the Splenium of the Corpus Callosum and the terior Cornua of the Lateral Ventricles. (Viewed from behind.) (After Toldt, as of Human Anatomy,' Rebman, London and New York.)



er with the corpus callosum, the fan-like bands of the two hemispheres form ile containing the thalami, the third ventricle, the caudate nuclei, and the r and central portions of the lateral ventricles. In horizontal sections, ternal capsule appears bent at an angle, the **genu,** which approaches the of the lateral ventricle along the line of the boundary between the thalamus e caudate nucleus. Along the genu runs the stria terminalis of the thala- nd through the genu the capsule receives fibers from the internal medullary of the thalamus, from the stratum zonale of the thalamus and from that caudate nucleus. At the genu each capsule is separable into two parts:— **anterior (frontal) portion,** spreading between the caudate and lenticular (2) the **posterior (occipital) portion,** between the lenticular nucleus and the us (fig. 737).

tionally, the internal capsule may be divided into a frontal, a frontoparietal and an l part.

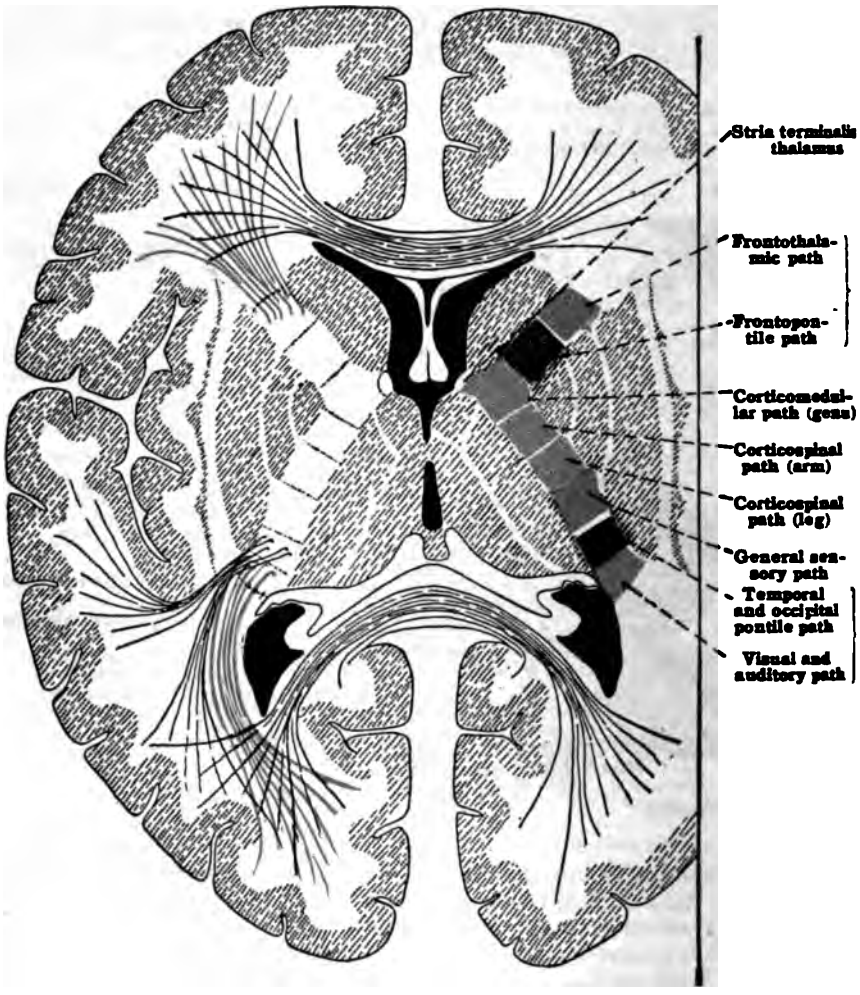
frontal part consists of (1) an *anterior segment,* carrying chiefly fibers coursing in both s between the thalamus and the cortex of the frontal lobe, and (2) a *posterior segment* the frontopontile tract.

frontoparietal part may be considered in four segments:—(1) An anterior segment, , carrying impulses from the cortex to the nuclei of the motor cranial nerves; (2) pos- this is the *corticospinal segment for the arm and thorax,* descending cortical fibers to the ord; also the *corticorubral tract;* (3) next is the *corticospinal segment for the lower*

extremity; (4) a posterior segment carrying the *general sensory path* ascending from th lateral part of the thalamus and the red nucleus to the cortex. All the segments of t parietal part carry in addition, fibers in both directions between the cortex above thalamus and the nuclei of the striate body.

The occipital part consists (1) of an anterior segment which carries the descending *and occipital pontile paths*, and (2) a posterior segment carrying the *visual fibers* be occipital cortex and the nuclei of termination of the optic nerve. This segment also c *auditory fibers* passing to the cortex of the superior temporal gyrus from the r termination of the lateral lemniscus. Thus this segment carries a visual and an audit

FIG. 737.—DIAGRAM TO INDICATE THE TOPOGRAPHY OF THE PROJECTION FIBERS IN TH NAL CAPSULE. (In part after Villiger.)



The corona radiata.—Above the corpus callosum and laterally jo radiations, the fibers of the internal capsule are dispersed in all directio appearance known in coronal sections of the hemispheres as the corona produced by the ascending and descending fibers of the internal capsule with the radiations of the corpus callosum. The radiations related to th capsule may be divided into a frontal, a parietal and an occipital pa sponding to the frontal, parietal and occipital peduncles of the thalamus parts of the internal capsule.

The radiation derived from the posterior segment of the occipital pa internal capsule, the visual path, accumulates into a well-defined band which passes posteriorly into the occipital lobe, spreading in the lateral w posterior cornu of the lateral ventricle immediately lateral to the tapetu band consists for the most part of fibers arising in the pulvinar of the thal in the lateral geniculate body and going to the visual area of the occipit

and of fibers arising in this cortex to terminate in the thalamus and mesencephalon. Being thus concerned with the optic apparatus, it is known as the **occipitothalamic radiation** or **optic radiation** (fig. 736).

The external capsule is, as already noted, a thin sheet of white substance spread between the claustrum and the lenticular nucleus.

It owes its appearance as such to the presence of the claustrum. It joins the internal capsule at the upper, posterior, and anterior borders of the putamen, and below the claustrum it is continuous with the general white substance of the temporal lobe. Thus it contributes to an encapsulation of the lenticular nucleus by white substance. Most of the fibers contained in it belong to the association system. Its projection fibers consist of those of the inferior peduncle of the thalamus, which pass from the basal surface of the thalamus and, instead of continuing below to the cortex of the temporal lobe and insula, turn upward, around the lenticular nucleus to the cortex above the insula. Some of these thalamic fibers are known to pass upward through the lamina of the lenticular nucleus instead of through the external capsule.

The ascending projection fibers arise mostly from the cells of the nuclei of the thalamus; some arise from nuclei in the mesencephalon and from the red nucleus. They may be summarized as follows:—

(1) *The terminal part of the general sensory pathway of the body.* The portion of the medial lemniscus which arises in the nuclei of the fasciculus gracilis and cuneatus, of the opposite side, and the 'spinal lemniscus' (thalamospinal fasciculi), arising in the opposite side of the spinal cord, terminate in the ventral and lateral gray substance of the thalamus. The projection fibers given off by this pass chiefly through the posterior segment of the frontoparietal part of the internal capsule and radiate to and terminate in the somesthetic area of the cortex, chiefly in the posterior central gyrus. Some few may pass outside around the lenticular nucleus, and ascend by way of the external capsule.

(2) *The terminal part of the general sensory pathway of the head and neck.* The nuclei of termination of the sensory portions of the crainal nerves of the rhombencephalon (except the nuclei of the cochlear nerve) give fibers which course upward in the medial lemniscus (fillet) and reticular substance of the opposite side and terminate in the inferolateral portions of the thalamus. Thence arise projection fibers which ascend to the somesthetic area by practically the same route as those of the general sensory system for the body. A large portion of this part of the medial lemniscus arises from the nucleus of termination of the trigeminal nerve and is known as the *'trigeminal lemniscus.'*

(3) *The terminal part of the auditory pathway.* The ventral and dorsal nuclei of termination of the cochlear nerve send impulses which, by way of the lateral lemniscus, are distributed to the inferior quadrigeminate body, the medial geniculate body, and the nucleus of the lateral lemniscus of the opposite side. These nuclei send projection fibers through the posterior segment of the frontoparietal part of the internal capsule, and thence by the temporal portion of the corona radiata to the cortex of the superior temporal gyrus (auditory area). Probably some of these fibers pass by way of the inferior peduncle of the thalamus. Some of the fibers arising in the nuclei of termination of the vestibular nerve convey impulses which reach the somesthetic area, but the origin of the terminal portion of this system is uncertain.

(4) *The terminal part of the visual pathway.* The cells of the pulvinar and the lateral geniculate body, serving as nuclei of termination of the optic tract, give off projection fibers which pass by way of the posterior segment of the occipital portion of the internal capsule and the occipitothalamic radiation to the cortex of the occipital lobe, chiefly the region about the posterior end of the calcarine fissure—the visual area.

(5) *The terminal ascending cerebellar pathway.* The fibers of the brachium conjunctivum, after decussating, terminate both in the red nucleus and in the lateral nucleus of the thalamus. Some fibers from the red nucleus become projection fibers direct, others terminate in the medial and anterior portion of the lateral nucleus of the thalamus. From the thalamus the projection fibers of this system pass in the peduncles of the thalamus to the somesthetic area and general cortex, that of the frontal lobe especially.

The descending projection fibers arise as outgrowths of the pyramidal cells of the cerebral cortex. Practically all of them cross to the opposite side in their descent to the structures of the rhombencephalon and spinal cord. The majority of them arise near and within the gyri in which the respective ascending fibers terminate. Those transmitting cortical impulses to the cells giving origin to the motor fibers of the cranial and spinal nerves arise chiefly from the giant pyramidal cells of the precentral (anterior central) gyrus, the paracentral lobule and the posterior ends of the superior, middle, and inferior frontal gyri. These latter occupy nearly three-fourths (the anterior three segments) of the frontoparietal part of the internal capsule and the middle three-fifths of the basis of the cerebral peduncle, and are usually called *pyramidal* fibers (fig. 737).

The principal descending projection fibers may be grouped as follows:

(1) **The pyramidal fibers to the spinal cord** (corticospinal or pyramidal fasciculi proper). These arise from the giant pyramidal cells of the upper two-thirds of the precentral gyrus, the anterior portion of the paracentral lobule and the posterior third of the superior frontal gyrus. Those for the lumbosacral region of the spinal cord arise nearest the superomedial border of the cerebral hemisphere. The tract descends through the two middle segments of

the frontoparietal part of the internal capsule. Those carrying cortical impulses f muscles of the arm and shoulder course in the segment anterior to the course of those muscles of the leg. Both continue through the cerebral peduncles and the pons and th the pyramids of the medulla, and then decussate, passing down the spinal cord to ter about the ventral horn cells (the origin of the motor nerve roots) of the opposite side.

(2) **The pyramidal fibers to the nuclei of origin of the motor cranial nerves** aris the pyramidal cells in the inferior third of the precentral gyrus, the posterior end of the i frontal gyrus, the opercular margin of the posterior central gyrus, and probably some (movements) in the posterior end of the middle frontal gyrus. The locality of the or the pyramidal fibers terminating in the nuclei of the facial and hypoglossal nerves only h determined with certainty. The general tract passes in the genu of the internal c through the cerebral peduncle, and gradually decussating along the brain stem, termi the nuclei of the motor cranial nerves of the opposite side.

(3) **The frontal pontile path** (Arnold's bundle) arises in the cortex of the fronta anterior to the precental gyrus, descends through the frontal part of the corona radia posterior segment of the frontal portion of the internal capsule into the frontomedial por the cerebral peduncle, and terminates in the nuclei of the pons.

(4) **The temporal pontile path** (Türk's bundle) arises in the cortex of the superior and temporal gyri, passes through the posterior segment of the occipital part of the internal c enters the cerebral peduncle posterolateral to its pyramidal portion, and terminates nuclei of the pons. An occipitopontile path is described as arising in the occipital cor joining the temporal pontile path in the internal capsule to pass to the nuclei of the

(5) **The occipitomesencephalic path** (Flechsig's secondary optic radiation) arises cortex of the visual area of the occipital lobe (cuneus and about the calcarine fissure). forward through the occipitothalamic radiation, downward in the posterior segment occipital portion of the internal capsule, and terminates in the nucleus of the superior geminate body and the lateral geniculate body. It is probable that some of its fibers ter directly in the nuclei of the eye-moving nerves.

Those **fibers of the fornix** which arise in the hippocampus and terminate in the mammillare or pass through to the anterior nucleus of the thalamus of the same and c side (mammillothalamic fasciculus) or pass into the mesencephalon and probably to str lower down.

In the frontal part of the internal capsule fibers are said to course in both directions b the medial nucleus of the thalamus and the cortex of the frontal lobe. And in the fronto part of the capsule a tract is claimed to descend from the motor area of the cortex to term the red nucleus—a *'corticorubral tract.'* As noted in preceding paragraphs, some of th descending from the cortex are thought to make synapses in the corpus striatum, hypo nucleus and substantia nigra.

The commissural system of fibers.—The commissural fibers of the telen lon serve to connect or correlate the functional activities of one hemi with those of the other. They consist of three groups:—The corpus cal the anterior commissure and the hippocampal commissure.

(1) The **corpus callosum,** the great commissure of the brain. A general descri this with the medial and lateral striæ running over it has already been given. It is a thi of white substance, about 10 cm. wide, which crosses between the two hemispheres at the of the longitudinal fissure. Its shape is such that in its median sagittal section its p given the names *splenium, body, genu,* and *rostum* (figs. 708 and 719). Its lower su medially joined to the fornix, in part by the septum pellucidum and in part directly. L it is the tapetum of the roof of the lateral ventricle of either side. The majority of it arise from the cortical cells of the two hemispheres and terminate in the cortex of opposite that of their origin. In dissections, its fibers are seen to radiate toward all the cortex—the radiation of the corpus callosum. These radiations may be divid frontal, parietal, temporal and occipital parts. The occipital parts curve posteriorly strong bands from the splenium into the occipital lobes, producing the figure known forceps major. Anteriorly, the frontal parts are two similar but lesser bands whic from the genu forward into the frontal lobe, producing the **forceps minor.**

(2) The **anterior commissure** has been described in connection with the rhinenc In addition to the olfactory fibers coursing through it from the olfactory bulb and part area of one hemisphere to the uncus and olfactory bulb of the opposite hemisph commissural fibers between the two hippocampal gyri, comprising its greater p also carries fibers which arise in the cortex of the temporal lobe, the uncus chiefly, of and terminate in that of the opposite side. It crosses in the substance of the anterior b of the third ventricle, and through the inferior portions of the lenticular nuclei, and can only in dissections (figs. 723, 730). It is a relatively small, round bundle, and its mi between its terminal radiations presents a somewhat twisted appearance.

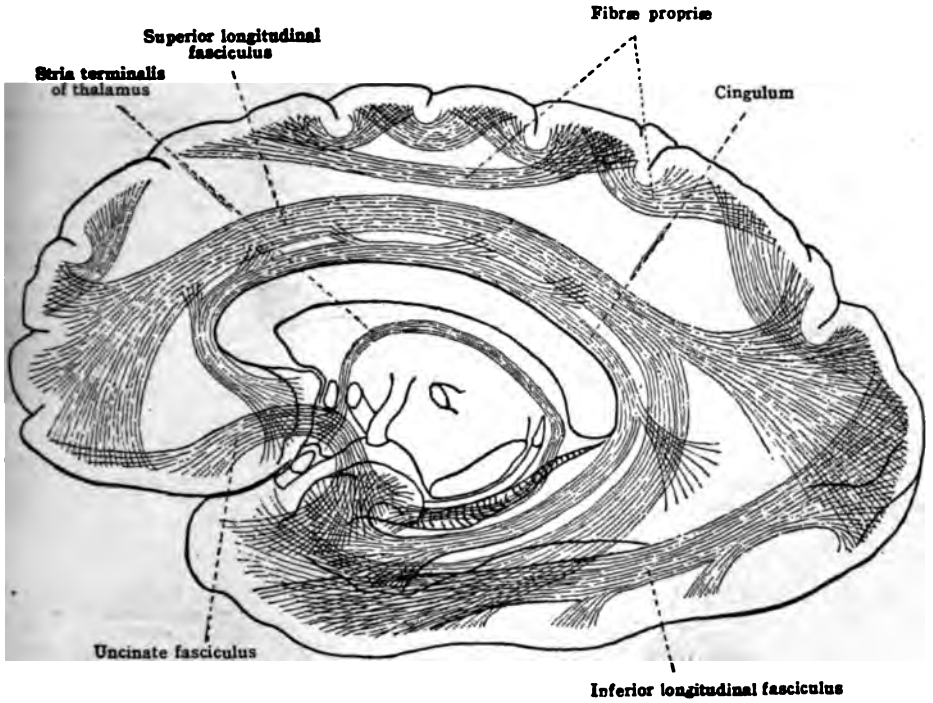
(3) The **hippocampal commissure** (*transverse fornix*) belongs wholly to the lim (rhinencephalon), and has been described there. It connects the hippocampal gyr two sides, and crosses the midline under and usually adhering to the inferior surfac splenium of the corpus callosum. Crossing the body of the fornix, it thins anteriorly an in the posterior angle of the septum pellucidum.

With these three commissures of the telencephalon, the three other commissures prosencephalon should be called to mind. The **inferior cerebral commissure** (C commissure), while occurring in the optic chiasma and allotted by position to the telenc really belongs to the diencephalon since it connects with each other the medial ge bodies of the two sides. The **supramammillary commissure, connecting the nuclei of th**

...ry bodies of the two sides, is allotted to the diencephalon (hypothalamus). The posterior ...al commisure, situated just below the stalk of the pineal body, belongs to both the dien... ...lon and mesencephalon. Its superior part, the *habernular commissure*, connecting the two ... of the habenulæ, belongs wholly to the diencephalon. In its inferior part, the fibers ...ng in the thalamus of one side and terminating in that of the other side belong likewise to the ...cephalon, but those passing between the superior quadrigeminate bodies of the two sides and ...en the so-called nuclei of the medial longitudinal fasciculi belong to the mesencephalon.

The association system of the hemisphere.—The possibilities for association-...dles connecting the different parts of the same hemisphere with each other are ...merable, and a large number are recognized. They serve for the distribution ...diffusion of impulses brought in from the exterior by the ascending projection ...tem, and it is by means of them that the different areas of the cortex may

FIG. 738.—SCHEMATIC REPRESENTATION OF CERTAIN OF THE ASSOCIATION-PATHWAYS OF THE CEREBRAL HEMISPHERE.



function in harmony and coördination. Most of the association-bundles are supposed to contain fibers coursing in both directions. Several of them have already been described in company with the gray masses with which they are concerned. They may be summarized as follows (see fig. 738):—

(1) Those of short course, the **fibræ propriæ**, which associate contiguous gyri with each other. These arise from the cells of a gyrus and loop around the floor of a sulcus, continually receiving and losing fibers in the cortex they associate. The stripes of Baillarger within the gray cortical layer might be included among the short association-bundles.

(2) The **cingulum** (girdle) lies in the gyrus cinguli and is shaped correspondingly. It extends from the anterior perforated substance and the subcallosal gyrus around the genu of the corpus callosum, then, under cover of the gyrus cinguli and around the splenium, and thence downward and forward in the hippocampal gyrus to the uncus. It is chiefly an aggregation of fibers of short course—fibers which associate neighboring portions of the cortical substance beneath which they course, and which, by continually overlapping each other, form the bundle.

(3) The **uncinate fasciculus** is a hook-shaped bundle which associates the uncus and anterior portion of the temporal lobe with the olfactory bulb, parolfactory area and anterior perforated substance and perhaps the frontal pole with the orbital gyri. Its shape is due to its having to curve medialward around the stem of the lateral cerebral fissure.

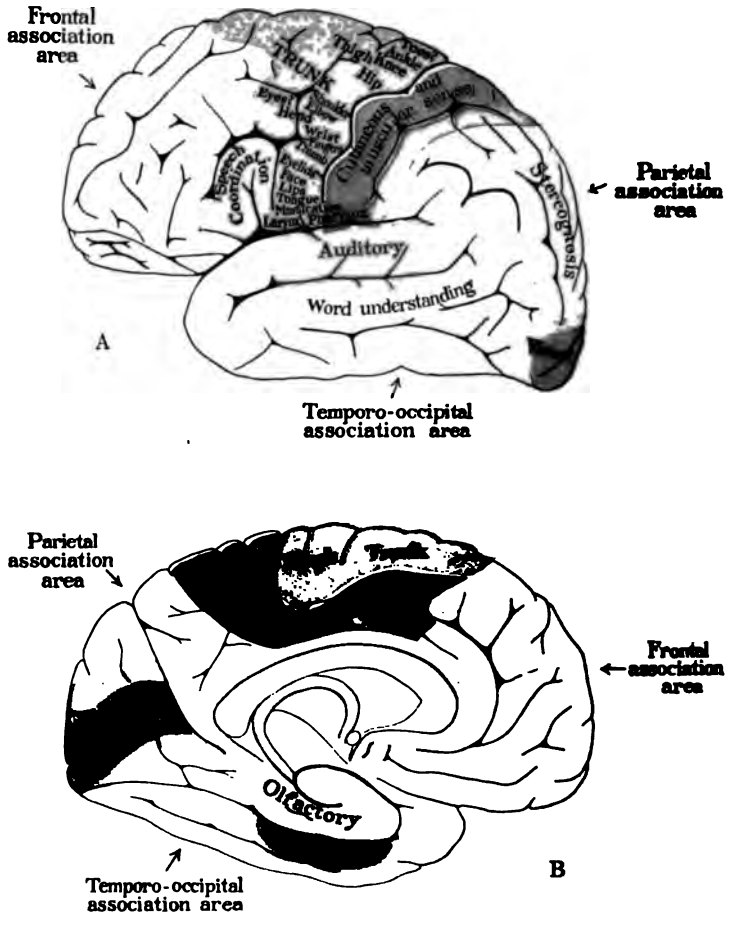
(4) The **superior longitudinal fasciculus** is the longest of the association-paths, and associates the frontal, occipital, and temporal lobes. From the frontal lobe it passes latreally in the frontal and parietal operculum, transverse to the radiations of the corpus callosum and the lower part of the corona radiata, and above the insula to the region of the posterior end of the lateral fissure, and thence it curves downward and forward to the cortex of the temporal lobe. Some of its fibers extend to the cortex of the temporal pole. The occipital portion consists

of a loose bundle given off from the region of the downward curve, which radiates the the occipital cortex.

(5) The inferior longitudinal fasciculus associates the temporal and occipital lobe extends along the whole length of these lobes parallel with their tentorial surfaces. Post it courses lateral to the lower part of the occipitothalamic radiation, from which it diff the fact that its fibers all arise within the hemisphere and are less compactly arrange associates the lingual and fusiform gyri and the cuneus with the temporal pole.

(6) A vertical or transverse occipital fasciculus (not included in fig. 738) associat tentorial surface of the occipital lobe with the superomedial and lateral parts of thi and adjacent portions of the parietal lobe.

FIG. 739.—DIAGRAMS SUGGESTING THE GENERAL MOTOR, GENERAL AND SPECIAL SE AND THE ASSOCIATION AREAS OF (A) THE CONVEX AND (B) THE MEDIAL SURFACE C CEREBRAL HEMISPHERE.



(7) The medial and lateral longitudinal striæ of the upper surface of the corpus c may be considered among the association pathways, since most of their fibers associate substance of the hippocampal gyrus with the subcallosal gyrus and the anterior pe substance of the same hemisphere. Their significance as parts of the rhinencepha already been given.

(8) Likewise the longitudinal fibers in the stria terminalis of the thalamus (ten circularis) may be considered among the association pathways, since these connect th daloid nucleus with the anterior perforated substance.

(9) The numerous fibers passing in both directions between the cerebral cortex nuclei of the corpus striatum belong to the association system. These do not form a bundle, though they contribute appreciably to the corona radiata. However, a described as the occipitofrontal fasciculus probably consists largely of the more running fibers of this nature. The existence of this fasciculus has been noted in degen and in cases of arrested development of the corpus callosum. Its fibers are describe tributing greatly to the tapetum, and as coursing beneath the corpus callosum imm next to the ependyma of the lateral ventricle. As a mass, they appear in intimate cor with the caudate nucleus, and are spread toward both the frontal and the occipital lobes

the latter), in the mesial part of the corona radiata of those lobes. It is described as also containing fibers in both directions associating the occipital with the temporal lobe. *Vertical association-fibers* pass through the caudate and lenticular nuclei between the cortex above and that of the temporal lobe below.

(10) Since the olfactory bulb is a part of the hemisphere proper, the *olfactory tract* may be considered an association pathway connecting the olfactory bulb with the parolfactory area, the subcallosal gyrus, the anterior perforated substance, and the uncus. As already shown, a portion of the fibers of the tract belongs to the commissural system.

THE FUNCTIONAL AREAS OF THE CEREBRAL CORTEX

The definitely known areas of specific function of the human cerebral cortex are relatively small. They comprise but little more than a third of the area of the entire hemisphere. They are—(1) the general sensory-motor or somesthetic area, and (2) the areas for the organs of special sense. They represent portions of the cortex in which terminate sensory or ascending projection-fibers bearing impulses from the given peripheral structures, and in which arise motor or descending projection-fibers bearing impulses in response.

Knowledge of the location of the areas has been obtained—(1) by the Flechsig method of investigation, and to a considerable extent by Flechsig himself; (2) from clinicopathological observations, largely studies of the phenomena resulting from brain-tumors, cerebral thrombi and traumatic lesions; (3) by experimental excitation of the cortex of monkeys and apes, the resulting phenomena being correlated with the anatomical findings and compared with the observations upon the human brain. The remaining larger and less known areas of the cortex are referred to as 'association-centers' or areas of the 'higher psychic activties.'

In development, the sensory fibers to the specific areas acquire their medullary sheaths first, before birth, and then the respective motor fibers from each become medullated. It is not until a month after birth that the association-centers show medullation and therefore acquire active functional connection with the specific areas.

In defining an area it is not claimed that all the fibers bearing a given type of impulse terminate in that area, nor that all the motor fibers leading to the given reaction originate in the area. It can only be said that of the fibers concerned in a given group of reactions, more terminate and arise in the areas cited than in any other areas of the cortex. The corresponding motor fibers arise both in the region of the termination of the sensory fibers (sensory area) and also in a zone (motor area) either partially surrounding or bordering upon a part of the region of the termination.

There is yet much lack of agreement among observers both as to the number of localized functional areas and as to the exact position of certain of the areas claimed. The following are considered the more generally accepted of the areas:—

(1) **The somesthetic (sensory-motor) area,** the area of general sensibility, and the area in which arise the larger part of the cerebral motor or pyramidal fibers for the cortical control of the general muscular system. As is to be expected, it is the largest of the specific areas. It includes the anterior central gyrus, posterior central gyrus, the posterior ends of the superior, middle, and inferior frontal gyri, the paracentral lobules, and the immediately adjacent part of the gyrus cinguli. The ascending or sensory fibers are found to terminate most abundantly in the part posterior to the central sulcus (Rolandi), the posterior central gyrus being the special *area of cutaneous sensibility* (see Cushing, 1909, and Head, 1918, for human cortex), and the adjacent anterior ends of the horizontal parietal gyri have been designated as the area of '*muscular sense.*' Both these areas are carried over upon the medial surface to involve the lower part of the paracentral lobule and a part of the gyrus cinguli. The anterior central gyrus gives origin to relatively more motor fibers than the other portions of the somesthetic area. In distribution, the muscles furthest away from the cortex are innervated from the most superior part of the area, the leg area being in the superomedial border of the hemisphere, while that for the head is in the anterior and inferior part of the area (fig. 739). The muscles of mastication and the laryngeal muscles are controlled from the frontoparietal operculum. Broca's convolution, the opercular portion and part of the triangular portion of the inferior frontal gyrus, of the left hemisphere, constitutes the especial motor coördination-area of speech, and Mills has extended this area to include the superoanterior portion of the insula below. The various authorities differ considerably as to the exact locations of many of the areas for the cortical control of given sets of muscles. Further observations must be skillfully made for localization of areas of the human cortex in detail and further correlations must be determined between the experiments upon the cortex of anthropoid apes and the functions of that of man. The accompanying diagrams (figs. 739, 740) are compiled from several of the diagrams more usually given and must be considered as only approximately correct.

(2) **The visual area.**—The especial sensory portion of this area is that immediately bordering upon either side of the posterior part of the calcarine fissure. The entire area, motor and sensory overlapping each other, includes the whole of the cuneus. The motor visual area proper is described as the more peripheral portion of the entire area. In addition, an area producing eye movements is described as situated in the posterior end of the middle frontal gyrus.

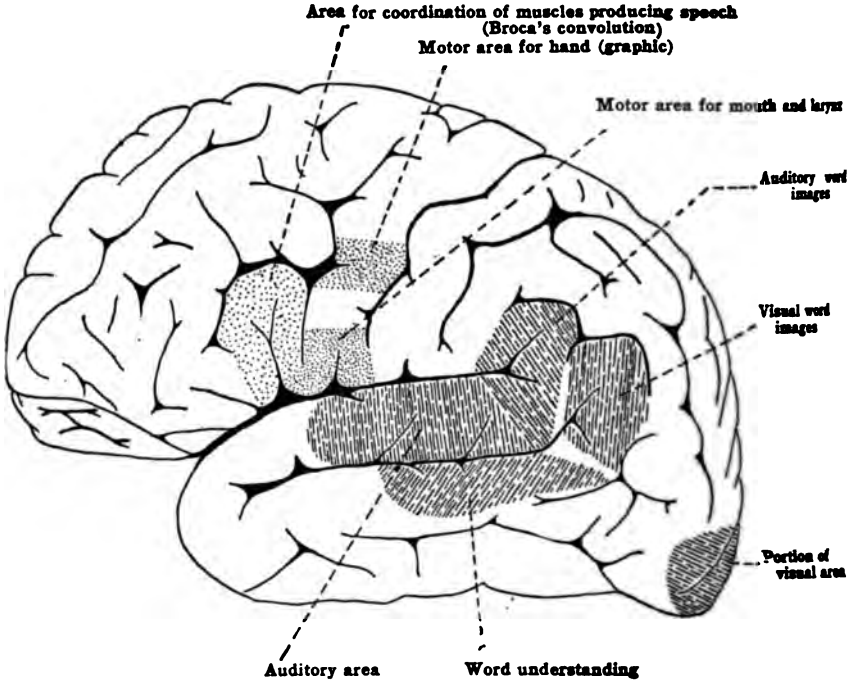
(3) **The auditory (cochlear) area** comprises the middle third of the superior temporal gyrus and the transverse temporal gyri of the temporal operculum. The motor portion of this area lies in its inferior border. The fibers arising in the area course downward in the temporal pontile path to the motor nuclei of the medulla.

(4) **The olfactory area** consists of the olfactory trigone, the parolfactory area, the subcallosal gyrus, part of the anterior perforated substance, the hippocampal gyrus (especially the uncus), and the callosal half of the gyrus cinguli. Its motor or efferent area lies chiefly in the hippocampal gyrus, the fibers from which pass out from the telencephalon by way of the fornix and cingulum

(5) **The gustatory area** is supposed to comprise the anterior portion of the fusiform gyrus and the zone (motor portion) about the anterior extremity of the inferior temporal sulcus. This area has been claimed to extend through the isthmus of the gyrus fornicatus to include a part of the callosal margin of the gyrus cinguli.

(6) **The association-areas.**—The relatively large areas allotted at present to the so-called higher psychic activities are indicated in fig. 739. The great relative extent of these is one of the characteristics of the human brain. They probably merely represent the portions of the cortex of which little is known, and may eventually be subdivided into more specific areas. They are considered to be connected with the structures below by fewer projection fibers than are the recognized areas named above, while, on the other hand, they are rich in association fibers. By means of the latter they are in intimate connection with the specific areas and have abundant means of correlating and exercising a controlling influence upon the functions of these areas. According to Flechsig, they consist of—(1) a *parietal association-area*, comprising that part of the parietal cortex between the somesthetic area and the visual area; (2) an *occipito-temporal association-area*, including the unspecified portions of the temporal lobe and the adjoining portion of the occipital lobe not included in the visual area; (3) a *frontal association-area*

FIG. 740.—CONVEX SURFACE OF LEFT CEREBRAL HEMISPHERE WITH DIAGRAMMATIC PRESENTATION OF THE AREAS SUGGESTED AS CONCERNED WITH SPEECH.



including all the frontal lobe anterior to the somesthetic and olfactory area. A large frontal area is especially distinctive of man. In the folds of the inferior parietal lobule of the parietal association-area such intellectual activities as the optic discrimination of words, letters, numbers, and objects generally are supposed to take place, while the superior parietal lobule continued into the posterior part of the præcuneus is the general region for the perception of form and solidity of objects—the stereognostic center.

The *insula* is suggested as the area in which auditory, olfactory and gustatory impulses are associated with the motor areas beginning in the operculum dorsolaterally adjacent to it.

Observations of symptoms and the position of lesions accompanying them have made it possible to arrive at some trustworthy conclusions regarding the cortical areas controlling speech. Broca announced in 1861 that the inferior frontal gyrus of the *left* hemisphere was peculiarly concerned with speech. This area was later confined to the posterior end or opercular portion of this gyrus and the name 'Broca's Convolution' was given it. It is now known that Broca's convolution and the adjacent portion of the triangular part of the inferior frontal gyrus as well comprise the *motor* area or *emissive speech-area*—the area especially devoted to the control of that coördinated action of the muscles concerned which makes possible articulate speech. Patients in whom this area is impaired are unable to give utterance to words though they may understand them both written and spoken, and though they may give utterance to sound. This inability is known as *motor aphasia*. Results of observed lesions have further shown that the area in which the *auditory images* of words are retained (word memories) comprises the posterior end of the superior temporal gyrus and the adjoining portion of the supramarginal gyrus. Injury to this area is accompanied by inability to recognize spoken words although the patient hears them and may recognize and understand written words, a phenomenon known as 'word-deafness' or auditory *sensory aphasia*. This area may be considered

as continuous with the superior portion of the posterior end of the middle temporal gyrus which has been suggested as the area of 'word-understanding,' or *'lalognosis.'* On the other hand, the area in which visual images of words are retained is located as the angular gyrus. Injury to this results in an inability to recognize printed or written words although the patient may hear, understand and speak them. This is called *'word-blindness,* (visual sensory aphasia). This area is nearest the special area of vision on the one hand and on the other hand, is continuous into the area to which word-understanding is attributed. For purposes of writing, it must be associated with the motor area for the muscles of the hand in the precentral gyrus.

While the motor area for speech is most functional in the left hemisphere of right-handed individuals, and *vice versa,* the remaining areas concerned are probably equally functional in the two hemispheres.

III. GENERAL SUMMARY OF SOME OF THE PRINCIPAL CONDUCTION-PATHS OF THE NERVOUS SYSTEM

In the following summary the arabic numerals indicate the nuclei or ganglia containing the cell-bodies of the neurones interposed in the chains; the letters in parenthesis indicate the different names given to the different levels of the pathways through which their fibers run. For detailed descriptions of either nuclei or pathways see pages describing them. Only the more common neurone-chains are followed here.

I. The Spinocerebral and Cerebrospinal System

A. The ascending path of neurones (fig. 741).

1. Spinal ganglion—neurone of first order.
   (*a*) Terminal corpuscles and peripheral process of T-fiber.
   (*b*) Dorsal or afferent root of spinal nerve.
   (*c*) Ascending branch of bifurcation of dorsal root fiber in fasciculus gracilis or fasciculus cuneatus of spinal cord.
2. Nucleus of fasciculus gracilis or nucleus of fasciculus cuneatus in medulla oblongata —neurone of second order.
   (*a*) Internal arcuate fibers.
   (*b*) Decussation of lemniscus.
   (*c*) Interolivary stratum of lemniscus of opposite side.
   (*d*) Medial lemniscus.
3. Inferior and lateral nuclei of thalamus—neurone of third order.
   (*a*) Internal capsule, posterior segment of frontoparietal portion.
   (*b*) Corona radiata, frontoparietal part.
4. Posterior central gyrus of somesthetic area of cerebral cortex.
   (*a*) Association and commissural fibers of cortex.

1*x*. Spinal ganglion—neurone of first order.
   (*a*) Terminals, especially in skin, and peripheral process of T-fiber.
   (*b*) Dorsal or afferent root of spinal nerve.
   (*c*) Collaterals and terminal branches of bifurcation of dorsal root-fiber within spinal cord.

2*x*. Gray substance of spinal cord, dorsal horn especially—neurone of second order.
   (*a*) Decussation of fibers to opposite side within spinal cord.
   (*b*) Thalamospinal and tectospinal paths (*spinal lemniscus*).

3*x*. Inferolateral nuclei of thalamus—neurone of third order.
   (*a*) Internal capsule (medial side of frontoparietal portion).
   (*b*) Corona radiata.

4*x*. Posterior central gyrus of cerebral cortex—neurone of fourth order.
   (*a*) Association and commissural fibers of cortex.

B. Descending path of neurones (fig. 742).

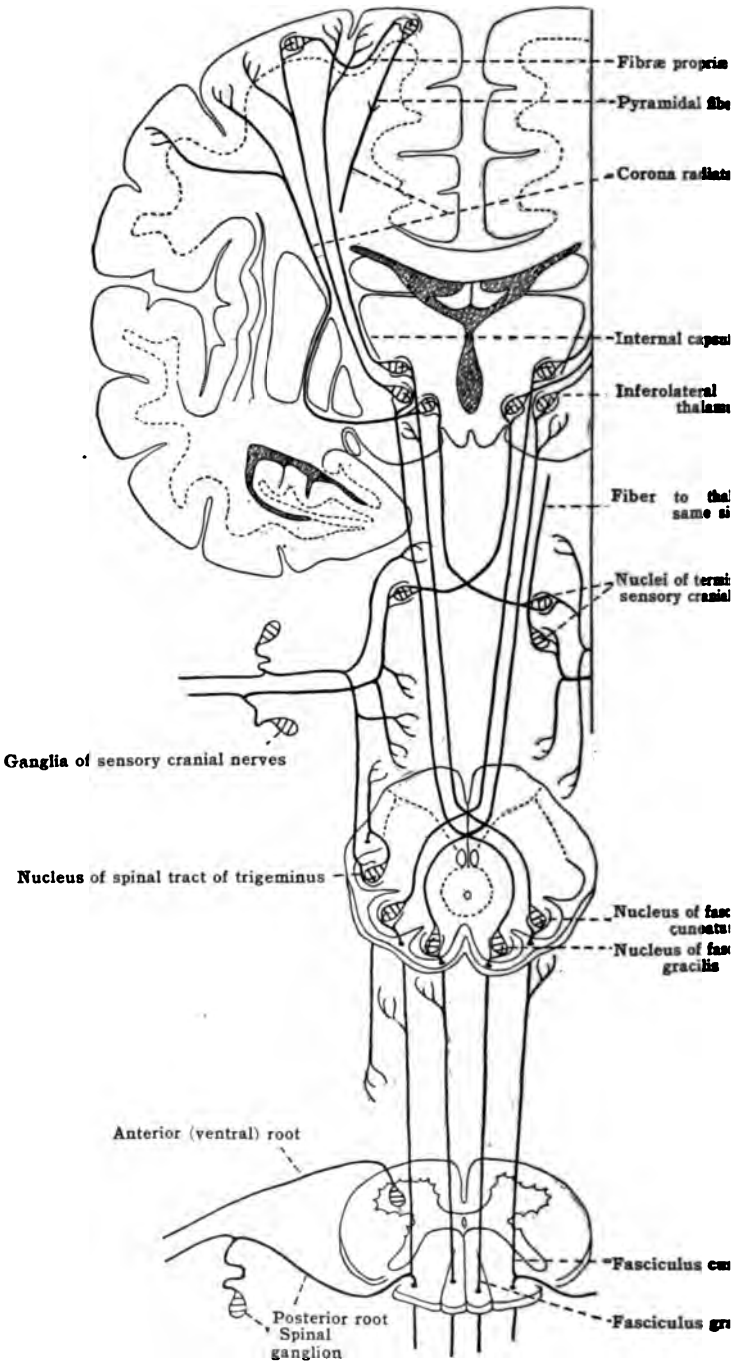
1. Giant pyramidal cells of precentral gyrus of somesthetic area.
   (*a*) Corona radiata, frontoparietal part.
   (*b*) Internal capsule, middle segments of frontoparietal portion.
   (*c*) Basis of the cerebral peduncle and the peduncle.
   (*d*) Pyramid of medulla oblongata.
   (e^1) Decussation of pyramids.
   (f^1) Lateral cerebrospinal fasciculus (crossed pyramidal tract).
   (e^2) Ventral cerebrospinal fasciculus (direct or uncrossed pyramidal tract).
   (f^2) Gradual decussation of latter in cervical and upper thoracic regions of spinal cord.
2. Cells of ventral horn of spinal cord of opposite side.
   (*a*) Ventral or efferent roots of spinal nerves.
   (*b*) Peripheral nerve-trunks directly to skeletal muscles or indirectly to smooth muscle or glands by way of sympathetic neurones.

II. Short Reflex Paths of Spinal Cord

1. Spinal ganglia.
   (*a*) Terminal corpuscles and peripheral process of T-fibers.
   (*b*) Dorsal root of spinal nerve.
   (*c*) Collaterals and terminal branches of bifurcation of dorsal root fibers within spinal cord.

(*d*) Directly to ventral horn cells of same level of spinal cord.
(*e*) Or, more commonly, to same through intermediation of Golgi cell of t
(*f*) Or to neurones of fasciculi proprii to ventral horn cells of other levels cord.

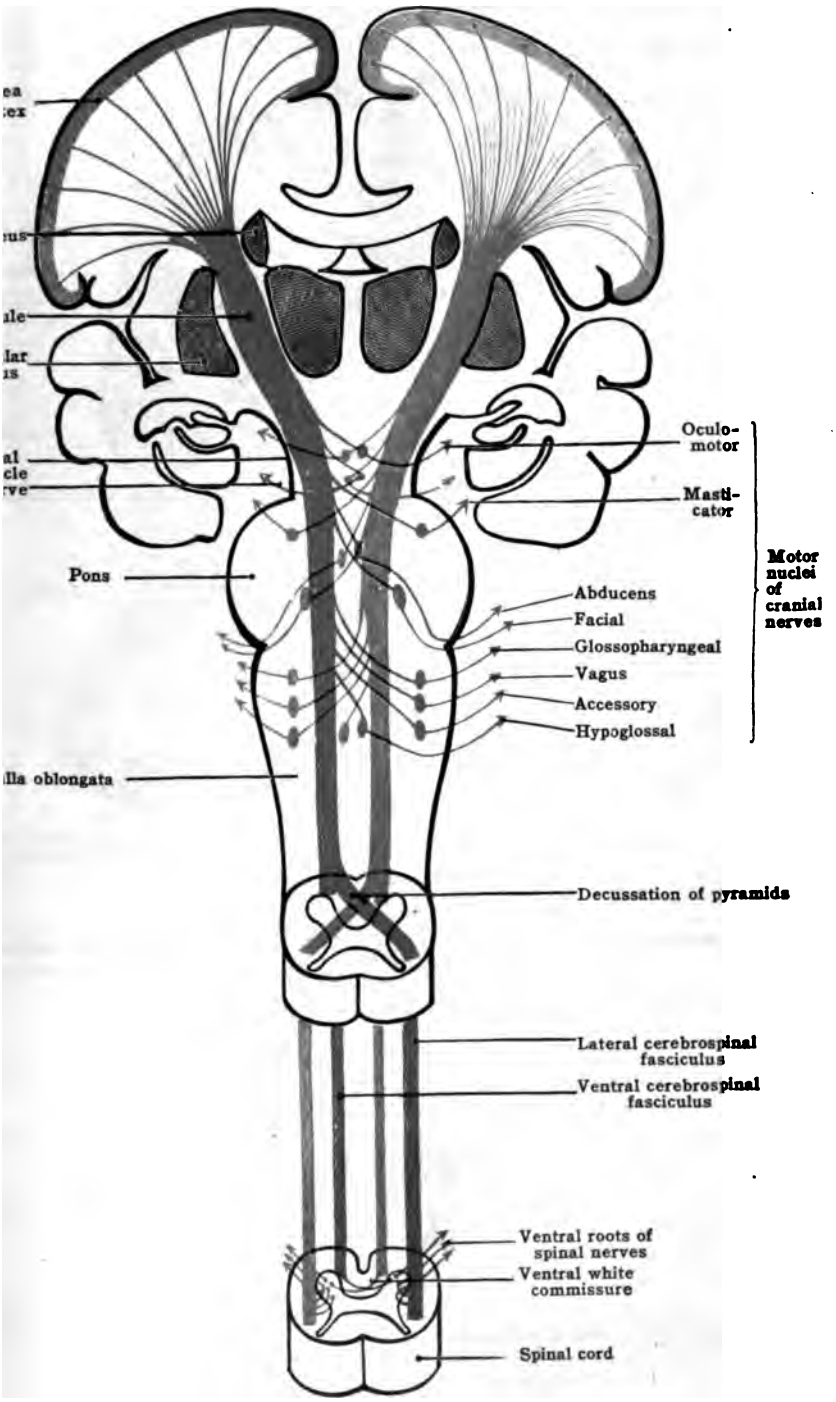
FIG. 741.—SCHEME OF PRINCIPAL SPINOCEREBRAL CONDUCTION PAT



2. Ventral horn cells of same (chiefly) and opposite side **and thence by way** roots and peripheral nerve trunks directly **to skeletal muscles.**
3. Dorsolateral group of ventral horn cells of same **(chiefly) and opposite** thence by ventral root fibers to cell-bodies in **sympathetic ganglia.**
4. Sympathetic axones to smooth muscle or glands.

ıL PATH FOR THE CRANIAL NERVES, EXCLUSIVE OF THOSE OF SPECIAL SENSE
ıding system of neurones.
ınglia of origin of sensory components of vagus, glossopharyngeus, glossopalatine and trigeminus.

G. 742.—SCHEME OF DESCENDING CEREBROSPINAL CONDUCTION-PATH.

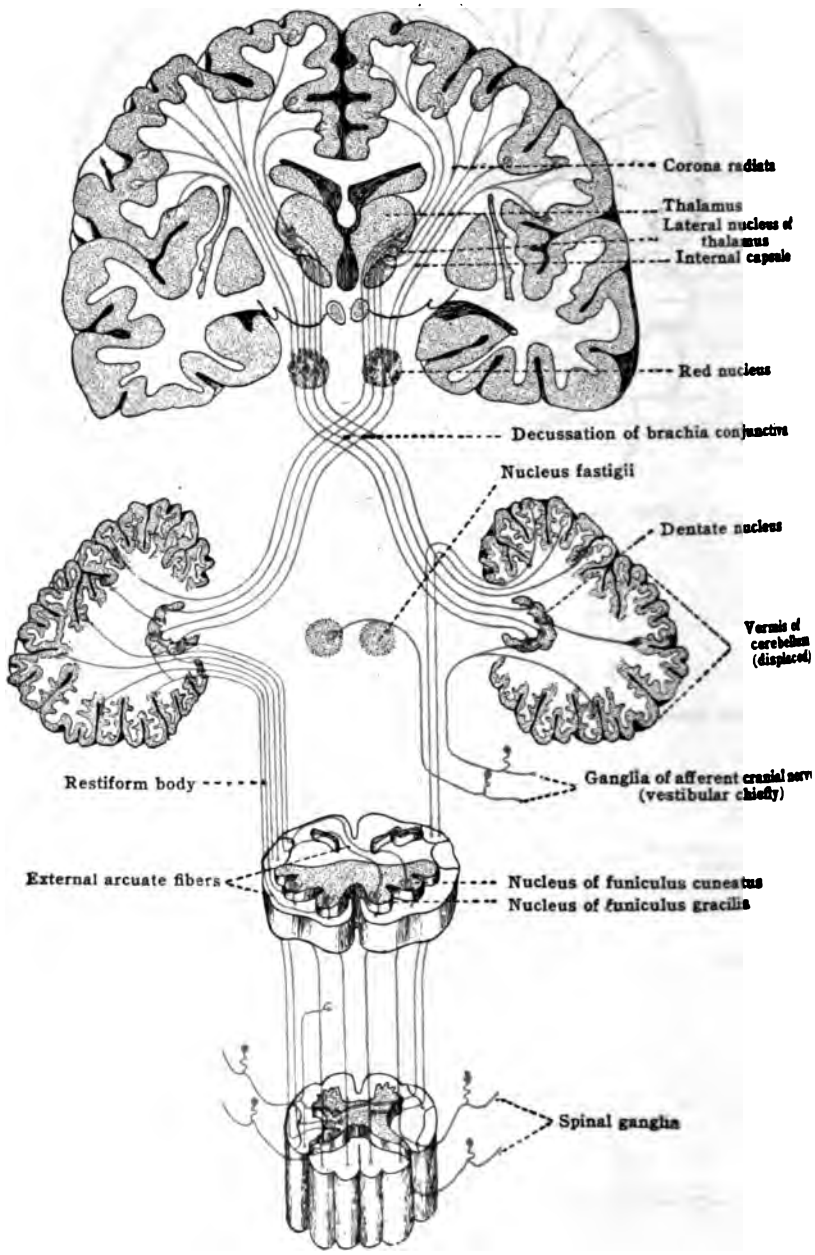


ı) Peripheral arborizations and afferent peripheral branches of T-fibers of same
ı) Central branches of T-fibers of same (sensory nerve roots).
uclei of termination of central branches (bifurcated and unbifurcated) in medulla oblongata.

(*a*) Reticular formation, internal arcuate fibers and medial lemniscus of the opp side. Trigeminal portion (trigeminal lemniscus) courses separated from m lemniscus in mesencephalon.

3. Inferior and lateral nuclei of thalamus.
   (*a*) Internal capsule, posterior segment of frontoparietal portion.
   (*b*) Corona radiata, frontoparietal part.
4. Cerebral cortex—chiefly lower third of posterior central gyrus.
   (*a*) Association and commissural fibers of cortex.

FIG. 743.—SCHEME OF PRINCIPAL ASCENDING CEREBELLAR CONDUCTION-PATHS.



B. Descending system of neurones.

1. Pyramidal cells of opercular region of somesthetic area.
   (*a*) Corona radiata, frontoparietal.
   (*b*) Internal capsule, genu chiefly.
   (*c*) Basis of cerebral peduncle and peduncle.
   (*d*) Decussation in brain-stem.
2. Nuclei of origin of motor cranial nerves and motor components of mixed cr nerves, of opposite side chiefly, and thence by way of these nerves to the re ive muscles supplied.

Notes: (1) Most of the descending cortical fibers to the nucleus of origin of the trochlear nerve and that portion of the nucleus of the oculomotor which supplies the internal rectus muscle apparently do not decussate but terminate in the nuclei of the same side.

(2) The efferent nucleus of the glossopalatine (salivatory nucleus) and the dorsal efferent nucleus of the vagus give rise to visceral efferent fibers, i.e., carry impulses destined for smooth muscle and glands by way of sympathetic neurones. The same is true for the superomedial part of the nucleus of the oculomotor.

(3) The nuclei of termination of the cranial nerves, especially those of the vestibular and trigeminus, send fibers also into the cerebellum.

IV. The Short Reflex Paths of the Cranial Nerves

These consist of the central branches of their afferent or sensory fibers, bearing impulses to the nuclei of origin of both their own motor components and to the nuclei of origin of other motor nerves. Fibers to the more distant nuclei pass to them by way of the medial longitudinal fasciculus. Instead of terminating in the motor nuclei directly, the sensory fibers are usually interrupted by a third or intermediate neurone interposed in the chain. The vagus and glossopharyngeal are connected by way of the solitary fasciculus and its nucleus with the structures below their level of entrance, the vagus with the ventral horn cells of the upper segments of the cervical cord, and through these with the muscles of respiration.

V. Conduction-Paths Involving the Cerebellum

A. Ascending cerebellar pathways.

1. Spinal ganglia.
   - (*a*) Terminal corpuscles, trunks and dorsal roots of spinal nerves.
   - (*b*) Collaterals and terminal branches of bifurcation of dorsal root fibers in spinal cord, chiefly those conveying impulses of *muscle-sense.*

2*x*. Dorsal nucleus (Clarke's column).
   - (*a*) Dorsal spinocerebellar fasciculus (direct cerebellar tract).
   - (*b*) Restiform body (inferior cerebellar peduncle)—
   - (*c*) Joined in medulla by external arcuate fibers (crossed and uncrossed fibers arising in nuclei of funiculus gracilis and cuneatus);
   - (*d*) Joined in medulla by fibers arising in nuclei of termination of afferent vagus, glossopharyngeal, vestibular, and trigeminal nerves;
   - (*e*) Joined by fibers both to and from (ascending and descending) the inferior olivary nucleus of the same and especially opposite sides (*cerebello-olivary fibers*).

2*y*. Nerve-cells in base of ventral horn of same and opposite side (lumbosacral region).
   - (*a*) Superficial anterolateral spinocerebellar fasciculus (Gowers' tract), ascending through spinal cord and reticular formation of medulla and pons.
   - (*b*) Anterior medullary velum and brachium conjunctivum to cerebellar cortex (vermis chiefly).

3. Cerebellar cortex, dentate nucleus, nucleus fastigii, nucleus emboliformis, and nucleus globosus.
   - (*a*) White substance (corpus medullare) of cerebellum, associating various regions of its cortex and its nuclei with each other.
   - (*b*) Brachium conjunctivum (superior cerebellar peduncle) arising chiefly from dentate nucleus.
   - (*c*) Decussation of brachium conjunctivum.

4. Red nucleus and lateral nucleus of thalamus. Most fibers of the brachium conjunctivum terminate in the red nucleus; many merely give off collaterals to it in passing to their termination in the thalamus. Most of the ascending fibers arising in the red nucleus also terminate in the thalamus; some ascend to the cerebral cortex direct.
   - (*a*) Internal capsule, middle third, and frontoparietal part of corona radiata.
   - (*b*) Somesthetic area of cerebral cortex and cortex of frontal lobe anterior to it.
   - (*c*) Inferior peduncle of thalamus to cortex of temporal lobe.

B. Descending cerebrocerebellar paths.

1. Pyramidal cells of somesthetic area send fibers through corona radiata, internal capsule, and cerebral peduncle to nuclei of pons and arcuate nucleus of same and opposite side.
2. Cells of cortex of posterior part of frontal lobe give fibers to form frontal pontile path through frontal parts of corona radiata and internal capsule and through medial part of cerebral peduncle to nuclei of pons of opposite side.
3. Cells of cortex of temporal lobe (superior and middle gyri) give fibers to form temporal pontile path which passes under the lenticular nucleus into anterior segment of occipital portion of internal capsule and lateral part of cerebral peduncle to nuclei of pons of opposite side. This path is joined in the internal capsule by a small occipitopontile path.
4. Cells of nuclei of pons send fibers by way of brachium pontis (middle cerebellar peduncle) to cortex of cerebellar hemisphere, of side opposite to that of the origin of the cerebral fibers making synapses with the cells of the pons.

C. Descending cerebellospinal paths.

1. Probably from cells of nucleus fastigius of same and opposite sides and probably from other nuclei of cerebellum arise fibers which terminate in the nuclei of termination of the vestibular nerve and reticular formation; these send fibers into the intermediate and anterior marginal fasciculi of spinal cord (fig. 661), and thence to the cells of the anterior horn.

2. The pathway arising in the red nucleus of the opposite side and descending in the rubrospinal tract of the lateral funiculus of the spinal cord (fig. 661). The rubrospinal tract decussates in the ventral portion of the tegmentum of the mesencephalon and is said to pass through the medulla oblongata in the medial longitudinal fasciculus. It must be noted here that in addition to the brachium conjunctivum some fibers arising in the cortex of the frontal lobe terminate in the red nucleus (corticorubral path).

VI. The Vestibular Conduction-Paths (Equilibration)

1. Vestibular ganglion gives origin to the peripheral utricular and three ampullar branches and to the combined and centrally directed vestibular nerve.
2. Lateral vestibular nucleus (Deiters'), medial nucleus, superior nucleus, and nucleus of descending or spinal root (nuclei of termination) give origin to fibers as follows:—
   (*a*) From lateral and superior nuclei to nucleus fastigii of opposite side and to cortex of vermis and to dentate nucleus (cerebellar connection).
   (*b*) From medial and superior nuclei to nuclei of origin of eye-muscle nerves of same and opposite sides, by way of medial longitudinal fasciculi.
   (*c*) From lateral nucleus and nucleus of descending root through reticular formation into lateral and ventral vestibulospinal tracts of spinal cord.
   (*d*) The nuclei receive fibers from the gray substance of the vermis. It is probable that all the nuclei of termination give off fibers bearing ascending impulses which ultimately reach the cerebral cortex, but the course pursued and neurones involved in such a chain are uncertain.

VII. The Auditory Conduction-Path (Cochlear Nerve)

1. Spiral ganglion of the cochlea gives origin to short peripheral fibers to organ of Corti, and to the centrally directed cochlear nerve.
2. Dorsal and ventral nuclei of the cochlear nerve (nuclei of termination).
   (*a*) Striæ medullares arise from dorsal nucleus and pass around outer side of restiform body (acoustic tubercle), then medianward under ependyma of floor of fourth ventricle to midline, then ventralward into tegmentum, where they decussate and join trapezoid body and lateral lemniscus of opposite side.
   (*b*) Fibers arising in ventral nucleus pass ventrally medianward and some terminate in the superior olivary nucleus of same side; others pass by way of trapezoid body and lateral lemniscus to terminate in superior olivary nucleus, nucleus of lateral lemniscus, medial geniculate body and nucleus of inferior quadrigeminate body of the opposite side.
3. Nuclei of superior olives of both sides and nucleus of lateral lemniscus send fibers to reticular formation and medial longitudinal fasciculus, associating auditory impulses with the nuclei of the motor cranial nerves.
4. Fibers from medial geniculate body and probably from nucleus of inferior quadrigeminate body pass into internal capsule and through temporal part of corona radiata to middle third of superior temporal gyrus and adjacent portions (auditory area).
5. It is probable that fibers from the auditory area of the cerebral cortex are also distributed to nuclei of the motor cranial nerves by way of the inferior quadrigeminate bodies.

VIII. Conduction Paths of the Visual Apparatus

A. Optic impulses.

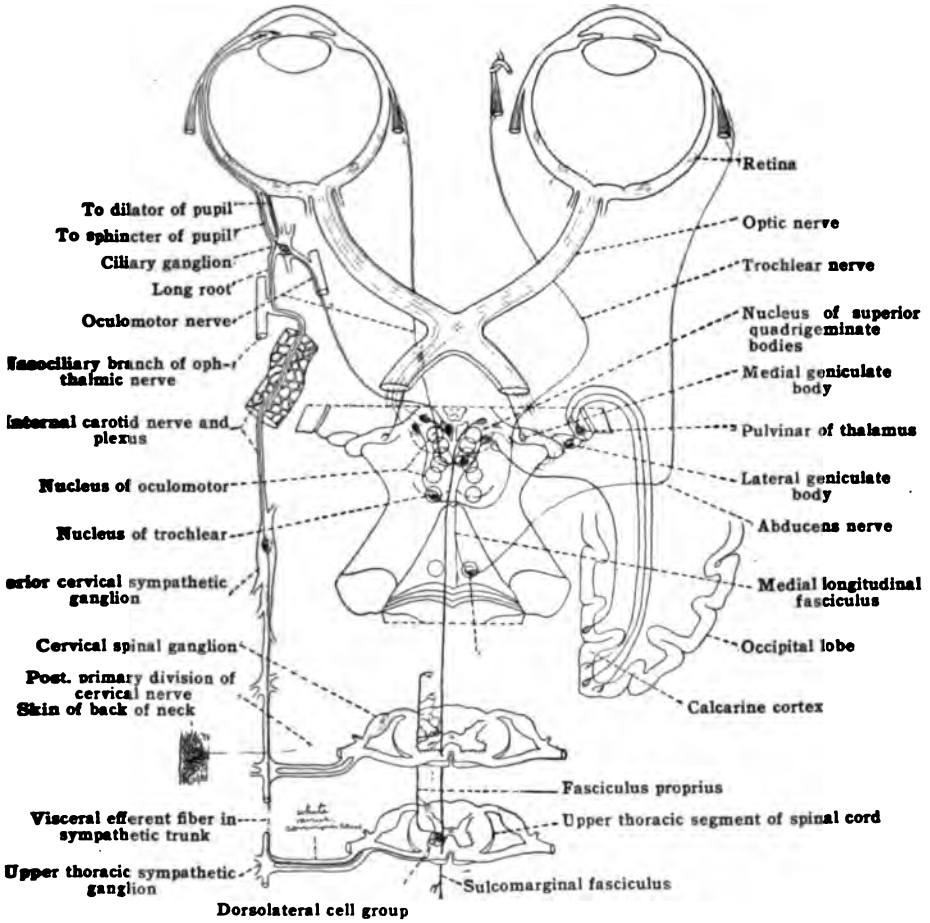
1 'Bipolar' cells of retina with short (peripheral) processes to layer of rods and cones (neuro-epithelium) and short centrally directed processes to ganglion-cell layer of retina (nucleus of termination).
2. Ganglion-cells of retina give origin to—
   (*a*) Optic stratum of retina.
   (*b*) Optic nerve.
   (*c*) Optic chiasma; fibers from nasal side of retina cross in chiasma to opposite side; fibers from lateral side of retina continue on same side in—
   (*d*) Optic tract to —
3. Pulvinar of thalamus, lateral geniculate body, and nucleus of superior quadrigeminate body.
   (*a*) Fibers from nucleus of superior quadrigeminate body pass ventrally, to nuclei of origin of oculomotor and trochlear nerves and to medial longitudinal fasciculus of same and opposite sides, and from it are distributed to nuclei of origin of abducens and facial nerves.
   (*b*) Fibers from lateral geniculate body and pulvinar pass through occipital portion of internal capsule and occipitothalamic radiation (optic radiation) to cortex of occipital lobe (visual area).
4. Cells of visual area of cortex send fibers through occipitothalamic radiation and occipital portion of internal capsule to nucleus of superior quadrigeminate body (occipitomesencephilic fasciculus), and thence, probably interrupted by cells of this nucleus, the impulses are carried to nuclei of eye-muscle nerves.
5. Cells of nucleus of superior quadrigeminate body and pulvinar send fibers by way of medial longitudinal fasciculus into lateral and ventral funiculi of spinal cord (see fig. 661), chiefly of the opposite side. Fibers from the quadrigeminate body cross midline chiefly in decussation of 'optic-acoustic reflex path' (fig. 703) and in fountain decussation.

6. The smaller cells of the superomedial group of the nucleus of the oculomotor nerve (nucleus of Edinger and Westphal) send axones, by way of the trunk of the nerve and the short root of the ciliary ganglion, which terminate about cells in—
7. The ciliary ganglion, whose cells send axones to enter the ocular bulb and terminate upon the smooth muscle fibers of the ciliary body and sphincter of the iris.

B. Spinopupillary ('ciliospinal') reflexes.

1. Peripheral processes of spinal ganglion cells terminating in the skin and central processes of same entering by way of dorsal roots of spinal nerves to bifurcate in spinal cord and give terminal twigs about—
2. Cells of the dorsolateral group of the ventral horn of the same and opposite sides of cervical and upper thoracic regions of spinal cord. These cells send (visceral efferent) axones by way of white rami communicantes of thoracic nerves and sympathetic trunk to terminate about cells in—

FIG. 744.—DIAGRAM OF PRINCIPAL PATHWAYS OF OPTIC APPARATUS.



3. The superior cervical sympathetic ganglion, which cells send axones chiefly by way of the carotid plexus and the sympathetic roots of the ciliary ganglion, through ciliary ganglion without synapses, into the ocular bulb to terminate in the ciliary body and radial (dilator) muscle fibers of the iris, producing dilation of the pupil.

C. Auditory-eye reflexes.

1. Cells of the nuclei of termination of the cochlear nerve and superior olive send fibers by way of the medial longitudinal fasciculus (some to this by way of the peduncle of the superior olive) to the nuclei of origin of the eye-moving nerves.
2. The same nuclei of the cochlear nerve send axones by way of the lateral lemniscus to terminate in the superior quadrigeminate body and thence may be sent impulses which are distributed to the nuclei of the eye-moving nerves.

IX. PRINCIPAL CONDUCTION-PATHS OF OLFACTORY APPARATUS

1. Bipolar cells of olfactory region of nasal epithelium send short (peripheral) processes to surface of the epithelium and centrally directed processes, the olfactory nerve, through lamina cribrosa of ethmoid bone into olfactory bulb (glomerular layer).

2. 'Mitral cells' of olfactory bulb give fibers which form—
   (*a*) The olfactory tract which divides into—
   (*b*) Medial olfactory stria through which fibers pass—(1) into parolfactory area (Broca's area); (2) into subcallosal gyrus; and (3) by way of anterior cerebral commissure to olfactory bulb and uncus of hippocampal gyrus of opposite side.
   (*c*) Intermediate olfactory stria to anterior perforated substance.
   (*d*) Lateral olfactory stria, which terminates to some extent in anterior perforated substance, but chiefly in uncus, hippocampal gyrus, and gyrus cinguli (olfactory area) of same side.
3. Cells of uncus and hippocampal gyrus give fibers which form—
   (*a*) The cingulum (in part), by which they are associated with the cortex of the gyrus cinguli and other areas of the cerebral cortex.
   (*b*) The hippocampal commissure (in part), by which they are correlated with the gray substance of the opposite side.
   (*c*) The fornix, which, interrupted in part in the nuclei of the corpus mammillare, conveys impulses—(1) to the anterior nucleus of thalamus of the same (chiefly, and opposite sides (mammillothalamic fasciculus), and (2) into the mesencephalon and substantia nigra (mammillomesencephalic fasciculus), and by way of this tract probably to the nuclei of the mesencephalon and medulla oblongata.
4. The parolfactory area, anterior perforated substance, anterior nucleus of thalamus and fornix give fibers which form the medullary stria of the thalamus and which terminate in the habenular nucleus.
5. Habenular nucleus sends fibers in fasciculus retroflexus to terminate in interpeduncular nucleus.
6. Interpeduncular nucleus sends fibers to nuclei of mesencephalon and probably to structures below it.

The Relations of the Brain to the Walls of the Cranial Cavity

The precise methods by which the exact positions of the most important fissures, sulci gyri, and areas can be ascertained and mapped out on the surface of the head in the living subject are fully described in Section XIV. Here, only a very general survey of the relations of the brain to the cranial bones is given and from a purely anatomical standpoint (fig. 745).

The parts of the brain which lie in closest relation with the walls of the cranial cavity are the olfactory bulb and tract, the basal and lateral surfaces of the cerebral hemispheres, the inferior surfaces of the lateral lobes of the cerebellum, the ventral surfaces of the medulla and pons, and the hypophysis.

Certain of these portions of the brain lie in relation with the basicranial axis, that is, with the basioccipital, the basisphenoid, and the ethmoid bones, while others are associated with the sides and vault of the cranial cavity. Considering the former portions first, the ventral surface of the medulla oblongata, which is formed by the pyramids, lies upon the upper surface of the basioccipital bone. More superiorly the ventral surface of the pons rests upon the basisphenoid, from which it is partly separated by the basilar artery and the pair of abducens nerves. In front of the dorsum sellæ the hypophysis (pituitary body) is lodged in the hypophyseal fossa. Still further forward the olfactory tracts lie in grooves on the upper surface of the presphenoid section of the sphenoid bone; and in front of the sphenoid the olfactory bulbs rest upon the cribriform plates of the ethmoid.

Posterior and lateral to the posterior part of the foramen magnum the lateral lobes of the cerebellum are in relation with the cranial wall, resting upon the lower parts of the supraoccipital and the posterior parts of the exoccipital portions of the occipital bone, while anteriorly each lobe is in relation with the inner surface of the mastoid process and the posterior surface of the petrous portion of the temporal bone. The area of the skull wall which is in close relationship with the cerebellar hemispheres may be indicated, on the external surface of the skull, by a line which commences at the inferior part of the external occipital protuberance and thence runs upward and lateralward. It crosses the superior nuchal line a little beyond its center, and, continuing in the same direction, crosses the inferior part of the lambdoid suture and reaches a point directly above the asterion (the meeting point of the occipital, temporal, and parietal bones); thence it descends, just in front of the occipitomastoid suture, to the tip of the mastoid process, and there turns medialward to its termination at the margin of the foramen magnum, immediately behind the posterior end of the occipital condyle.

The basal surface of each cerebral hemisphere may be said to consist of two parts, an anterior and a posterior, separated by the stem of the lateral cerebral fissure. The anterior part, formed by the orbital surface of the frontal lobe, rests upon the upper surfaces of the orbital plate of the frontal bone and the lesser wing of the sphenoid. It is, therefore, in close relation with the upper wall of the orbital cavity. The posterior part, behind the stem of the lateral fissure, begins with the anterior portion of the temporal lobe, including its pole. The pole itself projects against the orbital plate of the great wing of the sphenoid bone, and it is in relationship with the posterior part of the lateral wall of the orbit. The basal surface of the hemisphere, behind the pole of the temporal lobe is in contact with the upper surfaces of the great wing of the sphenoid and the petrous part of the temporal bone.

The convex surfaces of the cerebral hemispheres have the most extensive relationships with the cranial wall, and it is more especially to these surfaces that the surgeon turns his attention. The general area in which the convex surface of each cerebral hemisphere is in relation with the skull bones is readily indicated by a series of lines which correspond with the positions of its superciliary, inferolateral, and superomedial borders.

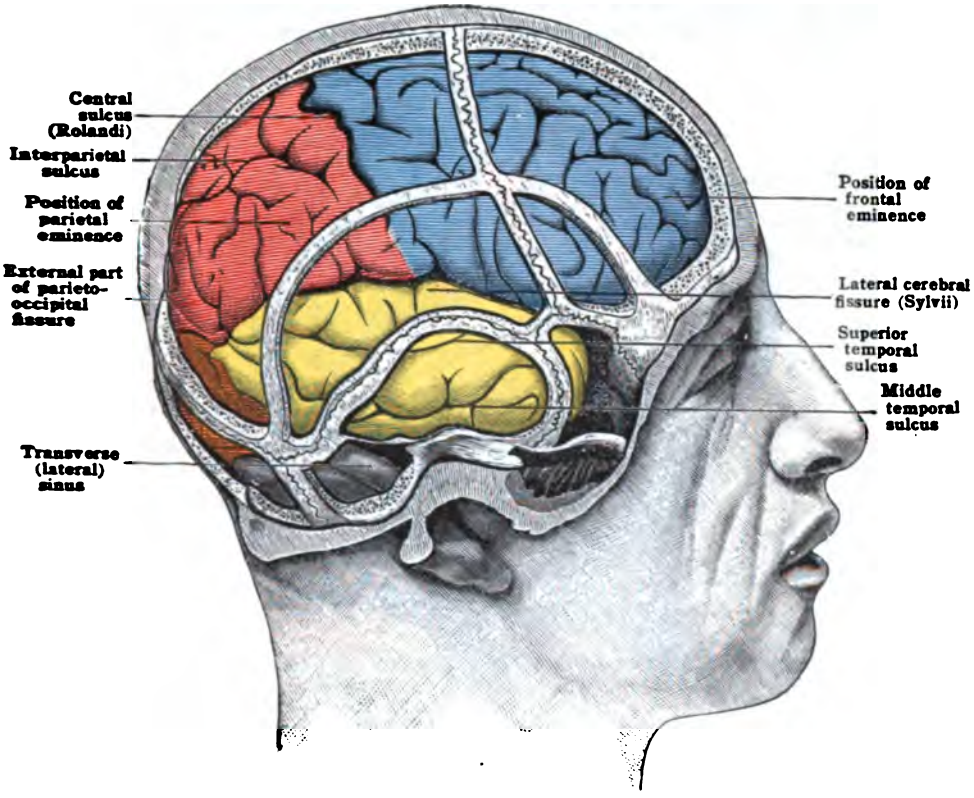
The line marking the superciliary margin of the hemisphere commences at the nasion (the midpoint of the frontonasal suture); it passes lateralward above the superciliary ridge, crosses

the temporal ridge, then, turning posteriorly in the temporal fossa, it reaches the parieto-sphenoidal suture, and continues backward along it to its posterior extremity.

The line marking out the inferolateral border commences at the posterior end of the parieto-sphenoidal suture, whence it passes downward, in front of the sphenosquamous suture, to the infratemporal crest (pterygoid ridge); there it turns posteriorly and, running parallel with and medial to the zygomatic arch, it crosses the root of the zygoma, and ascending slightly, it passes above the external auditory meatus. Continuing backward with an inclination upward it reaches a point immediately above the asterion; thence it descends, and, crossing the inferior part of the lambdoid suture and the superior nuchal line, it passes medialward to the inferior part of the external occipital protuberance.

The superomedial border of the hemisphere is defined by a line which runs from the nasion to the inion. This line should be drawn about 5 mm. lateral to the sagittal suture, because the medial area is occupied by the superior sagittal sinus, and it should be further away from the middle line on the right than on the left side, because the sinus tends to lie more to the right side.

FIG. 745.—DRAWING OF A CAST OF THE HEAD OF AN ADULT MALE.
(Prepared by Professor Cunningham to illustrate craniocerebral topography.)



The area of the cranial wall enclosed by the three lines which mark the positions of the superciliary, inferolateral, and the superomedial borders of the cerebral hemisphere is formed by the vertical plate of the frontal bone, the parietal bone, the great wing of the sphenoid, the squamous part of the temporal, and the upper section of the supraoccipital segment of the occipital bone. It covers the convex surfaces of the frontal, parietal, temporal, and occipital lobes of the cerebrum and the fissures and sulci which bound and mark them.

In every consideration of the topographical relations of the cerebral gyri to the walls of the cranial cavity it must be borne in mind that the conditions are not constant, and that, therefore, the relations are variable. The three main factors upon which this variability depends are age, sex, and the shape of the skull. As examples of the variations which occur it may be mentioned that the lateral cerebral fissure is relatively higher in the child than in the adult (compare figs. 745 and 746). The superomedial end of the central sulcus is further away from the coronal suture in the female and in the child than in the adult male, and in dolichocephalic than in brachycephalic heads. The angle formed between the line of the central fissure and the mid-sagittal plane, which averages about 68° in the adult, is more acute in dolichocephalic heads, and the external part of the parietooccipital fissure is further forward in the child, and possibly in the female, than it is in the adult male.

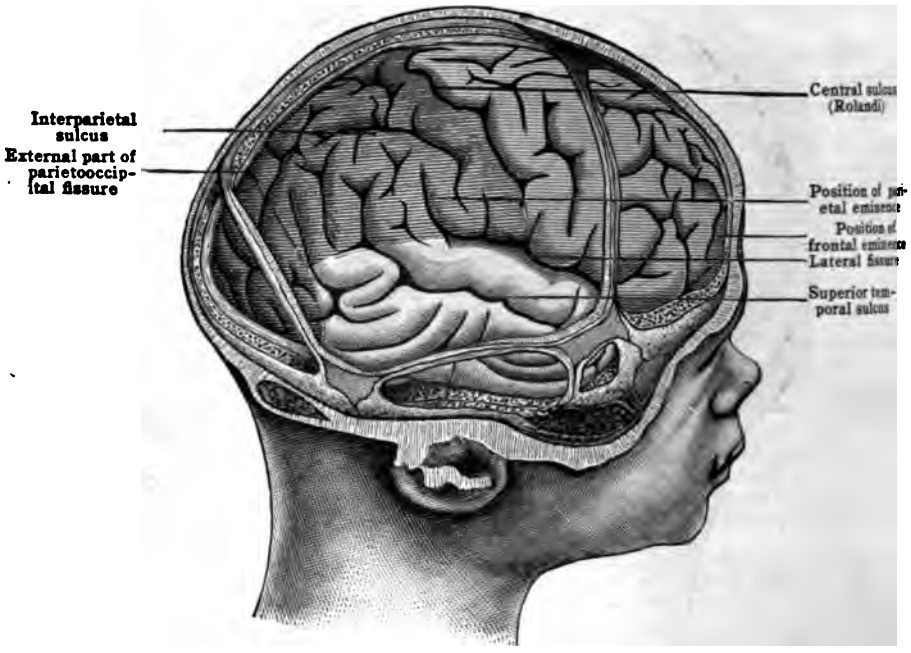
The position of the posterior horizontal limb of the lateral fissure varies even in the adult. Its posterior part is always under cover of the parietal bone, and it terminates either in front of or inferior to the parietal eminence, but the anterior part may be above, parallel with, or inferior

to the squamoparietal suture. In the adult the anterior part of the fissure runs upward and backward from the posterior end of the sphenoparietal suture along the anterior part of the squamoparietal suture to its highest point; thence it continues in the same direction beneath the parietal bone toward the lambda, terminating either in front of or below the parietal eminence. In the child, however, the fissure is considerably above the line of the squamoparietal suture (fig. 746), which it gradually approaches, attaining its adult position about the ninth year. This change of position, which occurs during the first nine years, is due partly to the ascent of the sutural line and partly to the descent of the fissure on the surface of the brain.

The frontal bone always covers the superior, middle, and inferior frontal gyri, except their posterior extremities, which are beneath the parietal bone (fig. 745). The ascending limb (ramus anterior ascendens) of the lateral fissure, which cuts into the posterior part of the inferior frontal gyrus, runs parallel with and under cover of the lower part of the coronal suture, or immediately in front of it, and the anterior horizontal limb is parallel with and beneath the upper margin of the great wing of the sphenoid.

The parietal bone is in relation with the convex surfaces of four lobes of the cerebrum. Speaking very generally, it may be said that the anterior third covers the posterior part of the

FIG. 746.—DRAWING OF A CAST OF THE HEAD OF A NEWLY BORN MALE INFANT.
(Prepared by Professor Cunningham to illustrate craniocerebral topography.)



frontal lobe, including the anterior central gyrus, and the posterior ends of the superior, middle, and inferior frontal gyri and precentral sulcus. The posterior two-thirds of the bone are superficial to the parietal lobe, the posterior part of the temporal lobe, the anterior part of the occipital lobe, the posterior part of the horizontal limb of the lateral fissure, the superior and inferior parts of the postcentral sulcus, the interparietal sulcus, the posterior sections of the superior and middle temporal sulci, and the external part of the parieto-occipital fissure. The central sulcus is beneath the parietal bone at the junction of its middle and anterior thirds (fig. 745).

In the adult, the upper end of the central sulcus is situated at about 55 per cent. of the whole length of the nasoinionic line posterior to the nasion. It is about 4 or 5 cm. from the coronal suture. The inferior end of the sulcus, which extends to near the posterior horizontal limb of the lateral fissure, lies beneath the point of intersection of the auriculobregmatic line with a line drawn from the stephanion (the point where the temporal ridge cuts the coronal suture) to the asterion. This point is about 46 per cent. of the horizontal arc measured from the glabella to the inion.

The superior end of the parieto-occipital fissure usually lies about 5 mm. in front of the lambda, and the course of the fissure may be indicated by a line drawn from 5 mm. in front of the lambda to a point immediately above the asterion, and, as the latter point corresponds with the preoccipital notch on the inferolateral border of the hemisphere, the line in question will indicate the adjacent margins of the parietal, temporal, and occipital lobes.

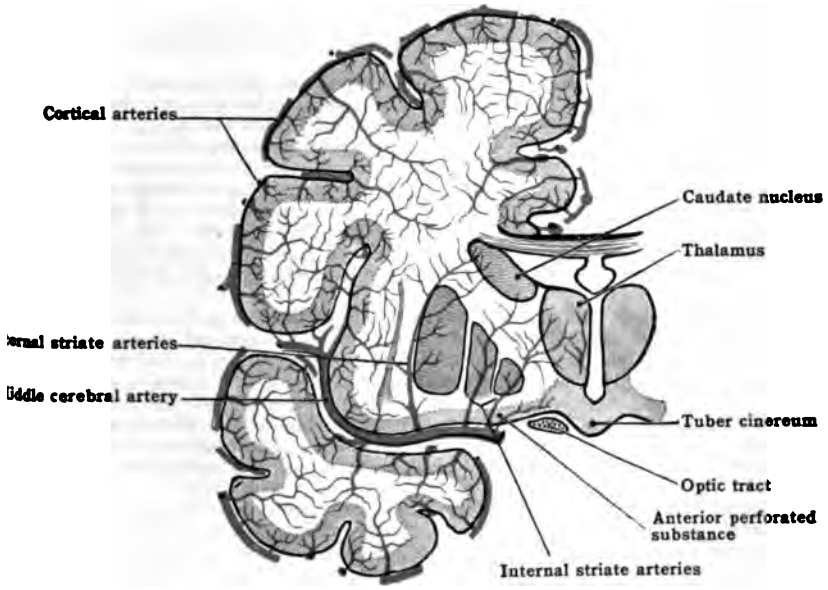
The occipital bone is in close relation with the cerebellum, as already pointed out, but it also covers the posterior part of the lateral surface of the occipital lobe of the cerebral hemisphere. The great wing of the sphenoid covers the outer surface of the pole of the temporal lobe, and the squamous part of the temporal bone covers the anterior parts of the superior, middle, and inferior temporal gyri and the sulci which separate them.

The Blood-Supply of the Encephalon

The double origin of the continuous arterial system of the brain given by the confluence of two vertebral arteries and the two internal carotid arteries, together with the description of the general distribution of the different cerebral, mesencephalic, and cerebellar arteries into which the system is divided, and the origin and course of the corresponding veins, are fully dealt with in Section VI. Here attention may be called briefly to the abundant and systematic terminal distribution of the terminal branches of the system and their intimate arrangement for the actual nourishment of the nervous tissues within.

The general plan of the blood supply for the entire encephalon may be summarized as follows:—(1) At their origin the different arteries are so connected, directly or indirectly, on the base of the encephalon, that the blood approaching the brain by way of the vertebral and internal carotid arteries is practically a common supply for all the arteries of the encephalon, so that a given part of it may possibly pass into any one of them. (2) In the pia mater of each primary division of the encephalon, the different arteries again become connected with each other directly in a superficial, freely anastomosing plexus, continuous throughout. (3) From this plexus of the surface, naturally composed in part of the trunks of the different arteries themselves, arise central branches which enter directly into the nervous substance and which break

Fig. 747.—Diagram Showing the Manner of Distribution of the Cortical and Central Branches of the Cerebral Arteries.



into twigs that are *terminal;* i.e., twigs that *do not* anastomose with the twigs of other central branches. (4) The arterial capillary system arising from the terminal twigs passes over into venous capillaries which converge to form corresponding venous twigs which in their turn pass to the surface and join in forming a peripheral, anastomosing venous plexus superimposed upon the similar arterial plexus. (5) From this venous plexus arise the different veins of the encephalon, which may or may not accompany the arteries for a short distance, and which finally empty into the sinuses in the cranial dura mater. These, likewise confluent, empty into the internal jugular veins. The choroid plexuses of the ventricles of the brain are modifications of the general anastomosing peripheral plexuses. The choroid plexuses of the lateral and third ventricles are derived largely from the branches of the choroid arteries, which arise separately from the internal carotid artery.

The blood supply of the cerebrum may best be taken as an illustration of the general plan of the blood-vascular system of the encephalon. The terminal or internal branches of the pial plexus, derived from the posterior, middle, and anterior cerebral arteries, are arranged in two groups, a **ganglionic** (nuclear) and a **cortical group.** The **ganglionic** branches themselves form four groups in each hemisphere:—

(1) The *anteromedial group* consists of central branches from the plexus of the domain of the anterior cerebral artery, which pass through the medial part of the anterior perforated substance and supply the head of the caudate nucleus, the septum pellucidum, the columns of the fornix, and the lamina terminalis.

(2) The *anterolateral group* consists of central branches from the domain of the middle cerebral artery. These pierce the anterior perforated substance in two subgroups—(*a*) the internal and (*b*) the external striate arteries (fig. 747.) The **internal striate arteries** pass through the segments of the globus pallidus of the lenticular nucleus and through the internal capsule, to both of which they give branches, and they terminate in the caudate nucleus and thalamus. The **external striate arteries** are larger and more numerous. They pass upward between the external capsule and the putamen, and then through or around the upper part of the putamen into the internal capsule, where they form two groups, the *lenticulothalamic*

and the *lenticulocaudate groups*. The former terminate in the thalamus and the latter in the caudate nucleus. On account of its larger size at its origin and its direct linear continuation with the internal carotid, emboli (*thrombi*) pass more frequently into the middle cerebral artery than into the anterior cerebral artery. One of the lenticulocaudate arteries which is larger and longer than the others and which is a direct branch from the middle cerebral artery has been called the **'artery of cerebral hemorrhage'** (Charcot), on account of the greater frequency with which it is ruptured.

(3) The *posteromedial* arteries are central branches of the posterior cerebral artery. They also enter the anterior perforated substance, but supply the floor of the third ventricle, the posterior part of the thalamus, and the hypothalamic region.

(4) The *posterolateral group* are also central branches of the posterior cerebral artery. They supply the posterior part of the internal capsule, the pulvinar of the thalamus, the geniculate bodies, the corpora quadrigemina and their brachia, the pineal body, and the cerebral peduncles.

The *cortical group* of the cerebral arteries arise from the anastomosing plexus in the pia mater of the cortical surfaces of the hemisphere. They pass into the cortical substance both from the summits of the gyri and from the walls of the sulci. They consist of short, medium, and long central branches, and pass at right angles into the gyri. The short branches terminate in the cortical substance; the medium branches supply the more adjacent white substance, and the longer branches pass more deeply into the general medullary center of the hemisphere.

All of both the ganglionic and the cortical arteries are terminal in the sense that they do not anastomose in the substance of the cerebrum.

The blood-vascular system of the other divisions of the encephalon is in accordance with the same general plan of that of the cerebrum. Slight individual modifications of the general plan are to be expected.

The **blood-vessels of the mesencephalon,** in addition to the supply derived from the posterolateral group of ganglionic arteries, include the vessels of the quadrigeminate bodies and those of the cerebral peduncles. The **arteries** of the quadrigeminate bodies are usually six in number, three for each side—the **superior, middle,** and **inferior quadrigeminate arteries.** The superior and middle are branches of the posterior cerebral and the inferior are branches of the superior cerebellar arteries. The superior supply the superior quadrigeminate bodies and the pineal body; the middle supply both the superior and inferior quadrigeminate bodies, and the inferior the inferior quadrigeminate bodies. They all anastomose in the pia on the surface of the stratum zonale, forming a fine-meshed plexus, and from this superficial plexus the central branches pass into the substance of the bodies. The **veins** terminate in the vein of Galen (v. cerebri magna.)

The **arteries of the cerebral peduncles** form two groups, medial and lateral. The **medial peduncular arteries** are branches of the basilar and the posterior cerebral arteries. They pass to the medial sides of the peduncles and supply the superior and medial part of the tegmentum. The vessels of this group which accompany the fibers of the oculomotor nerves are known as the radicular arteries; they supply the root-filaments and the nuclei of the nerves, which receive no other branches. The **lateral peduncular arteries** are branches of the posterior cerebral and superior cellebellar arteries. They supply the lateral portions of the peduncles and the lateral part of the tegmentum. The **veins** of the mid-brain terminate in the basilar veins and the vein of Galen.

The blood-vessels of the cerebellum.—**Six arteries** supply the cerebellum: two, the **posterior inferior cerebellar,** are derived from the vertebral arteries and the remaining four, two **anterior inferior** and two **superior cerebellar,** from the basilar artery. The course and general distribution of the arteries are described in Section VI, but here it must be noted that the branches of these six vessels form a rich network in the pia mater on the surfaces of the cerebellar lobes, and that extensions of the plexus pass with the folds of the pia mater into the sulci and fissures. From the superficial plexus central branches pass into the interior of the cerebellum and their collaterals from capillary plexuses in the white and gray substance. The extension of the surface plexus are of three lengths: – (1) a longer set, which pass through the cortex of the cerebellum and supply the white substance of the corpus medullare; (2) a set of shorter arterioles which pass through the molecular layer of the cortex and break up in its granular layer; (3) the shortest set pass into the cortex and immediately break up in its molecular layer. The meshes of the capillary plexuses in the gray substance are ovoidal and their axes run radially. The meshes of the plexuses in the white substance are parallel with the nerve-fibers. In addition to the vessels mentioned, a distinct central branch is distributed to each dentate nucleus. This springs either from the superior cerebellar or from the anterior inferior cerebellar artery of the corresponding side.

The **efferent veins** of the cerebellum do not accompany the arteries; they form a plexus in the pia mater which receives tributaries from the capillaries of the terminal branches of the central arteries in the interior, and they form three groups on each cerebellar surface, the vermian veins and the lateral veins. The **superior vermian vein** runs forward on the superior surface of the vermis and terminates in the vein of Galen. The **inferior vermain vein** runs posteriorly and ends in one of the transverse sinuses. The **superior lateral veins** open into the superior petrosal or transverse sinuses, and the **inferior lateral veins** into the inferior petrosal and transverse sinuses. The vein from the dentate nucleus usually joins the inferior lateral veins.

The blood-vessels of the pons.—The arteries to the pons are branches of the basilar artery, and of its anterior inferior and superior cerebellar branches. The plexus in the pia mater is comparatively unimportant, and the branches which enter the substance of the pons form two main groups, the central and the peripheral. The **central arteries** spring directly from the basilar. They pass backward along the raphe, giving branches to the adjacent parts, and they terminate in the nuclei of the pons and those in the floor of the fourth ventricle. The **peripheral arteries** are radicular and intermediate. The *radicular branches* spring from the peripheral plexus and from the anterior inferior cerebellar arteries; they accompany the roots of the

geminus, abducens, facial, vestibular, and cochlear nerves, supply their fibers and the adjacent rts, and they end in the grey nuclei with which the nerve-fibers are connected. The *inter-diate arteries* enter the surfaces of the pons irregularly and break up into capillaries in its bstance, just as the central arteries. The veins form a plexus on the surface. The dorsal d lateral part of this plexus is drained into the basilar vein on each side, and the inferior part connected by efferent channels with the inferior petrosal sinus and the cerebellar veins.

The blood-vessels of the medulla oblongata.—The arteries of the medulla are derived irectly from the vertebral arteries, from their anterior and posterior spinal and posterior inferior erebellar branches, and from the basilar artery. The branches of these vessels form a plexus in he pia mater from which, and from the arteries themselves, three main groups of vessels pass nto the medulla—the choroidal, the central, and the peripheral. The choroidal arteries are erived chiefly from the posterior inferior cerebellar arteries. They supply the choroid plexus of the fourth ventricle. The anterior central arteries rise from the anterior spinal artery, from the basilar artery, and from the peripheral plexus; they pass caudalward along the raphe, supplying the adjacent parts of the ventral funiculi and the olivary bodies and they break up into fine terminals in the gray substance of the floor of the fourth ventricle around the nuclei of the cranial nerves. The posterior central arteries spring from the posterior spinal arteries; they pass down the median septum of the inferior part of the medulla and supply the adjacent nervous substance. The peripheral arteries, like those of the spinal cord, are separable into radicular and intermediate groups. The *radicular arteries* pass from the anterior and posterior spinal branches and from the trunks of the vertebral arteries and accompany the fibers of the last six cranial nerves into the substance of the medulla. They supply the nerve-roots and adjacent white substance and they terminate in capillaries in the gray substance of the lateral part of the floor of the ventricle. The *intermediate peripheral arteries* spring from the arteries prveiously named and from the peripheral plexus, and they pass directly into the funiculi of the medulla, where they terminate in a capillary plexus which supplies the white substance and the gray nuclei; some of these arteries, more especially those derived from the posterior inferior cerebellar and the posterior spinal arteries, extend inward to the lateral part of the floor of the fourth ventricle. Twigs of all peripheral arteries anastomose with the common superficial plexus in the pia mater with which all central arteries are connected.

The veins which issue from the medulla form a peripheral plexus in the pia mater in which there are two main longitudinal channels, and anterior median and a posterior median vein. The former communicates posteriorly with the anterior median vein of the cord, and anteriorly with the veins of the pons and with the veins which accompany the hypoglossal nerves. The latter veins empty into the internal jugular veins. The posterior median vein is continuous caudally with the corresponding vein of the cord, and anteriorly, in the region of the calamus scriptorius, it divides into branches which join the radicular veins. The blood is carried away from the peripheral plexus mainly by the radicular veins, which pass along the roots of the last six cranial nerves. Those which accompany the hypoglossal nerves have already been referred to. The others end in the terminal parts of the transverse sinuses, the inferior petrosal sinuses, or the inferior part of the occipital sinuses.

The nerve supply of the blood vessels of the brain consists of a perivascular plexus of sympathetic nerve-fibers upon the walls of the vessels and medullated fibers which accompany the vessels and apparently terminate, for the most part, in the connective tissue about them. The former are thought to be vasomotor in function; the latter probably sensory fibers of the craniospinal type. Nerves were first described only for the larger vessels by Huber.

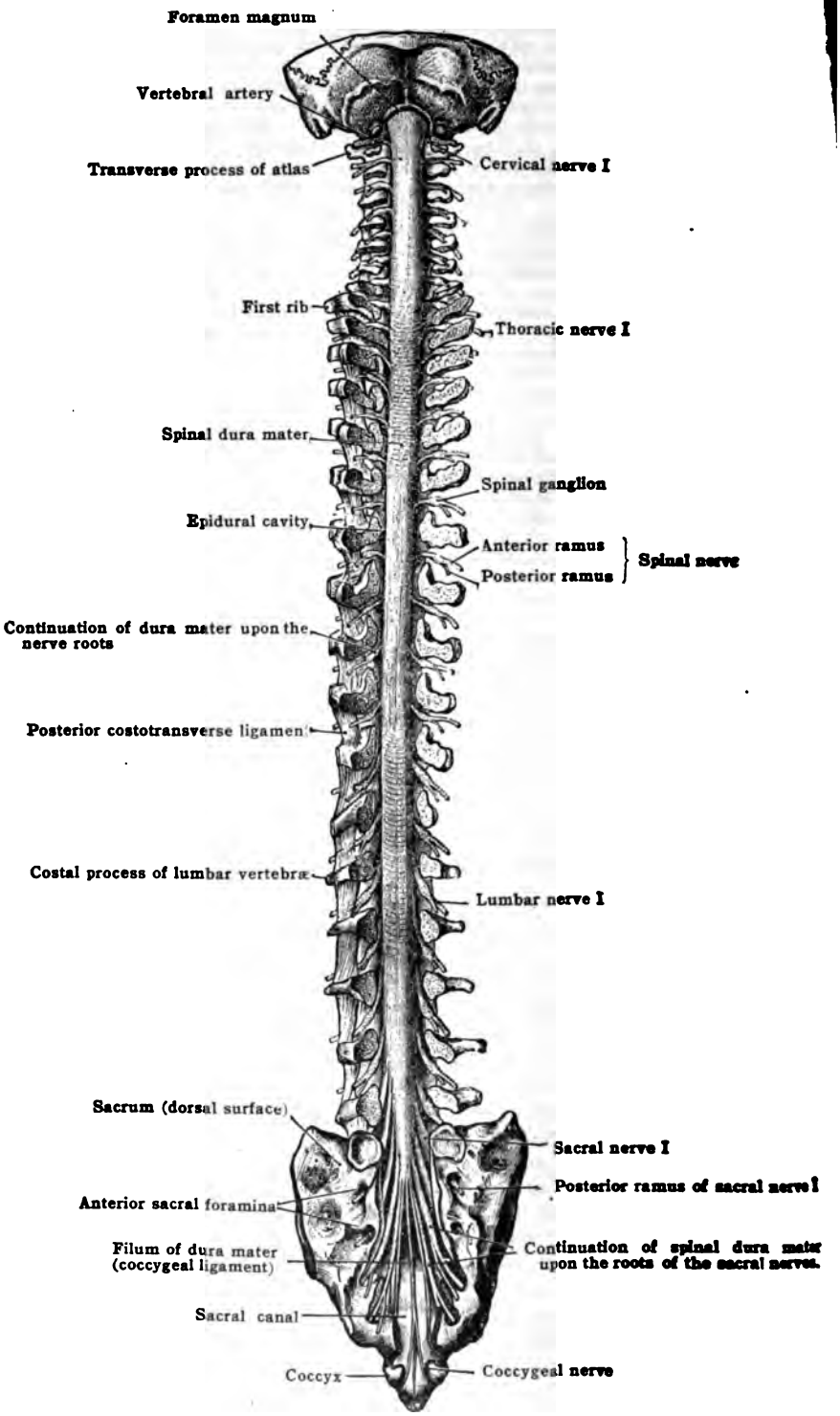
IV. THE MENINGES

Three membranes, collectively called the **meninges,** envelope the entire central nervous system, separate it from the walls of the bony cavities in which it lies, and aid in its protection and support. They consist of feltworks in which white fibrous connective tissue predominates, and through them pass the blood-vessels which supply the central nerve-axis and the nerves by which the axis is connected with the periphery. Though there are definite spaces or cavities between them, the membranes are not wholly separated from each other, and they are both continuous with and contribute to the walls of the blood-vessels and the sheaths (epineurium) of the nerves passing through them. Beginning with the outermost, they are—(1) the *dura mater*, the thickest, most dense and resistant of the membranes; (2) the *arachnoid*, the much less dense, web-like middle membrane; and (3) the *pia mater*, a thin, compact membrane, closely adapted to the surface of the central system, into which it sends numerous connective tissue processes. The pia is highly vascular, containing the rich superficial plexuses of blood-vessels from which the intrinsic blood supply of the central system is derived. The space between the dura mater and the arachnoid is known as the *subdural cavity*, and that between the arachnoid and the pia mater is the *subarachnoid cavity*.

The Dura Mater

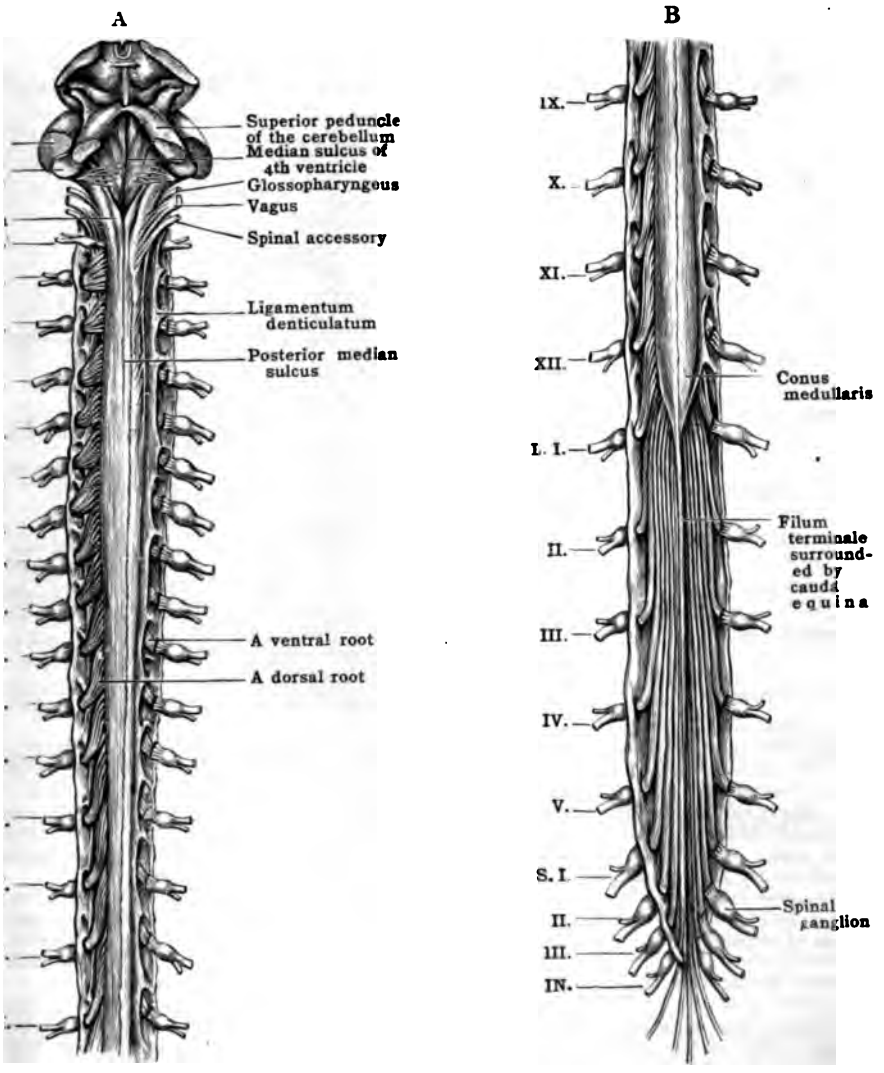
In the fresh condition the dura mater appears as a bluish-white, exceedingly resistant membrane, forming the outermost envelope of the entire central nervous

FIG. 748.—SHOWING THE SPINAL DURA MATER EXPOSED *in situ*. (Dorsal aspect.) (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



. Its external surface or that next to the bony wall is rough, while its al surface appears smooth, due to the fact that the subdural cavity partakes nature and has the lining of a lymph-space. The cranial dura mater s of two distinct, closely associated layers, the outermost of which serves internal periosteum of the cranial bones. The spinal dura mater is de- l as consisting of but one layer. The internal periosteum of the spinal though continuous at the foramen magnum with the outer layer of the

9.—Dorsal Aspect of the Medulla Oblongata and Spinal Cord with the Dura Mater Partially Removed. (Hirschfeld and Leveillé.)

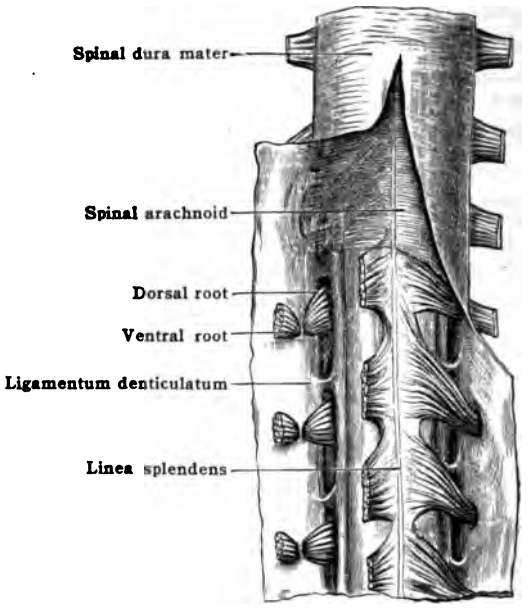


l dura mater, is not considered a part of the spinal dura mater, from the hat it is so widely separated from the layer actually investing the spinal by the epidural space. Thus, since the cranial and spinal portions of the nater differ, they are described separately.

e spinal dura mater is a fibrous tube with funnel-shaped caudal end which es and forms the outermost support of the spinal cord. It consists of but yer and this corresponds to the inner layer of the cranial dura mater. It at the foramen magnum and terminates in the spinal canal at about the f the second piece of the os sacrum. It is firmly attached to the periosteum surrounding bones only in certain localities:—

(1) The upper end of the tube blends intimately with the internal periosteum of th at the margin of the foramen magnum, and thus in this locality it becomes continuous outer layer of the cranial dura mater. Also in this locality it is attached firmly, th intimately, to the periosteum of the posterior surfaces of the second and third cervical This locality may be considered the upper fixation-point of the spinal dura mate extends laterally and contributes to the connective tissue investments of each pair nerves, and as such it passes into the intervertebral foramina and becomes continuous periosteum lining each. (3) Along its ventral aspect the spinal dura mater is att numerous processes to the posterior longitudinal ligament of the vertebral cana attachments are more or less delicate, loose, and irregular, and are easily torn or cut in the specimen. They are stronger and more numerous in the cervical and lumbar regio the thoracic. (4) In the space between the dura and the walls of the vertebral canal *cavity*) lies the rich *internal vertebral venous plexus*, and along the lateral aspect th occasionally connected with the periosteum through the tissue of the walls of the vess plexus, especially in case of the vessels which penetrate the dura. Along its dorsal a spinal dura mater is practically free from the wall of the vertebral canal. (5) At

FIG. 750.—VIEW OF MEMBRANES OF SPINAL CORD FROM VENTRAL ASPECT.



and funnel-shaped extremity, opposite the second sacral vertebra, the dura suddenly into a filament extending onto the coccyx and breaking up into a number of proce become continuous with the periosteum of the dorsal surface of the coccyx. Thi is the coccygeal ligament or filum of the dura mater, and its attachment may be the lower fixation-point of the spinal dura mater. (See figs. 748 and 655). The ext tube is maintained chiefly by means of the two fixation-points, for all the other at are sufficiently loose to permit of the movements of the vertebral column.

The *inner surface* of the spinal dura mater appears smooth, but upon closer exami found to be connected with the arachnoid by a few delicate subdural trabeculæ—occ strands of connective tissue bridging the subdural space (fig. 758). Along its late the inner surface is at intervals quite firmly attached to the pia mater by the dentat ligamenta denticulata, which are prolonged from the pia through the arachnoid.

Further, it is continuous at intervals with both the pia mater and arachnoid by connective-tissue sheaths of the nerve-roots which are prolonged from the pia and the dura mater in the passage of the nerve-roots through it. The dura is also pier spinal rami of the vertebral arteries, and the connective tissue of the outer walls of th blends with all three of the meninges. The filum terminale of the pia mater extend termination of the spinal cord into the point of the funnel-shaped end of the dura there blends with it in line with the coccygeal ligament of the outer surface.

The tube of the spinal dura mater varies in caliber with the variations in the dian spinal cord. However, the termination of its cavity occurs about seven segments termination of the spinal cord. This extension contains the long intradural nerve- ing the cauda equina, and the caliber of this part, before its sudden contraction, great as that found in any other region. As each pair of nerve-roots of the ca passes outward, they lie free for a variable distance in this tubular extension of the the latter blends with and contributes to the thickness of their sheaths.

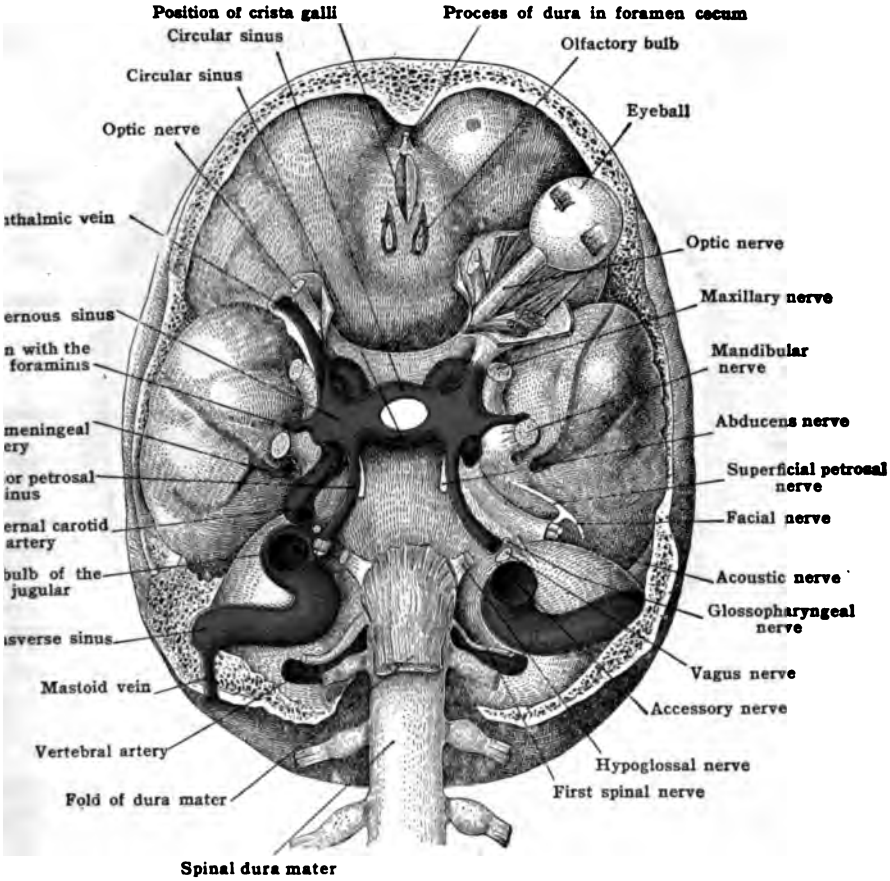
The subdural cavity, the space between the dura mater and the ara the thinnest of the meningeal spaces. Along the ventral aspect espe

rachnoid is quite closely applied to the inner surface of the dura mater. It is a small amount of cerebrospinal fluid (lymph) which prevents friction n the opposing surfaces, and is continuous with the fluid in the like space cranial meninges.

space is projected into the venous sinuses of the cranium in the region of the Pacchionian fig. 757), and its fluid is likewise in contact with the blood-vessels passing through it. obably continuous with the lymph-spaces of the nerve-roots passing through it, for fluids injected into it pass into the nerve-roots. The arachnoid is so thin and gauze- a ready interchange of fluids between the subdural and the subarachnoid spaces is possible le transfusion.

e cranial dura mater [dura mater encephali].—The dura mater investing the performs a double function—it serves as an internal periosteum for the

FIG. 751.—THE DURA MATER ENCEPHALI OF THE BASE OF THE CRANIUM.
(After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



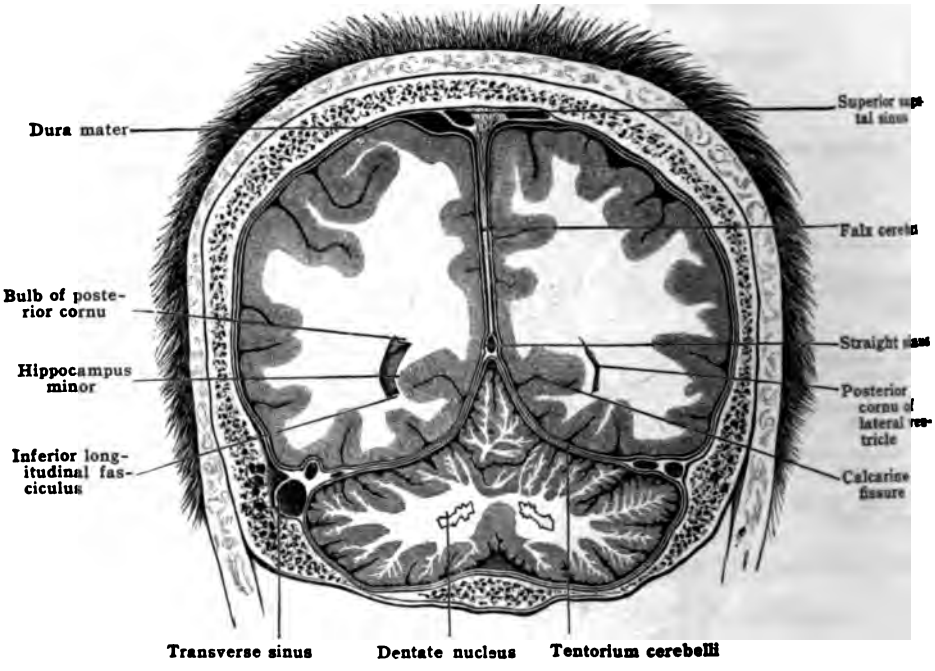
bones and gives support and protection to the brain. In conformity with ible function it consists of two layers, easily separable in the child, but adhering to each other in the adult, except in occasional localities, where xist small clefts lined with mesothelium. The large blood-sinuses and venunæ, corresponding to the internal vertebral venous plexus of the vertebral are placed between the two layers and the semilunar ganglia of the trigemo lie between them. The cranial dura begins with the adhesion of the dura mater to the periosteum at the foramen magnum, and it forms a sacvelope about the entire encephalon. Consisting of two layers, it is a much membrane than that of the spinal cord.

e *outer surface* of the cranial dura mater when torn away from the cranial appears very uneven, and when placed in water presents a flocculent ance.

This is due to the many fine bundles of connective tissue and the small blood-vessels which pass between the dura and the cranial bones and which are partially pulled out of their openings in the latter in the process of separation. The abundance of these connections, and, therefore the degree of adhesion to the bones, varies in different localities. The separation is much less difficult from the inner table of the bones of the vault of the cranium than from the bones of the base of the cavity. The adhesions to the vault of the cranium are most firm along the lines of the sutures. This is due to the fact that during the period before the sutures are closed the outer layer of the dura mater (internal periosteum) is directly continuous with the external periosteum, and, in consequence of this condition during development, the connective tissue connection is more abundant along these lines and some is caught in the closure of the sutures. Along the vault there are occasionally noticed small lymph-spaces between the bone and the dura mater. The stronger adherence to the base of the cranial cavity is due to the numerous foramina in the floor, through which all the larger cranial blood-vessels and the cranial nerves pass, and the dura mater is continuous with the connective tissue investments of these as well as with the periosteum lining the foramina. Also the floor of the cavity is more uneven than the vault, and the projections of the bones here tend to increase the firmness of attachment. The weight of the brain upon the floor probably contributes to the result.

FIG. 752.—CORONAL SECTION OF THE HEAD, PASSING THROUGH THE POSTERIOR CORNUA OF THE LATERAL VENTRICLES.

(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.



The *inner surface* of the inner layer of the cranial dura mater forms the outer boundary of the subdural cavity. Except for the occasional delicate subdural trabeculæ and the passage of blood-vessels and nerve-roots, this surface appears smooth and glistening, being lined by a layer of mesothelium and containing a small amount of the cerebrospinal lymph.

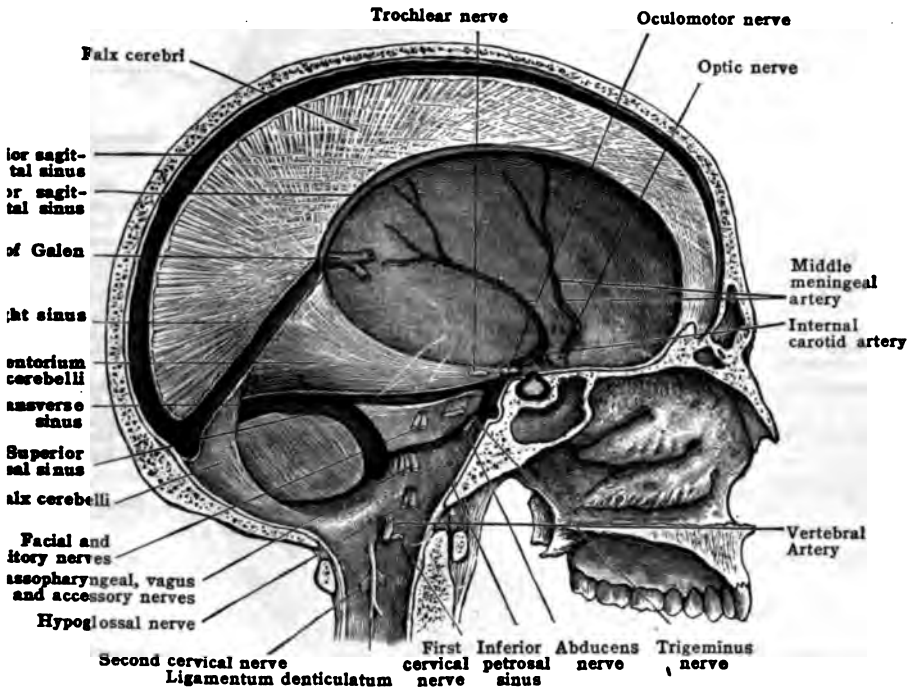
The subdural cavity of the base of the brain is prolonged a short distance outward along the roots of the various cranial nerves before it is obliterated by the blending of the dura mater with the sheaths of the nerves. This outward extension of the space is most marked about the optic and auditory nerves. In the optic especially, the dura mater remains separate from the nerve throughout its length, only fusing with its sheath upon the posterior surface of the ocular bulb (fig. 751).

In addition to its two layers, one of the most striking differences between the cranial dura mater and that of the spinal cord is that the inner layer of the former undergoes striking septa-like duplications or folds, forming exceedingly strong partitions which project between the larger subdivisions of the encephalon. These are four in number, two large and two small—the falx cerebri and the tentorium cerebelli; the falx cerebelli and the diaphragma sellæ. The larger enclose within their folds the great venous sinuses, into which most of the blood of the encephalon collects to pass outward by way of the internal jugular veins (figs. 753, 754).

The falx cerebri is the most striking of these partitions. It is a sickle-shaped which projects vertically from the vault into the longitudinal fissure between cerebral hemispheres. It begins attached to the crista galli in front, and es to terminate by blending with the superior surface of the transversely ed tentorium cerebelli. Its convex, superior border joins the outer layer of dura along the medial plane of the vault, and encloses the superior sagittal s. Its concave border is free and contains in its posterior two-thirds the ller inferior sagittal sinus.

he anterior and narrower end is often perforated and occasionally so much so as to appear coarse, fibrous reticulum. The posterior part of the concave border touches the upper ce of the corpus callosum, but the anterior part, which does not descend so low, is separated the corpus callosum by a part of the subarachnoid space. The base of the fold which s downward and blends with the upper surface of the tentorium cerebelli, contains the ght sinus running along the line of junction.

753.—THE CRANIUM WITH ENCEPHALON REMOVED TO SHOW THE FALX CEREBRI, THE NTORIUM CEREBELLI, AND THE PLACES WHERE THE CRANIAL NERVES PIERCE THE DURA ATER. (Sappey.)



The tentorium cerebelli is a large transverse, semilunar fold, concave forward scends from its central part which is elevated, and consequently it forms a shaped covering. Its superior surface is in relation with the tentorial sur- of the cerebral hemispheres, and its inferior surface conforms accurately to uperior surface of the cerebellum. The outer or convex border of the fold ached on each side to the posterior clinoid process, the superior border of the us portion of the temporal bone, the mastoid portion of the temporal bone, posterior inferior angle of the parietal bone, and the transverse ridges of ccipital bone. The transverse sinus lies in this border. From the internal ital protuberance to the mastoid portion of the temporal bone and along petrous part of the temporal bone it encloses the superior petrosal sinus.

he greater part of the inner or anterior border of the tentorium is free, and it forms the or and lateral boundaries of an arched cavity, the **tentorial notch** or foramen ovale of ioni, which encloses the mesencephalon, and through which ascend the cerebral peduncles he posterior cerebral arteries. The anterior extremities of the inner border cross the outer r, and they are attached to the anterior clinoid processes. A depressed angle is formed en the inner and outer borders of the tentorium in the middle fossa of the skull at the l portion of the posterior clinoid process, and in this angle the root of the oculomotor pierces the inner layer of the dura mater.

The nerves of the dura mater are partly derived from the sympathetic filaments wh accompany the arteries and partly from the cranial nerves. The nerves, other than sympat tic filaments, which supply the cranial dura mater are sensory fibers derived from the tri minus (chiefly) and vagus nerves, and possibly from the first cervical nerves. The branch from the trigeminus are derived from the three divisions of that nerve on either side, and it been stated that branches are given from the nasal branch of the ophthalmic division to t dura mater in the anterior fossa.

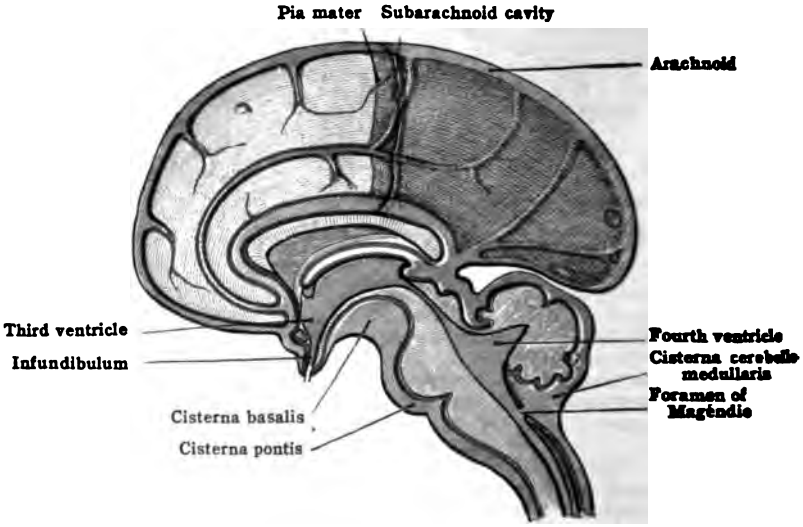
The meningeal branch of the opathalmic division of the trigeminus supplies the tentoriu that from the maxillary division accompanies the branches of the middle meningeal arte The meningeal branch of the mandibular division (nervus spinosus) passes into the skull throu the foramen spinosum and is distributed to the dura mater over the great wing of the sphen and to the mastoid cells. The *'recurrent branch of the hypoglossal nerve'* passes to the d mater of the posterior fossa of the cranium. This recurrent or meningeal branch of the hy glossal nerve really consists of fibers derived from the superior cervical ganglion of the sym thetic, and contains sensory fibers from the first and second cervical nerves. The meningeal branch of the vagus springs from the ganglion of the root of the nerve, and is distributed the posterior cranial fossa. The sympathetic filaments are distributed to the smooth mu in the walls of the blood-vessels.

The cranial **subdural cavity** is not of uniform thickness throughout, be thinner along the basal aspect of the encephalon. The lymph contained in i usually but little more than is sufficient to keep moist its bounding surfaces. is continuous with the lymph-spaces of the nerves and those of all the tis bathed, and it is continuous with the similar cavity of the vertebral canal. lymph is in free contact with the blood-vessels passing through it and w those in the tissues it bathes, and it is replenished by filtration through t walls. Though extensive, the subdural space is thin at best, for the dura mat quite closely applied to the second of the three meninges.

The Arachnoid

The arachnoid or 'serous' membrane is the middle of the three meninges o central nervous system. As in the case of the other two, an attempt is mad give this membrane a name descriptive of its texture. It is a gauzy reticulu almost web-like delicacy, which in reality pervades the space it occupies.

Fig. 756.—Diagram showing the Relations of the Pia Mater, the Arachnoid, and Subarachnoid Cavity to the Brain.

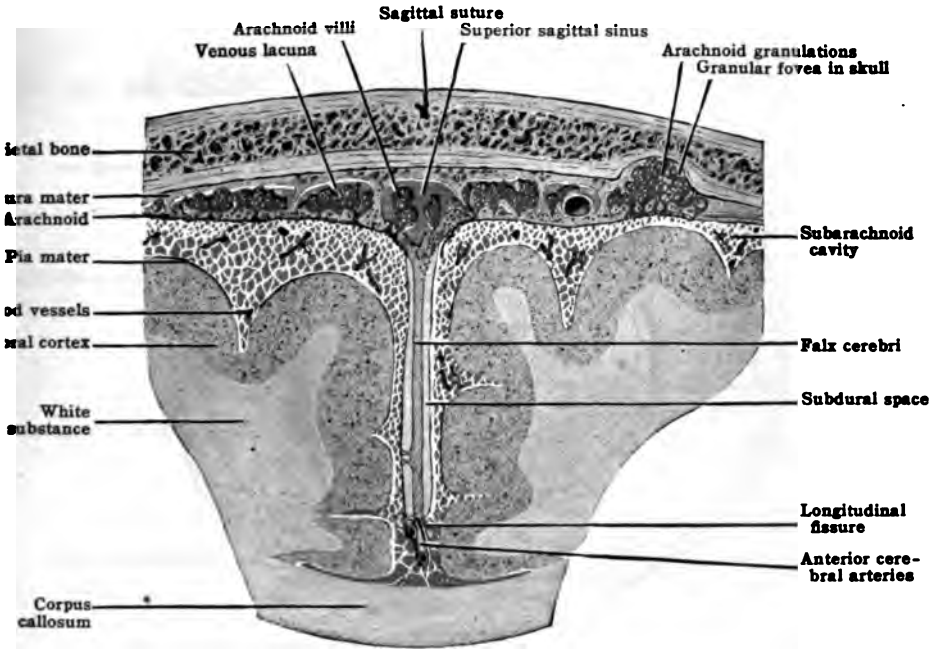


Its *outer surface*, or that closely related to the dura mater and bounding the subdural alone shows a sufficiently organized structure to merit the name of membrane. This s is covered by a layer of mesothelium which is identical with that lining the inner surface dura mater and is continuous with it by way of the cells covering the blood-vessels, the roots, the ligamenta denticulata of the spinal cord, and the occasional delicate tra passing between the dura mater and the arachnoid. Immediately under the mesoth the connective-tissue fibers of the arachnoid are woven into a very thin, more or less co web. This, however, quickly grades into a loose, spongy reticulum which pervades th subarachnoid cavity throughout, and the strands of which are directly continuous in

compact tissue of the pia mater. Thus an *inner surface* can hardly be claimed. This sponge-like arachnoid tissue holds the cerebrospinal fluid of the subarachnoid cavity, meshes of the sponge constituting a reticular web of intercommunicating spaces lined by thelial cells covering the strands of the web. In addition, the cavity is traversed by the al and cranial nerves, by the blood-vessels passing to and from the pia, and, in the vertebral l distinctively, it is traversed by the ligamenta denticulata and the filum terminale. ugh these the arachnoid is further continuous with the pia mater. The cranial subarachnoid ty is larger, and the strands of the web are relatively more abundant than in that of the bral canal.

The cranial arachnoid is directly continuous into that of the spinal cord, and he two localities does not differ as much as does the dura mater. Within the nium, the arachnoid does not closely follow the surface of the encephalon. It olded in between the cerebellum and cerebral hemispheres, following the con- r of the tentorium cerebelli, but it does not fold into the fissures and sulci ept the anterior part of the longitudinal fissure and slightly into the lateral lvian) fissure. Otherwise it fills in the inequalities of surface of the encephalon,

757.—Coronal Section Transverse to the Great Longitudinal Fissure, Showing the Meninges. (Spalteholz.)



outer surface forming a sheet enveloping the whole and bridging over the sulci the deeper grooves between the gross divisions. Upon the summits of the gyri it nore closely applied to the pia mater, and there its reticulum becomes more se. The sulci, occupied by its reticulum, form a continuous system of channels d more abundantly by the cerebrospinal fluid.

The arachnoid folds in between the cerebellum and medulla oblongata, and the base of the brain it ensheathes the olfactory bulbs and tracts, and its outer face forms a continuous sheet stretching from one temporal lobe to the other bridging over the interpeduncular fossa and the inequalities of surface in the ion of the optic chiasma and the stems of the lateral fissures. Obviously, refore, the subarachnoid cavity between its outer surface and the pia mater is considerable depth in certain localities. These localities comprise the *subchnoid cisternæ*. These occur where the cavity at the base of the brain is espely large, and make possible a 'water-bed' which serves to protect the brain from rious contiguity with the bones.

The following cisterns are distinguished (fig. 756):—

1) **The cisterna basalis** lies at the base of the cerebrum and is divided by the optic chiasma two parts —(*a*) the *cisterna chiasmatis* and (*b*) the *cisterna interpeduncularis*.

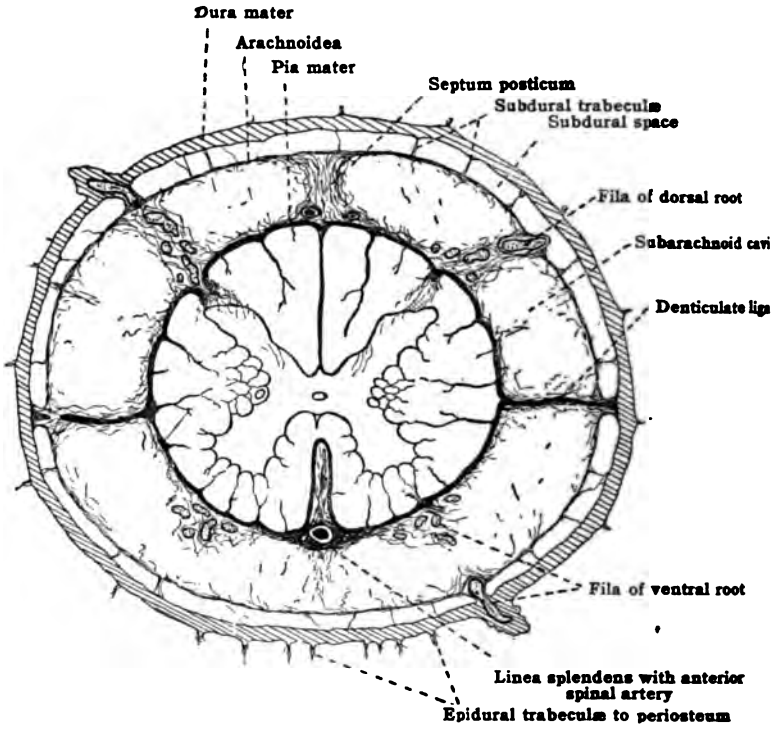
(2) **The cisterna pontis** is situated about the pons, especially in its basilar sulcus and transverse fissures of either border, and is continuous anteriorly with the cisterna basalis posteriorly with the subarachnoid cavity about the medulla.

(3) **The cisterna superior** lies in the angle between the splenium of the corpus callosum the superior surfaces of the cerebellum and the mesencephalon, and is connected ventr around the cerebral peduncles, with the cisterna basalis.

(4) **The cisterna cerebellòmedullaris** (cisterna magna) is the cavity between the infe surface of the cerebellum and the dorsal surface of the medulla oblongata. It is continu below into the spinal subarachnoid space. The fluid in this cavity is directly continuous w that in the fourth ventricle by way of the foramen of Magendie (median aperture), and t lateral apertures of the fourth ventricle.

Pacchionian bodies [granulationes arachnoideales] (fig. 757).—In certain situ tions, more particularly along the margins of the longitudinal fissure, particularly in the frontal region, and to a much less extent upon the superior surface the vermis of the cerebellum. the subarachnoid tissue elaborates numerous sm

FIG. 758.—DIAGRAM OF TRANSVERSE SECTION OF UPPER THORACIC REGION OF THE SPI CORD SHOWING THE RELATIONS OF THE SPINAL MENINGES AND THEIR CAVITIES



ovoid or villus-like projections, the Pacchionian bodies. Each arach villus consists of a retiform network of subarachnoid connective tissue v meshes are filled with cerebrospinal fluid. The Pacchionian bodies on the v of the brain project through the inner layer of the dura mater, both into the rior sagittal sinus and into the venous spaces or parasinoidal sinuses which the sides of that sinus, and, as they become larger, they press against the layer of the dura and produce ovoid depressions in the inner plate o cranium. Within the sinuses they are covered by the endothelium lining sinuses.

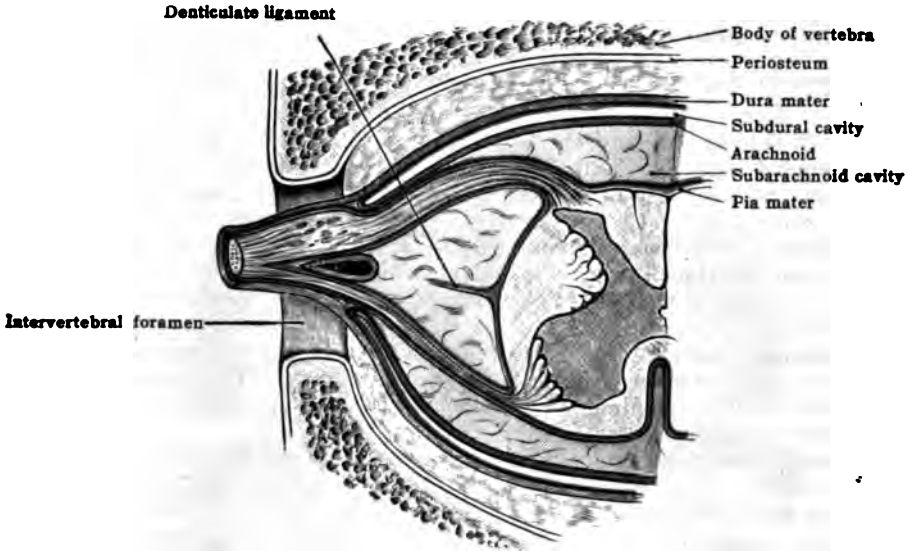
They probably facilitate the passage of lymph from the subarachnoid cavity into th sinuses, and thus may aid in relieving pressure within. On the other hand, through th cerebrospinal fluid is replenished at need from the blood plasma. They are not pre birth, but they appear at the tenth year and increase in number and size with advancing They are less marked in the female than in the male.

The spinal arachnoid (figs. 758, 759) is a loose, reticular sac which is capacious about the lumbar enlargement of the spinal cord and about the equina. Like that of the encephalon, the portion next to the dura mater

[illegible]mbles a membrane, being a loosely organized feltwork, covered on the side of [illegible] subdural cavity by a layer of mesothelium common to that cavity. Through- [illegible] its length the spinal subarachnoid cavity is relatively wide, and, as in the [illegible]nium, contains a fine, spongy, web-like reticulum, numerous threads of which [illegible] continuous with the pia mater. This spongy tissue is the inner modification [illegible]he arachnoid, and its meshes are occupied by the cerebrospinal fluid. It is [illegible] so abundant as in the cranial subarachnoid cavity.

[illegible]n addition to the delicate threads, the arachnoid is more firmly attached to the pia mater [illegible] three imperfect partitions. The most continuous of these is arranged along the dorsal [illegible]-line and is known as the **septum posticum** of Schwalbe (subarachnoid septum). This may [illegible]described as a linear accumulation of the spongy tissue which pervades the subarachnoid [illegible]ce. It is most incomplete in the upper cervical region, where it becomes merely a line of [illegible]ds connecting with the pia. It is most complete as a septum in the lower cervical and in [illegible] thoracic region, but at best it maintains a spongy character. The other two partitions are [illegible]med by the **denticulate ligaments**, which extend laterally from either side of the spinal cord, [illegible]necting the pia and dura mater and involving the arachnoid in passing through it. Within [illegible] subarachnoid cavity these form more or less complete septa, though outside the arachnoid [illegible]y are attached to the dura only at the intervals of their pointed dentations. They belong [illegible] the pia matter and will be described with it. The arachnoid is further continuous with [illegible] pia by way of the connective tissue sheaths of the roots of the spinal nerves and the blood- [illegible]sels passing through the subarachnoid cavity.

FIG. 759.—DIAGRAM SHOWING RELATIONS OF MENINGES TO SPINAL NERVE-ROOTS.



Vessels and nerves.—The arachnoid has no special blood-supply and probably no special nerves other than those supplying the walls of the blood-vessels passing through it.

The cerebrospinal fluid.—The subarachnoid cavity is the great lymph-space of the central nervous system. That of the spinal region is directly continuous into that of the cranium, and the fluid contained communicates freely with that in the ventricles of the brain and the central canal of the medulla and spinal cord by way of the foramen of Magendie or medial aperture into the fourth ventricle. In addition, there are the lateral apertures into the fourth ventricle and there is possibly an interchange of fluid between the lateral ventricle and the subarachnoid cavity of the base of the brain by diffusion through the thin floor of the choroid fissure. The arachnoid throughout is not a membrane sufficiently compact to seriously oppose diffusion between the fluid contained in its cavity and that contained in the subdural cavity, and the mesothelium covering it probably even facilitates such activities. The cerebrospinal fluid occupying the cavities is a transparent fluid of a slight yellow tinge, characteristic of the lymph in other lymph-spaces of the body. It is not very great in amount, probably never exceeding 200 c.c. in normal conditions. It is greatest in amount in old age, when the cavities are larger, due to atrophy and shrinkage of the nervous tissues. It collects from the lymph spaces in the meninges, and from exudation through the walls of the vascular choroid plexuses and sinuses of the system it bathes. Its amount may be temporarily increased by a period of increased blood-pressure in the cranial vessels. Pressure due to its abundance may be relieved by diffusion through the membranes containing it, and especially through the villi of the Pacchionian bodies into the venous sinuses and lacunæ, and thence into the venous system through the internal jugular veins.

The Pia Mater

The **pia mater,** the third of the meninges, is a thin membrane which envelops and closely adheres to the entire central nervous system and sends numerous processes into its substance. It likewise contributes the most proximal and compact portion of the sheaths of the nerve-roots in their passage through the meningeal spaces. It is very vascular in that the superficial plexuses of blood-vessels of both the brain and spinal cord ramify in it as they give off the central branches into the nervous substance. The structure and arrangement of the membrane vary somewhat in the cranial and spinal regions.

The spinal pia mater consists of two layers, an inner and an outer. It is thicker and more compact than that of the encephalon, due to the extra development of its outer layer, which is in the form of a strong, fibrous layer with the fibers arranged for the most part longitudinally.

Its inner layer is a thin feltwork of fibers which is closely adherent to the surface of the spinal cord throughout, sending numerous connective-tissue processes into it which contributes to the support of the nervous tissues. The larger of these processes carry with them the numerous intrinsic blood-vessels from the superficial plexus. The two layers are closely connected with each other, and are distinguished by the difference in the arrangement of their fibers. The spinal pia mater also appears less vascular than the cranial from the fact that the blood-vessels composing the plexus lying in it are obviously much smaller than those of the encephalon.

The membrane dips into the anterior median fissure and also bridges it over by forming an extra thickening along it. This thickening appears as a band along the mid-line of the ventral surface of the cord, the **linea splendens** (fig. 750). It carries, or ensheathes, the anterior spinal artery, the largest of the arterial trunks of the superficial plexus (figs. 665, 758).

The pia mater contributes the innermost and most compact portion of the epineurium of each of the nerve-roots, and thus, upon the roots, it is prolonged laterally into the intervertebral foramina, where the dura mater blends with it in producing the increased thickness of the epineurium.

From each side of the cord the pia mater gives off a leaf-like fold, the **denticulate ligament** (figs. 749, 750, 758), which spreads laterally toward the dura mater midway between the lines of attachment of the dorsal and ventral nerve-roots. The outer edge of this fold is dentate or scalloped into about twenty-one pointed processes, which extend through the arachnoid and are attached to the inner surface of the dura mater. The dentations are usually attached between the levels of passage of the roots of the spinal nerves, the uppermost one a little cephalad to the first cervical nerve and the region where the vertebral artery perforates the dura mater; the most caudal one between the last thoracic and first lumbar nerves, or, between the last two thoracic nerves. The ligaments, aided slightly by the septum posticum, serve to hold the spinal cord more or less suspended in the subarachnoid cavity.

Below, at the sudden, conical termination of the spinal cord in the lumbar portion of the vertebral canal, the pia mater is spun out into a thin, tubular filament, the **filum terminale,** which continues caudalward into the sac formed by the dura mater about the cauda equina, and at the end fuses with the dura mater in line with the filum of the spinal dura mater (coccygeal ligament) of the outside (figs. 655, 748).

The cranial pia mater is closely applied to the external surface of the brain, dipping into all the fissures, furrows, and sulci. It is connected with the arachnoid by numerous filaments of the spongy subarachnoid tissue and by the blood-vessels traversing the subarachnoid cavity. It is also pierced by the cranial nerves, and furnishes them their sheaths, which become continuous with the arachnoid and dura mater.

Its *outer surface* bounds the subarachnoid cavity. It is with difficulty separable into two layers of mixed white fibrous and elastic connective tissue, with slightly pigmented connective-tissue cells enmeshed between them. Its *inner surface* sends a large number of fibrous processes into the nervous substance, which blend with the neuroglia and aid in the support of the nervous elements. The larger of these processes accompany the central arterial and venous branches of the rich superficial plexuses of blood-vessels contained in the pia on the surface of the brain. Pieces of the pia when pulled off and placed in water present a flocculent appearance as to their inner surfaces, due to these processes having been pulled out.

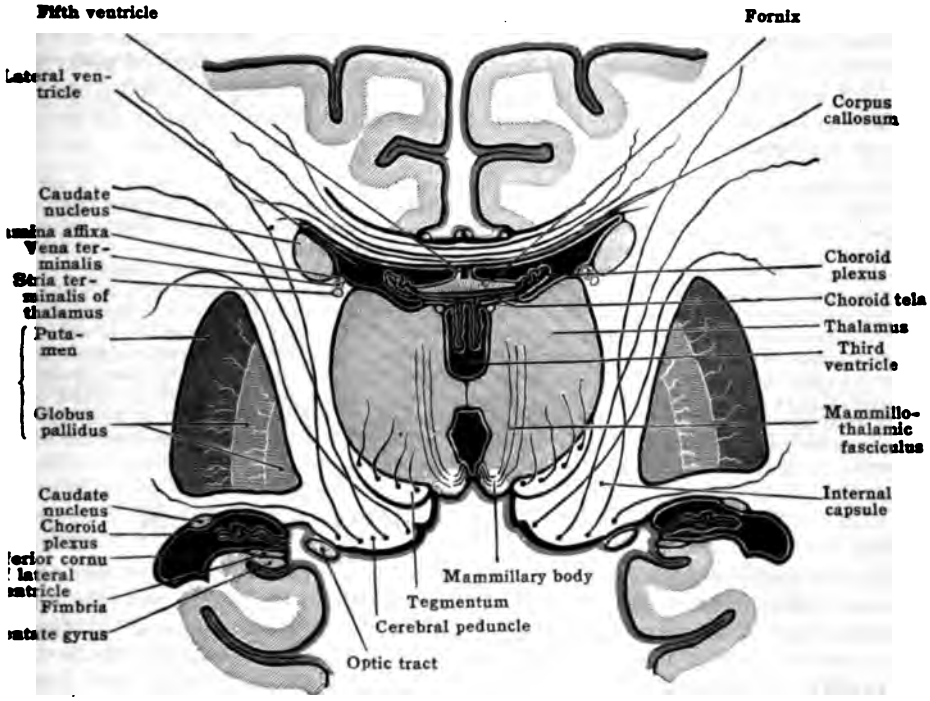
The cranial pia mater sends strong, vascular duplications into two of the great transverse fissures of the encephalon; viz., the *transverse cerebellar fissure,* between the cerebellum and the medulla oblongata, and the *transverse cerebral fissure,* between the cerebellum, mesencephalon, and thalamencephalon below, and the

hanging cerebral hemispheres. These duplications are spread over the cavi- of the fourth and third ventricles, and are known as the *choroid telæ* of these tricles respectively.

The tela chorioidea of the fourth ventricle is that duplication which extends the transverse cerebellar fissure, between the inferior surface of the cerebellum rmis chiefly) and the dorsal surface of the medulla (fourth ventricle). The two ers of this fold of the pia remain separate and a portion of the cisterna posterior he subarachnoid cavity lies between them.

The inferior of the layers is the tela chorioidea proper (fig. 680.) It is triangular in shape, with base cephalad at the nodule of the vermis and its apex below at the level of the tuber vermis. superior layer of the fold is the pia mater of the inferior vermis. The tela chorioidea proper trengthened by the epithelioid roof (ependyma) of the fourth ventricle and is continuous with pia mater of the medulla oblongata and spinal cord. In roofing over the calamus scriptorius onstitutes the obex. A little above the calamus scriptorius it is pierced by the foramen of gendie and the two lateral apertures into the fourth ventricle occur in its superolateral ions.

. 760.—Diagram of Coronal Section of Cerebrum through Middle of Thalamencephalon Showing Relations of Pia Mater Encephali and Choroid Plexuses of Third and Lateral Ventricles.



In front of the foramen of Magendie the vessels of the choroid tela, which are ived from the posterior inferior cerebellar arteries, form two longitudinal, ulated strands which invaginate the epithelioid roof of the ventricle, one on ıer side of the mid-line, and project into its cavity. These form the **choroid xus of the fourth ventricle.** At the base of the triangular tela the two choroid **xuses** join each other and then turn transversely lateralward into the lateral re- **ses** of the ventricle, where they pass behind the restiform bodies and form the *nucopiæ.*'

The choroid tela of the third ventricle, or **velum interpositum,** is a triangular olication of the pia mater which extends between the fornix above and the thal- i and third ventricle below, and in front fuses with the brain substance at the erventricular foramina (figs. 727, 760).

In the transverse cerebral fissure the layers of pia forming this tela are separate, the upper ıg the pia of the under surface of the corpus callosum and continuous with that of the ten- al surfaces of the occipital lobes; the lower being continuous into the pia enfolding the eal body and covering the mesencephalon, anterior medullary velum, and cerebellum. The

layers forming the portion of the duplication which roofs over the third ventricle are loosely adherent to each other and form the tela chorioidea proper of that ventricle. The upper surface of this portion is in relation with the fornix and its lower surface, covered by the ependyma lining of the ventricle, lies laterally over the superior surfaces of both thalami, and medially forms the roof of the third ventricle between them. The epithelioid ependyma is continuous with that covering the thalami and lining the ventricles. Between the two layers of this portion, and embedded in a small amount of the spongy subarachnoid tissue retained between them, are the two veins of Galen (internal cerebral). Posteriorly these veins unite in the region of the pineal body to form the single great cerebral vein (*vena cerebri magna*) which empties into the straight sinus. Anteriorly the veins of Galen receive the veins of the septum pellucidum from each lamina of the septum pellucidum above, and also the terminal vein (vein of corpus striatum), lying in the stria terminalis of the thalamus, empties into them from each side.

The choroid tela of the third ventricle or velum interpositum extends laterally between the fornix and fimbria above and the stria terminalis of the thalamus below into each lateral ventricle. The blood-vessels of the border projecting into the lateral ventricle are amplified into a plexus which appears as a strip of reddish, lobulated, villus-like processes known as the **choroid plexus of the lateral ventricle.** The plexus, being in the border of the tela, begins at the interventricular foramen, extends through the body or central portion of the lateral ventricle, and downward into its inferior cornu. It is most developed at the junction of the body with the inferior cornu, and is there known as the **glomus chorioideum.**

From the inferior surface of the choroid tela of the third ventricle, hanging down on either side of the midline into the cavity of the ventricle, are two other longitudinal, lobulated strands of blood-vessls which are the **choroid plexuses of the third ventricle.** At the anterior end of the third ventricle these two plexuses join with each other and also with the plexus of the lateral ventricle of each side through the interventricular foramina.

The choroid plexuses of both the ventricles are covered by a layer of ependyma, *epithelial choroid lamina*, which is but a reflection of the ependyma lining the cavities throughout and represents the remains of the germinal layer of the embryonic brain-vesicles. The blood-vessels of the choroid plexus of the lateral ventricle receive blood by the choroid artery (a direct branch of the internal carotid), which enters the plexus through the choroid fissure immediately medial to the uncus, and also by the choroidal branches of the posterior cerebral artery, which supply the plexus of the body of the ventricle. The choroid plexuses of the third ventricle receive blood chiefly by branches from the superior cerebellar arteries. The greater part of the blood of both plexuses passes out by way of the tortuous choroid veins, which, at the interventricular foramina, empty into the venæ terminales (veins of the corpus striatum), which, in their turn, go to form the greater part of the veins of Galen. Thence the blood passes by way of the vena cerebri magna into the straight sinus. It is probable that the cerebrospinal fluid of the third and lateral ventricles is derived chiefly by diffusion through the walls of the vessels of the choroid plexuses.

THE PERIPHERAL NERVOUS SYSTEM

The intimate connection and consequent control exercised by the central nervous system over all the tissues and organs of the body is attained through the peripheral part of the nervous system. This part or system, abundantly attached to the central system, consists of numerous bundles of nerve-fibers which divide and ramify throughout the body, anastomosing with each other and forming various plexuses, large and small. The terminal rami divide and subdivide until the divisions attain the individual nerve-fibers of which they are composed, and finally the nerve-fibers themselves divide and terminate in relations with their allotted peripheral elements. It is by means of these that stimuli arising in the peripheral tissues are conveyed to the central system, and that impulses in response are borne from the central system to the peripheral organs. For purposes of description, as well as upon the basis of certain differences in structure, arrangement, and distribution, the peripheral nervous system is separated into two main divisions: (1) **the craniospinal** and (2) **the sympathetic system.**

Both of these divisions include numerous ganglia or peripheral groups of nerve-cells from which arise a considerable proportion of the fibers forming their nerve-trunks, but neither of the divisions may be considered wholly apart from the central system nor are they independent or separate from each other. The sensory or afferent fibers of the craniospinal nerves pass by way of the afferent nerve-roots into the central system and contribute appreciably to its bulk, and the motor or efferent fibers of these nerves have their cells of origin (nuclei) situated within the confines of the central system. The sympathetic system is intimately asso-

ciated with the craniospinal, and consequently with the central system—(1) by means of fibers which enter and terminate in the craniospinal ganglia and the spinal cord and brain to supply the blood-vessels there; (2) by efferent fibers of central origin which course in the nerve-trunks and terminate in the ganglia of the sympathetic system; (3) also, the sympathetic trunks usually contain numerous afferent craniospinal fibers which thus course to their peripheral termination, usually in the so-called 'splanchnic area,' or domain of the sympathetic, in company with the sympathetic fibers. Likewise the peripheral branches of the craniospinal nerves usually carry for varying distances numerous sympathetic fibers which are on their way to terminate upon their allotted peripheral tissue-elements.

The following differences between the craniospinal and sympathetic systems of nerves may be cited: (1) The craniospinal nerves are anatomically continuous with the brain and spinal cord; probably no fibers arising in the sympathetic ganglia actually enter the central system other than for the innervation of its blood-vessels. (2) The ganglia of the craniospinal nerves all lie quite near the central axis, in line on either side of it, and at more or less regular intervals; the sympathetic ganglia are scattered throughout the body tissues, are far more numerous and more variable in size, and many of these ganglia are not symmetrical for the two sides of the body. (3) The craniospinal nerves are paired throughout, and the nerves of each pair are symmetrical as to their origin and also, with certain exceptions (notably the vagus), in their course and distribution; most of the larger and more proximal of the sympathetic nerve-trunks and plexuses are symmetrical for the two sides of the body; many of them are not, and many of the smaller and most of the more peripheral nerves and ganglia, large and small, are not paired at all. (4) Even in their finer twigs, the craniospinal nerves of the two sides probably do not join with each other across the midline of the body; the sympathetic nerves do so abundantly, especially within the body-cavity. (5) The craniospinal nerves are distributed to the ordinary sensory surfaces of the body and the organs of special sense and to the skeletal, (striated or 'voluntary') muscles of the body; the sympathetic fibers are devoted chiefly to the supply of the so-called involuntary muscles of the body, including the smooth muscle in the walls of the viscera and in the walls of the blood and lymph vascular-systems, and also to (striated) cardiac muscle, while others serve as secretory fibers to the glands. (6) Craniospinal nerve-fibers are characterized in general by well-developed medullary sheaths, making the nerves appear as white strands; most of the sympathetic fibers are non-medullated, some are completely and some partially medullated, but none possess as thick medullary sheaths as those of the craniospinal nerves. Thus sympathetic nerves appear as gray strands n the periphery.

The craniospinal nerves.—There are forty-six pairs of craniospinal nerves, of which thirty-one pairs are attached to the spinal cord (spinal nerves) and fifteen pairs to the encephalon (cranial nerves). The spinal nerves are the more primitive and retain the typical character, i. e., each is attached to the spinal cord by two roots, a dorsal or sensory ganglionated root, and a ventral, which is motor and not ganglionated. Most of the cranial nerves have only one root, which in some cases corresponds to a dorsal root and therefore has a ganglion, and in other cases corresponds, physiologically at least, to a ventral root of a spinal nerve. Among other individual differences, the fibers of the first cranial nerve, for example, do not collect to form a distinct nerve-trunk and its fibers are not medullated.

I. THE CRANIAL NERVES

Customarily, the cranial nerves are described as comprising twelve pairs and each is referred to by number. However, present knowledge of their origin, central connections and peripheral distribution suggests that those enumerated as the fifth, seventh, and eighth pairs under the old nomenclature are better each separated into its two component nerves, each of which merits a separate description and a separate name. None of the cranial nerves corresponds closely to a typical spinal nerve with its motor and sensory root. The so-called motor portion of the fifth is no more its motor root than is the seventh nerve. The sensory portion of the seventh is not wholly sensory and rather resembles the ninth pair in distribution, and it has long been commonly referred to as a separate nerve. The two parts of the eighth nerve, both sensory, are known to be wholly different in functional character and are so named. Further, the names of the nerves, descriptive of their function, are pedagogically much more efficient than the use of numbers in referring to them.

Separating the three pairs mentioned, each into its two nerves, gives fifteen pairs instead of twelve. Their names and functional nature are given in the fol-

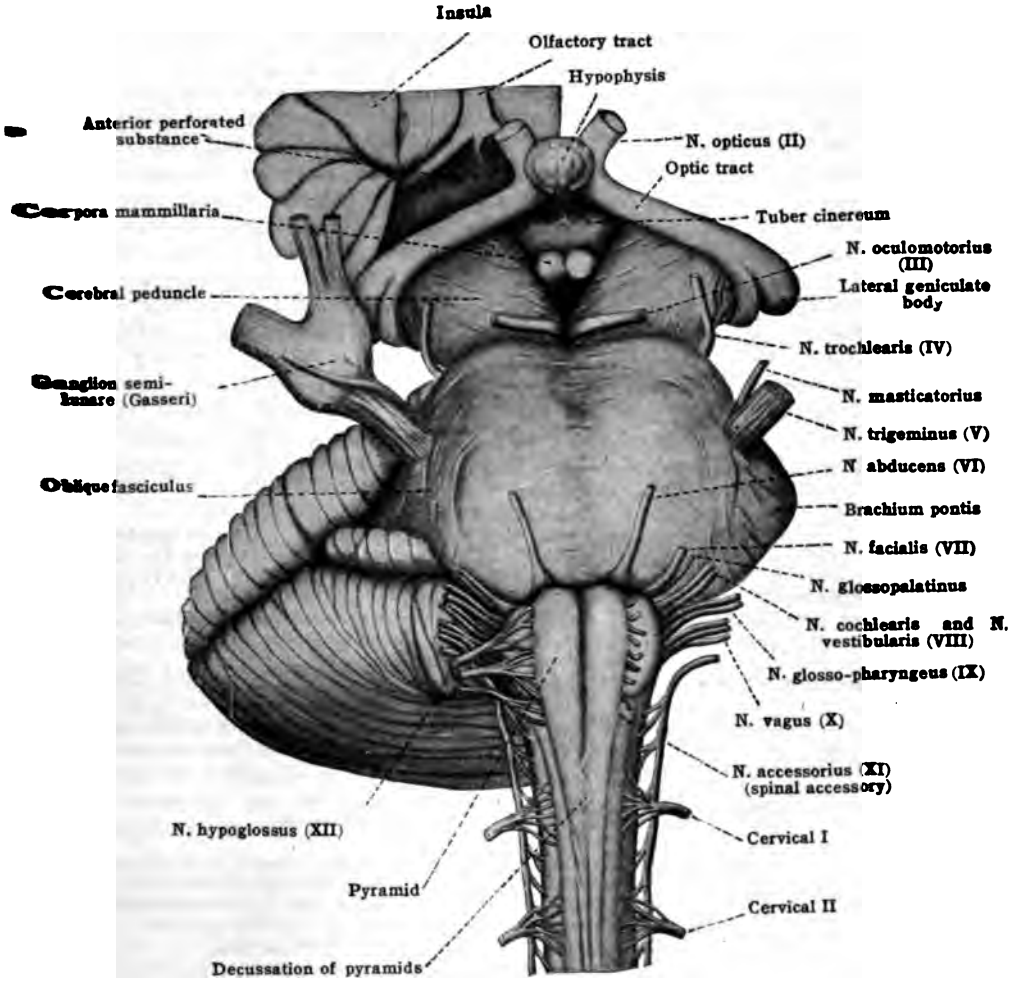
lowing table. The Roman numerals given in parentheses correspond to the n numbers given when twelve pairs only are considered. It is also customar enumerate the cranial nerves from in front backward and caudalward, and custom is followed here, but again it would be pedagogically better to take t in the reverse order. Then each in its turn could be directly considered a continuous series with the spinal nerves below and the similarities to and pro sive modifications from the spinal type could be better realized. It will be rem bered that *somatic efferent* or *motor* fibers are those which terminate directly t the fibers of skeletal muscle while *visceral efferent* or motor fibers transfer t impulses to sympathetic neurones, and the axones of the latter terminate t gland cells and upon the fibers of cardiac and smooth muscle.

NAME	NATURE	GENERAL DISTRIBUTION
Olfactory (I)	Sensory	Olfactory region, nasal epitheliu
Optic (II)	Sensory	Retina.
Oculomotor (III)	Motor { Somatic	Eye-moving muscles.
	Motor { Visceral	Ciliary body, iris.
Trochlear (IV)	Motor-somatic	Eye-moving muscles.
Abducens (VI)	Motor-somatic	Eye-moving muscles.
Trigeminus (V)	Sensory	Face, mouth, and scalp.
Masticator (*minor part or motor root of trigeminus*)	Motor-somatic	Muscles of mastication.
Facial (VII)	Motor { Somatic	Facial muscles.
	Motor { Visceral (?)	Salivary glands, vessels (?).
Glossopalatine. (*Intermediate part of facial.*)	Sensory { Somatic / visceral }	Tongue, palate.
	Motor-visceral	Salivary glands.
Cochlear (*auditory*) (VIII)	Sensory	Internal ear (cochlea)
Vestibular (*equilibrator*) (VIII).	Sensory	Semicircular canals, utriculus culus.
Glossopharyngeal (IX)	Sensory { Somatic / Visceral }	Tongue, palate, pharynx.
	Motor { Somatic	Pharynx.
	Motor { Visceral	Glands and vessels.
Vagus (X)	Sensory { Visceral / Somatic }	Alimentary canal, lung, heart
	Motor { Somatic	Larynx, pharynx.
	Motor { Visceral	Alimentary canal, heart, laryn chea, lung.
Hypoglossal (XII)	Motor-somatic	Tongue-moving muscles.
Spinal accessory (XI)	Motor { Somatic	Neck and shoulder-muscles.
	Motor { Visceral	Pharynx, larynx, heart.

The cranial nerves, like the spinal nerves, are developed from cells of the t tive neural tube and, beginning with the trigeminus downward, all the se nerves are developed from the cells corresponding to those of the ganglion which give origin to the spinal ganglia and the sensory components or dorsal of the spinal nerves. Otherwise between the cranial nerves and the spinal r there are many important differences. Each spinal nerve has a dorsal or se root, which springs from the cells of a spinal ganglion; a ventral or motor whose fibers are processes of the nerve-cells which are situated in the walls central system, and at their attachment to the surface of the cord the two roo some distance apart. Only one of the (usually recognized) twelve pairs of c nerves corresponds at all closely with typical spinal nerves. This one trigeminus which possesses a sensory ganglionated root and near its attac is accompanied by a small motor nerve, the masticator, which serves in small part as a corresponding motor root of the trigeminus. But even in th where the similarity between the cranial and spinal nerves is greatest, the still points of anatomical difference, which if not essential are very obvio the so-called motor root joins not the whole but only with one branch of th sory portion. The two are only slightly separated from each other at attachment to the surface of the brain. All the other cranial nerves diff still more marked manner from typical spinal nerves. The olfactory nerv afferent nerve whose cells of origin (olfactory ganglion) are scattered i mucous membrane of the nose, an organ of special sense, and its fibers a collected together into a nerve-trunk, but pass, as a number of small bu through the lamina cribrosa of the ethmoid bone directly into the olfactory The optic nerve is also a nerve of special sense. Its fibers form a very di

[redacted]dle, similar in appearance to an ordinary nerve, from which, however, it [redacted]ers essentially, both with regard to structure and development; for, unlike an [redacted]nary nerve, its connective tissue consists to a large extent of neuroglia instead [redacted]rdinary connective tissue, and its component nerve-fibers are of much smaller [redacted]ber than those of an ordinary nerve. It represents the location of the original [redacted]ic stalk, a diverticulum from the neural tube, and it associates the retina (optic [redacted]), a bit of modified cortex, with the encephalon. The optic nerve, therefore, [redacted]responds more closely with an association tract of the central system than with [redacted] ordinary nerve.

FIG. 761.—SURFACE ATTACHMENT OF THE CRANIAL NERVES.
(After Allen Thomson modified.)



The oculomotor, trochlear, abducens and hypoglossal nerves are practically purely motor nerves, and thus correspond only with the ventral roots of spinal nerves. The spinal accessory is purely motor. Its fibers arise from the cells of the anterir horn of the spinal cord and from a nucleus of the medulla which represents a displaced portion of that horn, but they do not leave the surface of the spinal cord and brain in the usual situation of ventral roots. On the contrary, they emerge in a series of rootlets from the lateral funiculus of the cord on the dorsal side of the ligamentum denticulatum, and from the upward prolongation of this funiculus.

The cochlear and vestibular are nerves of special sense, and in some respects both correspond closely with the dorsal root of a typical spinal nerve, and the gan-

glia of both represent spinal ganglia, but their distribution is limited to the membranous labyrinth.

The vagus and glossopharyngeal nerves contain both motor and sensory fibers, but they differ from typical spinal nerves in that the motor fibers, in company with the sensory, issue from the posterolateral sulcus of the medulla, and they are intimately intermingled, from their origin, with the sensory fibers, which latter arise from ganglia interposed in the trunks of the nerves and otherwise correspond with the fibers of the dorsal root of a typical spinal nerve.

Superficial attachments and origins.—It is customary to speak of the area where the nerve-fibers leave or enter the brain substance as the superficial attachments of the cranial nerves, and the groups of cells from which the fibers spring, and about which they terminate, as their nuclei of origin and termination, respectively.

THE OLFACTORY NERVES

The **olfactory nerve-fibers** (fig. 762) are the central processes of the bipolar olfactory nerve cell-bodies situated in the olfactory region of the nasal mucous membrane. In man, the olfactory region comprises the epithelium upon the superior third of the nasal septum and that upon practically the whole of the superior nasal concha. The area is relatively small as compared with that of other mammals and, as in other mammals, is characterized by an increased thickness of the epithelium and a yellowish brown color when fresh. The peripheral processes of the olfactory cell-bodies (the olfactory ganglion) are short and extend only to the surface of the olfactory epithelium. As the central processes pass upward from their cells of origin they form subepithelial plexuses in the mucous membrane, and from the upper parts of these plexuses, immediately below the lamina cribrosa of the ethmoid, about twenty filaments issue on each side. These filaments comprise the **olfactory nerve.** They are non-medullated. They pass upward, through the foramina in the lamina cribrosa, into the anterior fossa of the cranium in two rows, and after piercing the dura mater, the arachnoid, and the pia mater, they enter the inferior surface of the olfactory bulb.

They contribute to the superficial stratum of nerve-fibers on the inferior surface of the olfactory bulb, ending in the *glomeruli* formed by the terminal ramifications of the olfactory nerve-fibers in synapsis with the similar ramifications of the main dendrites of the large mitral cells which lie in the deeper part of the gray substance of the olfactory bulb.

The olfactory nerve-fibers are gray fibers, since they do not possess medullary sheaths, and they are bound together into bundles by connective-tissue sheaths derived from the pia mater, from the subarachnoid tissue, and from the dura mater.

Central connections—The olfactory impulses are transmitted by way of the peripheral processes of the olfactory neurones through the cell-bodies and the olfactory nerve-fibers and through the glomeruli to the mitral cells. Thence they are carried by the central processes (axones) of the mitral cells, which pass backward along each olfactory tract and its three olfactory striæ. (See Rhinencephalon, p. 901.)

THE TERMINAL NERVE (*Nervus Terminalis*)

In lower vertebrates and recently in those mammals whose sense of smell is relatively much more developed than in man, three nerves have been found in relation with the olfactory apparatus:—(1) The olfactory nerve proper whose fibers, as noted above, are the central processes of the nerve cell-bodies situated in the epithelium of the olfactory region of the nasal mucosa, and which terminate in the olfactory bulb; (2) the vomeronasal nerve, whose fibers are the central processes of nerve cell-bodies situated in the epithelium of the vomeronasal (Jacobson's) organ and which pass caudalward in the submucosa and upward to join the filaments of the olfactory nerve proper and which, in the dog, cat, rabbit, rat, etc., terminate in the accessory olfactory bulb—a small protuberance possessed by these animals on the posteromedial aspect of the olfactory bulb proper; (3) the terminal nerve, a small plexiform nerve, which unlike the other two is ganglionated.

In man, the vomeronasal (Jacobson's) organ is rudimentary after birth and, therefore, the vomeronasal nerve is not present, the only fibers for the vomeronasal region being those of general sensibility from the trigeminus and sympathetic fibers common to the epithelium of the entire nasal fossa.

The terminal nerve has been recently described as present in the human fetus and in the adult of other animals. It is mentioned here because of the expressed belief that it is an added cranial nerve and that it is present in the human adult. From the observations recorded for human and rabbit fetuses and the adult dog, ox, horse, squirrel and cat, the following description may be given: It is variably plexiform throughout its course. Peripheral twigs have been described for it as distributed to the mucosa of the nasal septum, some to the mucosa joining the olfactory

region while other and larger twigs extend further forward and are distributed to mucosa of the vomeronasal organ, accompanying and sharing in the distribution of the vomeronasal nerve when this is present. It is not certain that many of the fibers of these twigs are not fibers of the trigeminus and vomeronasal nerves. Its central connections are in the form of two or three small roots which pass through the cribriform plate of the ethmoid bone in company with and medial to the vomeronasal nerve and then, still plexiform, extend caudalward over the inferomedial aspect of the olfactory bulb and upon the olfactory peduncle or stalk (olfactory tract) beyond, a root often extending to near the lamina terminalis and optic chiasma. The roots disappear in the medial and inferomedial aspect of the frontal portion of the brain at different localities caudal to the olfactory bulb and usually near the olfactory peduncle, but often one may disappear in the region corresponding to the anterior perforated substance of the adult human brain.

Numerous small groups of ganglion-cells are found interposed along both the peripheral and intracranial course of the terminal nerve. A group, larger in size than the others and situated in the intracranial course of the nerve, is called the *ganglion terminale.* The fibers of the nerve are non-medullated. Both the ganglion-cells and the fibers of the nerve are described as having more the appearances characteristic of sympathetic neurones than of craniospinal. On the other hand, our conceptions of sympathetic neurones do not permit of their terminating within the central system except for the innervation of its blood-vessels. It may result that, instead of being an independent nerve as now claimed, the nervus terminalis is a part of the forward extension of the cephalic sympathetic, the larger ganglia and plexuses of which latter are well known, and that its neurones receive and convey impulses to the gland-cells of the nasal mucosa and to the muscle of the blood-vessels of the mucosa and those supplying blood to the inferomedial part of the frontal end of the cerebrum (Brookover, Larsell).

THE OPTIC NERVES

The fibers of the optic nerve are the central processes of the ganglion-cells of the retina. Within the ocular bulb they converge to the optic papilla, where they are accumulated into a rounded bundle, the **optic nerve.** The nerve thus formed pierces the choroid and the sclerotic coats, and, at the back of the bulb, enters the orbital fat, in which it passes backward and medialward to the optic foramen. After traversing the foramen it enters the middle fossa of the cranium, and joins with its fellow from the opposite side, forming the optic chiasma. It may, therefore, for descriptive purposes, be divided into four portions—the intraocular, the intraorbital, the intraosseous, and the intracranial (fig. 842). The total length of the nerve varies from forty-five to fifty millimeters.

The intraocular part is rather less than one millimeter in length. It passes backward from the optic papilla through the choroid and through the sclerotic coats of the bulb. As it passes through the latter coat of the bulb in many separate bundles, the area of the sclera it traverses has a cribriform appearance when the nerve is removed, and consequently is known as the *lamina cribrosa scleræ.*

The intraorbital part of the nerve emerges from the sclerotic about three millimeters below and to the medial side of the posterior pole of the bulbus, and it is about thirty millimeters long. It passes backward and medialward, surrounded by the posterior part of the fascia bulbi (Tenon's capsule) and by the orbital fat, to the optic foramen.

As it runs backward in the orbit it is in relation above with the nasociliary (nasal) nerve and the ophthalmic artery which pass obliquely from behind and laterally, forward and medialward across the junction of its posterior and middle thirds, and also in relation with the superior ophthalmic vein, the superior rectus muscle, and the upper branch of the oculomotor nerve. Below it are the inferior rectus muscle, and the inferior division of the oculomotor nerve. To its lateral side, near the posterior part of the orbit, are the ophthalmic artery, the ciliary ganglion, the abducens nerve, and the external rectus muscle. The anterior two-thirds of this portion of the optic nerve are surrounded by the ciliary arteries and the ciliary nerves and it is penetrated on its medial and lower aspect by the central artery of the retina. As it enters the optic foramen to become continuous with the intraosseous part, it is in close relation with the ligaments of Lockwood and Zinn (annulus tendineus communis) and with the four recti muscles which arise from them.

The intraosseous portion is from six to seven millimeters long. It lies between the roots of the small wing of the sphenoid and the body of that bone, and it is in relation below and laterally with the ophthalmic artery.

The intracranial portion (fig. 761), which is from ten to twelve millimeters long, runs backward and medialward, beneath the posterior end of the olfactory tract, and above the ophthalmic artery, the medial border of the internal carotid

glia of both represent spinal ganglia, but their distribution is limited to the membranous labyrinth.

The vagus and glossopharyngeal nerves contain both motor and sensory fibers, but they differ from typical spinal nerves in that the motor fibers, in company with the sensory, issue from the posterolateral sulcus of the medulla, and they are intimately intermingled, from their origin, with the sensory fibers, which latter arise from ganglia interposed in the trunks of the nerves and otherwise correspond with the fibers of the dorsal root of a typical spinal nerve.

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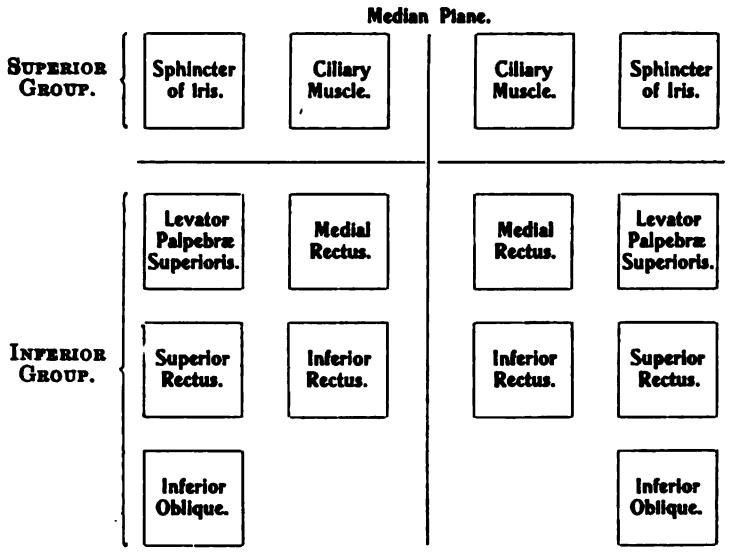


As they leave their nucleus of origin in the midbrain, the fibers of the oculomotor nerve form a series of fasciculi, which curve ventrally around and through the red nucleus and the medial part of the substantia nigra, to the oculomotor sulcus on the medial surface of the cerebral peduncle (fig. 761), where they emerge in from six to fifteen root-filaments which pierce the pia mater and collect into the trunk of the nerve. Immediately after its formation along the oculomotor sulcus, the trunk of the nerve passes between the posterior cerebral and the superior cerebellar arteries, and, running downward, forward, and laterally in the posterior part of the cisterna basalis, it crosses the anterior part of the attached border of the tentorium cerebelli at the side of the dorsum sellæ, and, piercing the arachnoid and the inner layer of the dura mater, it courses through the outer wall of the cavernous sinus about midway between the anterior and posterior clinoid processes. Immediately after its entry into the wall of the sinus it lies at a higher level than the trochlear nerve, but the latter soon crosses on its lateral side and gets above it, and directly afterward the oculomotor nerve divides into a smaller superior and a larger inferior branch (fig. 764). Before its division **communications** join it from the cavernous plexus of the sympathetic about the internal carotid artery, and from the ophthalmic division of the trigeminus. Both branches proceed forward, and the nasal branch of the trigeminus, which has passed upward, on the lateral side of the inferior branch of the oculomotor, lies between them. At the anterior end of the cavernous sinus the two branches pass through the superior orbital (sphenoidal) fissure, between the heads of the lateral rectus muscle, and enter the orbital cavity. In the orbit, the **superior branch** lies between the superior rectus and the optic nerve; it supplies the superior rectus and then turns round the medial border of that muscle and terminates in the levator palpebræ superioris. The **inferior branch** runs forward, beneath the optic nerve, and divides into three branches which supply the inferior and medial recti and the inferior oblique.

The branch to the inferior oblique muscle is connected with the ciliary ganglion by a short thick visceral efferent offset, the **short root of the ciliary ganglion,** by synapses of the fibers of which with the sympathetic neurones of this ganglion the oculomotor nerve sends impulses to the ciliary muscle and the sphincter muscle of the iris. The inferior branch also gives some small twigs to the inferior rectus. The branches of the oculomotor nerve which supply the recti muscles enter the muscles on their ocular surfaces, but the branch to the inferior oblique muscle enters the posterior border of that muscle.

Some of the fibers which spring from the medial portion of the oculomotor nucleus do not pass into the nerve of the same side, but into that of the opposite side, and it is believed that they are distributed to the opposite medial rectus muscle. Other fibers which arise from the nucleus descend in the medial longitudinal fasciculus and either terminate about the cells of the nucleus of the facial or join the facial nerve, in which they pass to the upper part of the orbicularis palpebrarum. The eye is opened by the oculomotor and closed by the facial nerve.

artery and the diaphragma sellæ to the chiasma. From the chiasma to the central connections of the nerve, the path is known as the optic tract.

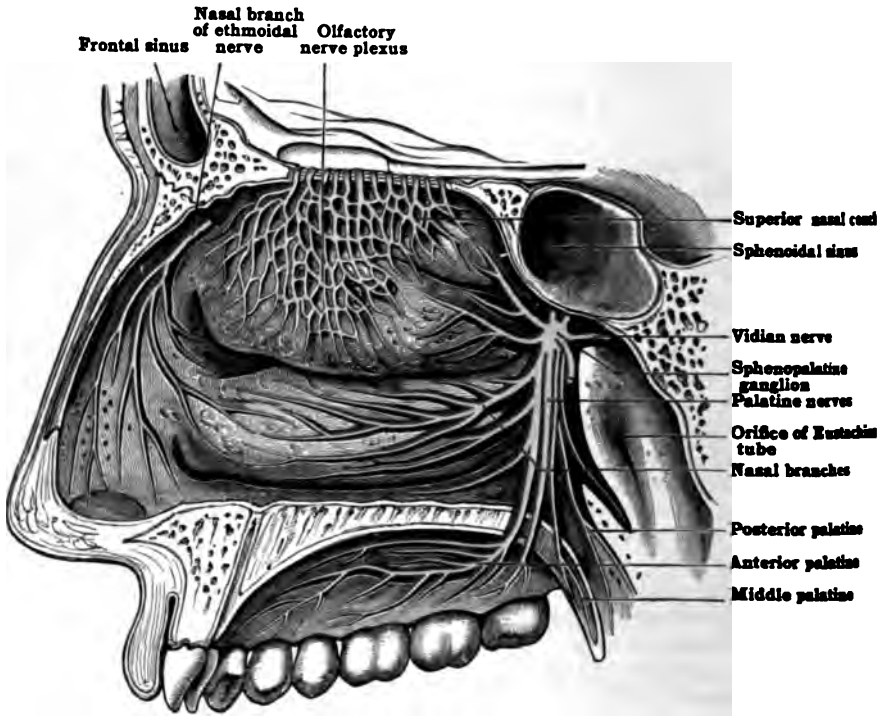
Central connections.—The central connections of the fibers of the optic nerve have been considered with the optic chiasma and the optic tract (see p. 886).

The sheaths of the optic nerve.—The optic nerve receives a sheath from each of the membranes of the brain, and prolongations of the subdural and subarachnoid cavities also pass outward along it to the posterior part of the sclera.

THE OCULOMOTOR NERVES

The oculomotor or third cranial nerve is a motor nerve. Each supplies seven muscles connected with the eye, two of which, the sphincter of the iris and ciliary muscle, are smooth muscle and within the eyeball. The remaining five

FIG. 762.—NERVES OF THE NASAL CAVITY.



(skeletal muscle) are in the orbital cavity, and four of them—the superior, inferior, and medial recti and the inferior oblique—are inserted into the eyeball, while the fifth, the levator palpebræ superioris, is inserted into the upper eyelid.

The fibers of the oculomotor nerve spring from their nucleus of origin situated in the substance of the floor of the cerebral aqueduct in the region of the superior quadrigeminal body (fig. 703). The cells of this nucleus are divided into two main groups, a superior and inferior (fig. 704). The superior group gives rise to visceral motor (autonomic) fibers and includes two nuclei, a medial and a lateral. The latter, besides being lateral, is also somewhat dorsal to the former. The inferior group (somatic motor) has been divided into five secondary nuclei, according to the eye-muscles the cells of each group innervate. Three of the five, lateral to the others and somewhat dorsally, and of the remaining two, which are placed medially, one encroaches upon the midline (*nucleus medialis*) and is continuous with the corresponding group of the opposite side and is common to the oculomotor nerves of both sides.

It has been found, by the study of diseased conditions and by experiments with animals, that the sources of innervation of the eye-muscles supplied by the nerve correspond to the several divisions of both the superior and inferior group of cells into a medial and lateral series. The relative position of the divisions of each group and the muscles they are thought to innervate are shown in the following diagram devised by Starr:

orbit and the levator palpebræ superioris. At the medial border of the roof it turns forward to its termination, and enters the orbital or superior surface of the superior oblique muscle to which its fibers are distributed.

The central connections of the nucleus of the trochlear nerve are similar to those of the oculomotor save that its cells probably do not send fibers which connect with the facial nerve. The trochlear is peculiar in that—(1) it is the smallest of the cranial nerves; (2) it is the only nerve having its superficial attachment upon the dorsal aspect of the encephalon; (3) it is the only cranial nerve whose fibers undergo a total decussation, and (4) in that it terminates in a muscle of the side of the body opposite that in which it has its origin. Gaskell has suggested that this latter condition has probably been brought about, phylogenetically, by the transference of the muscles which have carried their nerves with them. It should be remembered that most of the fibers arising from the medial group of the cells of the nucleus of the oculomotor cross the opposite side. This is thought to be especially true for those supplying the medial rectus muscle. It is claimed that the trochlear and the abducens also carry some somatic sensory fibers, but the proof of this is not so well established as for the oculomotor.

THE ABDUCENS

The abducens (or sixth) nerve on each side arises from the cells of a nucleus which lies in the gray substance of the floor of the fourth ventricle in the region of the inferior part of the pons (fig. 693). The nucleus is situated close to the middle line, ventral to the acoustic medullary striæ and beneath the colliculus facialis and it is in direct linear series with the nuclei of the oculomotor, trochlear and hypoglossal nerves. It is the third of the eye-moving nerves. The fibers which pass from the nucleus into the nerve run inferiorly and ventralward through the reticular formation, the trapezium, and the pyramidal fasciculi, and they emerge from the ventral surface of the medulla in the sulcus at the inferior border of the pons and the upper end of the pyramid of the medulla (fig. 761). From this superficial attachment the nerve runs upward and forward in the subarachnoid space between the pons and the basisphenoid and at the side of the basilar artery. A little below the level of the upper border of the petrous portion of the temporal bone it pierces the dura mater, passes beneath the petrosphenoidal ligament, at the side of the dorsum sellæ, and enters the dura of the medial wall of the cavernous sinus, in which it runs forward along the lateral side of the internal carotid artery. At the anterior end of the sinus it passes through the superior orbital (sphenoidal) fissure between the heads of the rectus lateralis, below the inferior branch of the oculomotor nerve, and above the ophthalmic vein. In the orbit it runs forward on the inner or ocular surface of the rectus lateralis, and finally it pierces this muscle and terminates upon its fibers.

While it is in the cavernous sinus it receives communications from the carotid plexus of the sympathetic and from the ophthalmic nerve.

All the fibers arising in the nucleus of the abducens do not pass into the nerve. Some of them ascend in the medial longitudinal fasciculus of the same and opposite sides, and terminate about cells of the medial group of the nucleus of the oculomotor nerve, by which the impulses are conveyed to the opposite medial rectus muscle. Thus impulses reaching the abducens nucleus can throw into simultaneous action the lateral rectus of the same side and the medial rectus of the opposite side, and thus turn both eyes in the same direction.

Central connections.—The nucleus of the abducens receives impulses from the anterior central gyrus of the opposite side by the pyramidal fibers, and it is associated with the sensory nuclei of other nerves by way of the medial longitudinal fasciculus, and that of the trigeminus especially through the reticular formation.

THE TRIGEMINUS

The trigeminus is the largest of the cranial nerves with the exception of the optic. It is usually described as the fifth cranial nerve and as possessing both a sensory and a motor root. For reasons already given, the 'motor root' is here described separately and given the separate name, *masticator nerve*. The fibers of the trigeminus proper, which are all sensory, spring from cells of the semilunar (Gasserian) gang on, which corresponds with the ganglion of the dorsal root of a spinal nerve, and they enter the brain-stem through the side of the anterior half of the pons (fig. 761).

The semilunar (Gasserian) ganglion (fig. 764) is a semilunar mass which lies in Meckel's cave, a cleft between the layers of the dura matter above a depression in the medial part of the upper surface of the petrous portion of the temporal bone. The concavity of the ganglion is turned forward, and from it three large nerves

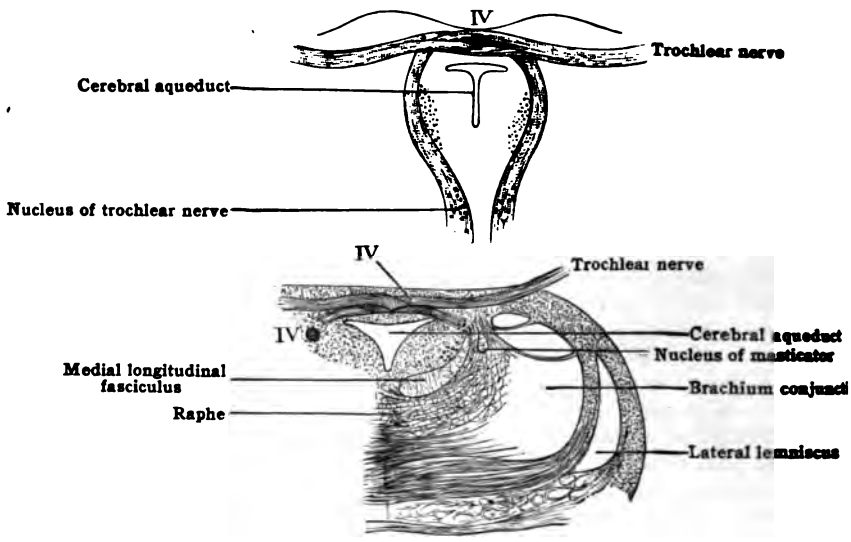
Against the common contention that the oculomotor is a purely motor nerve is the claim that it contains some somatic afferent (sensory) fibers carrying impulses of muscul from the muscles the nerve supplies. A few branched nerve cell-bodies have bee (Kopsch) scattered among its fibers in serial sections of its root. All the eye-moving receive sensory fibers from the ophthalmic branch of the trigeminus.

Central connections.—The nucleus of the oculomotor is associated with the middle po the anterior central gyrus, the posterior end of the middle frontal gyrus and with the about the visual area of the occipital lobe of the same and opposite sides by the py fibers. It is associated with the superior colliculus, and probably the cerebellum by th in the superior cerebellar peduncles, and with the sensory nuclei of the other cranial n the medial longitudinal fasciculus. To produce the coördinated activities of the eye-muscles, it must be associated with the nuclei of the trochlear and abducens.

THE TROCHLEAR NERVES

The fibers of each trochlear or fourth nerve (or patheticus) spring fr cells of a nucleus which lies in the gray substance of the floor of the cerebra duct in line with the oculomotor nucleus, but in the region of the inferior geminate bodies. As the fibers pass from their origins they run ventra laterally in the substance of the tegmentum for a short distance, then the

FIG. 763.—DIAGRAM OF SECTIONS THROUGH THE ORIGIN OF THE TROCHLEAR NERVE. (i (The upper figure is an oblique section, the lower is a coronal section.)



medianward and dorsalward, and, in passing through the anterior end of t rior medullary velum, they decussate totally with the fibers of the trochle of the opposite side (figs. 700, 761, 763). After the decussation the fiber from the surface of the superior medullary velum, at the side of the frenu usually in two small bundles, which pierce the pia mater and join togethe the slender trunk of the nerve. This trunk curves forward and ventra the base of the brain around the sides of the superior peduncle of the ce and cerebral peduncle of the side opposite to that in which the nerve or running parallel with and between the superior cerebellar and posterior arteries. As it reaches the base of the brain behind the optic tract t enters the cisterna basalis, in which it runs forward, immediately be piercing the free border of the tentorium cerebelli, to the superior bord petrous portion of the temporal bone, where it pierces the arachnoid and mater and enters the posterior end of the lateral (outer) wall of the c sinus. In the wall of the cavernous sinus it receives communications cavernous plexus of the sympathetic and, by a small filament, from the op division of the trigeminus. It gradually ascends, as it passes forwar lateral wall of the sinus, and, beyond the middle of the sinus, it crosses th side of the trunk of the oculomotor nerve and gains a higher position (At the anterior end of the sinus the nerve enters the orbit above the later and immediately turns medialward between the periosteum of the roc

orbit and the levator palpebræ superioris. At the medial border of the roof it turns forward to its termination, and enters the orbital or superior surface of the superior oblique muscle to which its fibers are distributed.

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The **semilunar** (Gasserian) **ganglion** (fig. 764) is a semilunar mass which lies in Meckel's cave, a cleft between the layers of the dura matter above a depression in the medial part of the upper surface of the petrous portion of the temporal bone. The concavity of the ganglion is turned forward, and from it three large nerves

the *ophthalmic*, the *maxillary* and the *mandibular*, are given off. From the convexity, which is directed backward, springs the root of the nerve. The medial end of the ganglion is in close relation with the cavernous sinus and the internal carotid artery at the foramen lacerum, and the lateral end lies to the medial side of the foramen ovale. The surfaces of the ganglion are striated, due to bundles of fibers traversing them. The upper surface is separated by the inner layer of the dura mater from the temporal lobe of the brain, and the lower rests upon the masticator nerve and the outer layer of dura mater upon the petrous portion of the temporal bone.

The fibers of the trigeminus root as they leave the semilunar (Gasserian) ganglion, form from thirty to forty fasciculi which are bound together into a flat band, from 6 to 7 mm. broad, which passes backward over the upper border of the petrous portion of the temporal bone and below the superior petrosal sinus into the posterior fossa of the cranium. In the posterior fossa it runs backward, medialward, and downward, and passes into the pons through its continuation into the middle peduncle of the cerebellum. In the tegmentum of the pons region, the fibers bifurcate into ascending and descending branches which terminate about the cells of the nucleus of termination of the trigeminus. This nucleus, large at the level of the entrance of the root, has tapering superior and inferior extremities. The inferior extremity of the nucleus, which is much the longer, descends as low as the upper portion of the spinal cord and the fibers of the root terminating about the cells of this extremity are known as the spinal tract of the trigeminus.

Central connections.—The nuclei of termination of the trigeminus send impulses to the somesthetic area of the cortex of the opposite side by the fibers of the medial leminscus (trigeminal lemniscus) and, for reflex actions, to the motor nuclei of other cranial nerves and to ventral horn cells of the cervical spinal cord by the medial longitudinal fasciculus and by fasciculi propri in the reticular formation of the same, and opposite sides.

THE BRANCHES OF THE TRIGEMINUS

The main branches of the trigeminus, given off by the front side of the semilunar ganglion, are three in number (ophthalmic, maxillary, and mandibular), each of which is referred to as a nerve and each of which is purely sensory, though the third branch, or mandibular nerve, is joined by the fibers of the masticator nerve which is motor.

(1) The Ophthalmic Nerve or First Division

The ophthalmic nerve, the first division of the trigeminus, is the smallest of the three branches which arise from the semilunar (Gasserian) ganglion. It springs from the medial part of the front of the ganglion and passes forward, in the lateral wall of the cavernous sinus, where it lies below the trochlear nerve and lateral to the abducens nerve and the internal carotid artery (fig. 764). A short distance behind the superior orbital (sphenoidal) fissure the nerve divides into three terminal branches—the frontal, lacrimal, and nasociliary (nasal) nerves. They pierce the dura mater, which closes the fissure, and pass forward into the orbit. Before its division the ophthalmic nerve receives filaments from the cavernous plexus of the sympathetic and it gives off, soon after its origin, a **tentorial (recurrent meningeal) branch** which runs backward, in close association with the trochlear nerve, and ramifies between the layers of the tentorium cerebelli. Further forward three branches spring from the ophthalmic nerve which contribute sensory fibers to the oculomotor, trochlear, and abducens nerves.

The terminal branches.—(*a*) The **frontal nerve** is the largest terminal branch. It pierces the dura mater and passes into the orbit through the superior orbital (sphenoidal) fissure, above the rectus lateralis and a little below and to the lateral side of the trochlear nerve. In the orbit it runs forward, between the levator palpebræ superioris and the periosteum, and breaks up into three branches, the supraorbital, frontal proper, and supratrochlear.

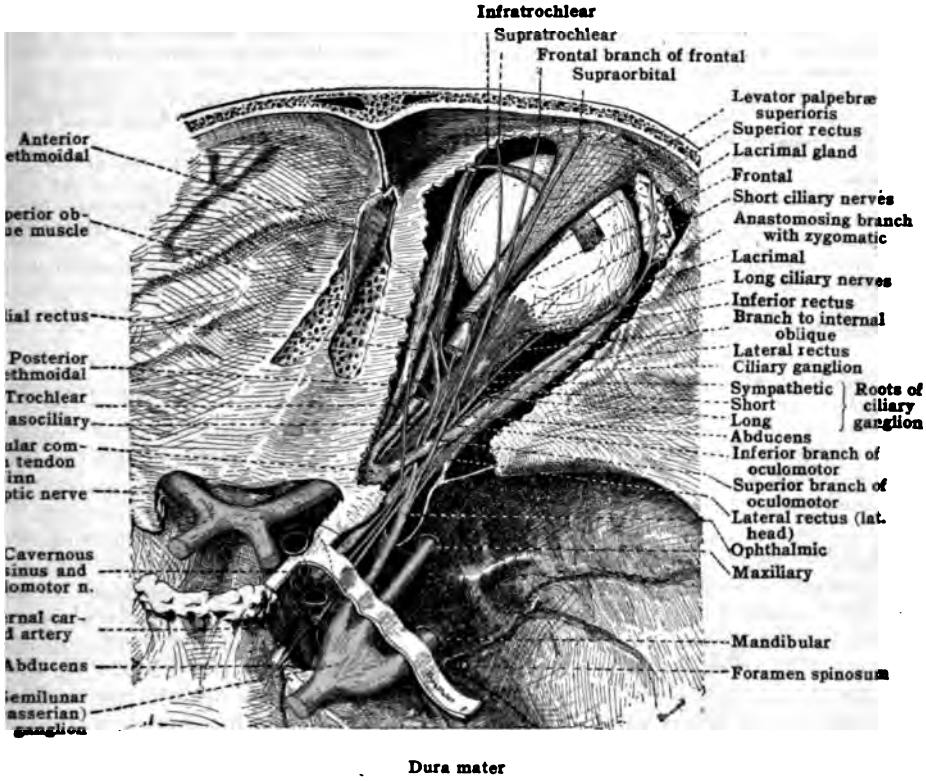
The **supraorbital nerve**, the largest of the three branches, leaves the orbit at the supraorbital notch (fig. 764). As it passes through the notch it gives off a small branch which enters the bone and supplies the diploë and the mucous membrane of the frontal sinus. Its terminal branches give twigs to the pericranium and to the skin of the scalp, the upper eyelid, the frontal region, and the parietal region almost as far as the lambdoid suture (fig. 770). One branch running at the upper margin of the orbital cavity unites with a branch of the facial nerve.

The **frontal branch**, given off at a variable point, lies medial to the supraorbital, passes through the frontal foramen, and is distributed to the skin of the forehead and upper eyelid (*fig. 764*).

The supratrochlear branch runs forward and medialward toward the upper and medial le of the orbit, where it passes above the pulley of the superior oblique muscle, pierces the ebral fascia, and ascends to the lower and middle part of the forehead, accompanied by frontal artery (fig. 764) Before it leaves the orbit it sends a branch downward behind or ont of the pulley of the obliquus superior which joins with the infratrochlear nerve, and as aves the orbit it gives off filaments to supply the skin and conjunctiva of the medial third ie upper eyelid. Its terminal branches pierce the orbicularis and frontalis muscles, and, as pass to the skin of the forehead, they communicate with branches of the facial nerve.

(*b*) **The lacrimal nerve** [n. lacrimalis] is the smallest of the three branches of the thalmic division. It passes through the superior orbital (sphenoidal) fissure ral to and slightly below the frontal nerve, and is directed forward and lateral- d, along the upper border of the rectus lateralis to the lacrimal gland (fig. 764).

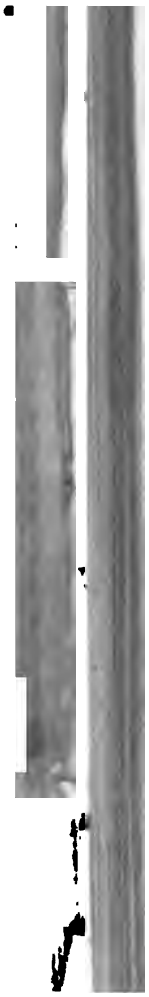
FIG. 764.—NERVES OF THE ORBIT FROM ABOVE AND BEHIND. (Schematic.)



the lateral wall of the orbit it receives a small branch from the zygomatic ve (the orbital branch of the maxillary nerve). This branch brings to the imal nerve secretory fibers for the lacrimal gland. A small twig passes beyond gland, pierces the palpebral fascia, supplies filaments to the conjunctiva, and ien distributed to the integument at the lateral angle of the eye and to the skin r the zygomatic process of the frontal bone.

(*c*) **The nasociliary (nasal) nerve** enters the orbit between the two heads of the us lateralis and between the superior and inferior branches of the oculomotor ve. In the orbit it lies at first lateral to the optic nerve, but, as it runs ob- ely forward and medialward to the medial wall of the orbital cavity, it crosses ve the optic nerve and between it and the rectus superior, and near the border he rectus medialis it divides into its terminal branches, the chief of which are *infratrochlear* and *anterior ethmoidal* nerves (fig. 764). In addition to those ived from the cavernous plexus before the division of the ophthalmic nerve, nasociliary nerve itself receives numerous sympathetic (secretory and vaso- or) fibers.

ts several branches are: (i) The **long root of the ciliary ganglion** which is given off at the rior orbital (sphenoidal) fissure. It is a slender filament which runs forward on the lateral of the optic nerve to the superior and posterior part of the ciliary ganglion (fig. 764).



the supratrochlear nerve. The **inferior palpebral branch** is distributed to the conjunctiva and skin of the medial part of both eyelids, the caruncle, and the skin upper part of the side of the nose.

(v) The **anterior ethmoidal** (distal part of the nasal) **nerve**, passing forward and ward between the obliquus superior and the rectus medialis, leaves the orbit through th rior ethmoidal foramen, accompanied by the anterior ethmoidal vessels, and enters i anterior fossa of the cranium (fig. 764). It then crosses the lamina cribrosa of the et lying outside the dura mater, which separates it from the olfactory bulb, and descends i nasal fossa through the ethmoidal fissure, a slit-like aperture at the side of the crista ga the submucosa of the nasal fossa it terminates by dividing into two sets of *anterior nasal br* the internal nasal branches and the external nasal branch (fig. 762).

The **internal nasal branches** divide into the **medial nasal branches** (the septal bran the nasal nerve), which run downward and forward on the upper and front part of the s and the **lateral nasal branches** (the external terminal branch of the **nasal** nerve), wh twigs to the anterior extremities of the superior and middle nasal conchæ (turbinated and to the mucous membrane of the lateral wall of the nose (fig. 762).

The **external nasal branch** (the anterior terminal branch of the nasal nerve) runs do in a groove on the inner surface of the nasal bone. It pierces the wall of the nose betw nasal bone and the upper lateral cartilage, and supplies the integument of the lower the dorsum of the nose as far as the tip.

(2) The Maxillary Nerve or Second Division of the Trigemi

The maxillary nerve is entirely sensory in function and it is intermed size between the ophthalmic and mandibular nerves. It springs from the of the anterior border of the semilunar (Gasserian) **ganglion** and runs forv the lower and outer part of the lateral wall of the **cavernous sinus** (fig Leaving the middle fossa of the cranium, by passing through the foramen dum, it enters the pterygopalatine (sphenomaxillary) fossa (figs. 762, 764) it is joined by twigs with the sphenopalatine ganglion; then, changing its it passes forward, as the **infraorbital nerve,** through the inferior orbital (s maxillary) fissure into the infraorbital sulcus in the floor of the orbit; con forward it traverses the infraorbital canal accompanied by the **infraorbital** and appears in the face, beneath the levator labii superioris (quadratus) anc the levator anguli oris (caninus) muscles where it divides into four sets of t branches which anastomose more or less freely with branches of the facia to form the **infraorbital plexus.**

Branches.—The branches of the maxillary nerve are—(*a*) branches gi in the middle fossa of the cranium; (*b*) branches given off in the pterygop (sphenomaxillary) fossa; (*c*) branches given off in the infraorbital sulc canal; and (*d*) terminal branches.

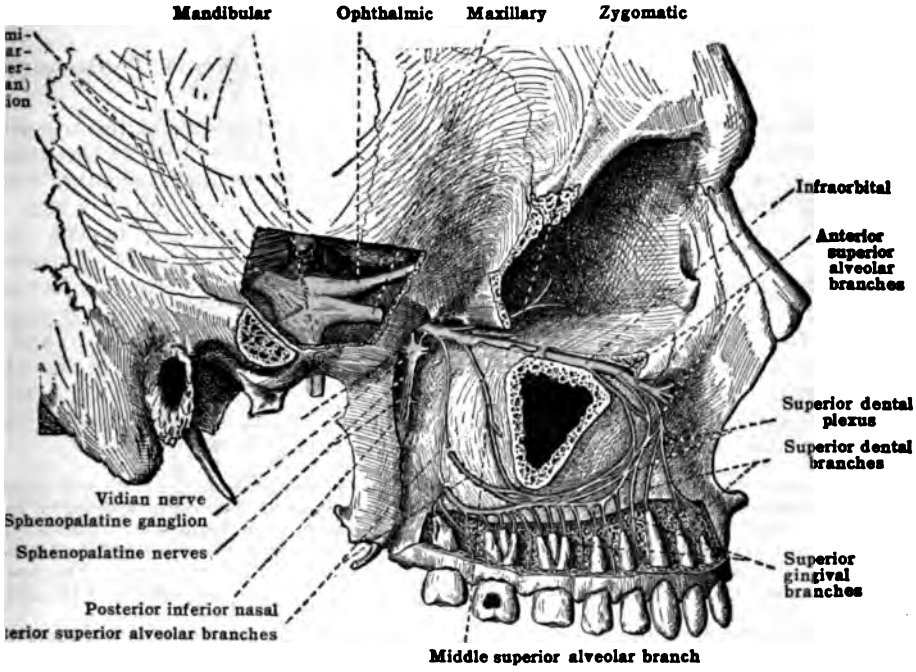
(*a*) The **middle (recurrent) meningeal branch**, given off in the midd

he zygomaticofacial (malar) branch runs forward, passes through a zygomatico-orbital **ien,** then through the zygomaticofacial (malar) foramen, pierces the orbicularis palpe- **m,** communicates with the zygomatic (malar) branch of the facial nerve, and supplies **kin** of the prominence of the cheek. The **zygomaticotemporal (temporal) branch** runs **rd** in a groove in the lateral wall of the orbit, passes through a zygomatico-orbital foramen, through the zygomaticotemporal (sphenomalar) foramen, and enters the temporal fossa. **ns** around the anterior border of the temporal muscle, pierces the deep layer of the tem- **fascia,** and runs backward for a short distance in the fat between the superficial and deep **lla,** then, turning lateralward, it pierces the superficial lamellæ about an inch above the **na,** anastomoses with the temporal branch of the facial nerve, and supplies the skin of the **ior** part of the temporal region.

he infraorbital nerve, that large part of the maxillary nerve lying distal to the spheno- **ine ganglion,** enters the orbit through the inferior orbital (sphenomaxillary) fissure, **npanied** by the infraorbital artery, and with it passes through the infraorbital canal **765**)) to the face, where it divides into four sets of terminal branches, some of which, by **omoses** with the branches of the facial nerve, form the **infraorbital plexus.**

hree sets of superior alveolar nerves arise from the maxillary and the infraorbital nerves, **ly,** the posterior superior alveolar branches, the middle superior alveolar branch, and the **ior superior alveolar branches.**

FIG. 765.—LATERAL VIEW OF THE MAXILLARY NERVE.



he posterior superior alveolar (dental) nerves are usually two in number, but sometimes **by a single trunk.** They pass downward and lateralward through the pterygomaxillary **e into** the zygomatic fossa, where they give branches to the mucous membrane of the gums **he** posterior part of the mouth; then they enter the posterior alveolar (dental) canals and **with** the other alveolar branches to form the **superior dental plexus,** through which they **branches** to the roots and pulp cavities of the molar teeth and to the mucous membrane **a maxillary sinus** (fig. 765).

c) The branches given off in the infraorbital sulcus and canal are the middle anterior superior alveolar (dental) nerves.

) The middle superior alveolar (dental) nerve leaves the infraorbital nerve in the pos- **· part** of the infraorbital sulcus, and, passing downward and forward in a canal in the max- **t** divides into terminal branches that anastomose with the other alveolar branches to form *uperior dental plexus.* Through the plexus it supplies the bicuspid teeth and gives branches **e** mucous membrane of the maxillary sinus and also to the gums (fig. 765).

i) The anterior superior alveolar (dental) nerve is the largest of the superior alveolar **es.** It is given off by the infraorbital nerve in the anterior part of the infraorbital canal, **passes** downward in a bony canal in the anterior wall of the maxilla. After uniting with **ther** alveolar nerves to form the superior dental plexus, it supplies the canines and the **ors** and gives branches to the mucous membrane of the maxillary sinus and the gums (fig.

It also gives off a **nasal branch** which enters the nasal fossa through a small foramen, and

The inferior palpebral branches, usually two, pass upward and supply sensory fibe the skin and conjunctiva of the lower eyelid (fig. 770).

The external nasal branches pass medialward under cover of the levator labii s (quadratus), and supply the skin of the posterior part of the lateral aspect of the nose.

The internal nasal branches pass downward and medialward under the lateral wa nose, and then turn upward to supply the skin of the vestibule of the nose.

The superior labial branches, three or four in number, as a rule are larger than the p and nasal branches. They pass downward to supply the skin and mucous membra upper lip and the neighboring part of the cheek.

(3) The Mandibular Nerve or Third Division of the Trigemi

The **mandibular division** is the largest of the three divisions of the tri (figs. 766 and 770). As a nerve, it is usually described as formed by the u two distinct nerves, namely, the entire masticator nerve and the large of sensory fibers derived from the semilunar (Gasserian) ganglion whi peripherally as the third division of the trigeminus. These two nerves separate until they pass through the foramen ovale and then unite imm outside the skull to form a large trunk which almost directly after its fo divides into a small *anterior* and a larger *posterior portion.* The trunk is s between the pterygoideus externus, laterally, and the otic ganglion a tensor veli palatini medially. In front of it is the posterior border of th goideus internus, and behind it, the middle meningeal artery. Two b arise from the trunk of the nerve before its division, namely, the spinou rent) nerve and the nerve to the pterygoideus internus.

The spinous (recurrent) nerve, after receiving a vasomotor filament from the otic enters the cranium through the foramen spinosum, accompanying the middle meninge and divides into an anterior and a posterior branch. The anterior branch communi the meningeal branch of the maxillary division of the trigeminus, furnishes filamen dura mater, and ends in the osseous substance of the great wing of the sphenoid. The branch traverses the petrosquamous suture and ends in the lining membrane of th cells.

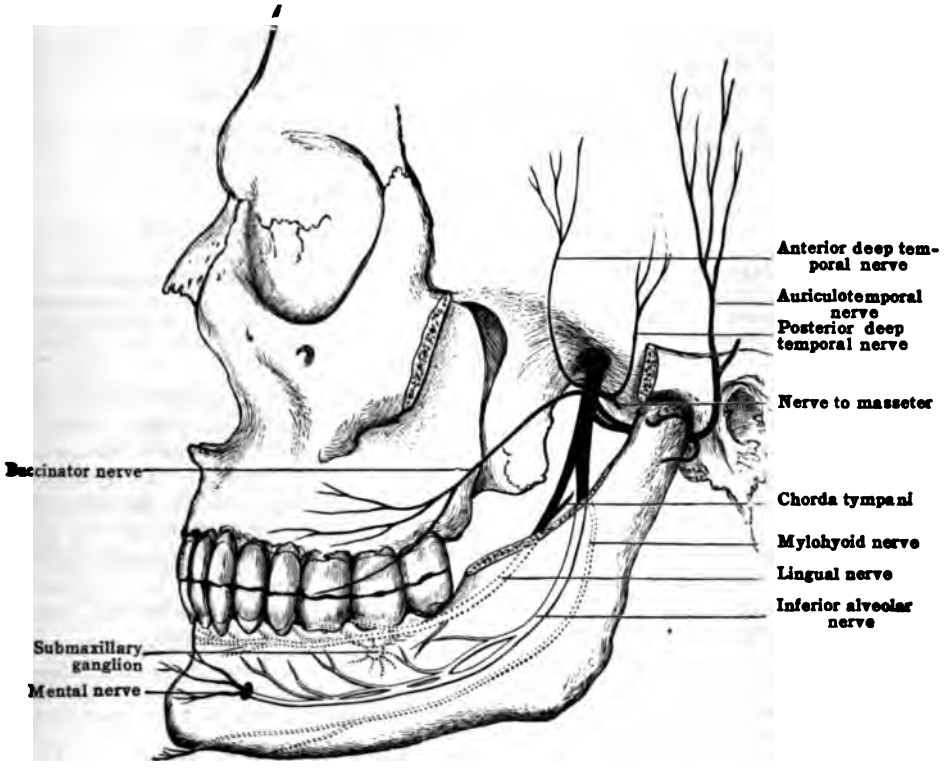
The fibers going to form the *nerve to the internal pterygoid muscle* are almost wh fibers and therefore comprise a branch of the masticator nerve and are described as s the description of the masticator (fig. 767).

The **anterior portion** of the mandibular nerve is smaller than the post is chiefly composed of motor fibers which form branches of the masticat and supply the muscles of mastication, the temporalis, masseter, an

The posterior portion of the mandibular nerve divides into three large branches. **o** of these, the lingual and the auriculotemporal nerves, are exclusively sensory; **third**, the inferior alveolar (dental) nerve, contains a strand of motor fibers, **mylohyoid** nerve, which comprise a branch of the masticator nerve.

The lingual nerve is the most anterior branch of the mandibular nerve (figs. **5, 773**). It lies in front and to the medial side of the inferior alveolar (dental) **ve** and descends at first on the medial side of the pterygoideus externus, then **ween** the pterygoideus internus and the ramus of the mandible to the posterior **rt** of the mylohyoid ridge, where it passes off the anterior border of the ptery**deus** internus; at this point it is situated a short distance behind the last

g. 766.—DISTRIBUTION OF THE MANDIBULAR DIVISION OF THE TRIGEMINUS COMBINED WITH BRANCHES OF THE MASTICATOR NERVE. (Henle.)



olar tooth and is covered in front by the mucous membrane of the posterior **rt** of the mouth cavity. After leaving the pterygoideus internus it crosses the **ers** of the superior constrictor, which are attached to the mandible, and turns **rward** toward the tip of the tongue, crossing the lateral surfaces of the stylo**ssus**, hyoglossus, and genioglossus. In its course across the hyoglossus it **s first** above, then to the lateral side of, and finally below Wharton's duct, and **it** ascends on the genioglossus it lies on the medial side of the duct.

Communications and branches.—While it is on the medial side of the pterygoideus externus **e lingual** nerve is joined, at an acute angle, by the chorda tympani (figs. 766, 773), a branch **the** glossopalatine nerve, and as it lies between the ramus of the mandible and the pterygoid**s internus** it is connected by a branch with the inferior alveolar (dental) nerve, and gives off **e or two** small branches, the **rami isthmi faucium**, which are ditributed as sensory fibers to **e tonsil** and the mucous membrane of the posterior part of the mouth (fig. 773).

While it is above the duct it gives a branch, which contains many sensory and visceral **erent** chorda tympani fibers, to the submaxillary ganglion (see pp. 981, 997), and it receives **anches**, chiefly sympathetic, from that ganglion. A little further forward it is connected by **e or two** branches, which run along the anterior border of the hyoglossus, with the hypo**ssal** nerve (fig. 773). It then gives off the **sublingual nerve**, which runs forward to supply the **blingual** gland and the neighboring mucous membrane. Its terminal (**lingual**) branches are **rived** chiefly from the glossopalatine nerve. They pierce the muscular substance of the **ngue** and are distributed to the mucous membrane of its anterior two-thirds. They interlace **th** similar branches of the other side and with branches of the glossopharyngeal nerve.

The **inferior alveolar (dental) nerve** is the largest branch of the posterior portion of the mandibular nerve. It commences on the medial side of the external pterygoid muscle and descends to the interval between the sphenomandibular ligament and the ramus of the mandible, where it receives one or two communicating branches from the lingual nerve. Opposite the middle of the medial surface of the ramus it enters the mandibular (inferior dental) canal, accompanied by the inferior alveolar (dental) artery, which lies in front of the nerve, and it runs downward and forward through the ramus and the body of the mandible (fig. 766). At the mental foramen it divides into two parts, one of which, the *mental nerve,* passes out through the mental foramen, the other, commonly called the *incisive branch,* continues forward in the canal, and supplies, through the inferior dental plexus, the inferior canine and incisor teeth and the corresponding regions of the gums.

Branches.—The branches of the inferior alveolar (dental) nerve are branches forming the inferior dental plexus, and the mental nerve. A bundle of motor fibers, the *mylohyoid nerve,* a branch of the masticator nerve, is given off just before the inferior alveolar nerve enters the mandibular canal.

The **inferior dental plexus** is formed by a series of branches which communicate with one another within the bone, giving rise to a fine network. From this plexus two sets of branches are given off: the **inferior dental branches,** corresponding in number to the roots of the teeth, enter the minute foramina of the apices of the roots and end in the pulp; the second set, the **inferior gingival branches,** supply the gums.

The **mental nerve** is a nerve of considerable size which emerges through the mental foramen (fig. 766). It communicates, near its exit from the bone, with branches of the facial nerve, and then divides into three branches. The smallest branch, turning downward, divides into several twigs, the *mental branches,* which supply the integument of the chin. The other two, *inferior labial branches,* pass upward, diverging as they ascend, and divide into a number of twigs. The stoutest twigs ramify to the mucous membrane which lines the lower lip. Other twigs are distributed to the integument and fascia of the lip and chin.

The **auriculotemporal nerve** usually arises from the posterior portion of the mandibular nerve by two roots which embrace the middle meningeal artery and unite behind it to form the trunk of the nerve. The trunk passes backward on the medial aspect of the pterygoideus externus, and between the sphenomandibular ligament and the mandibular orticulation, lying in close relation with the capsule of the joint. Behind the joint it enters the upper part of the parotid gland, through which it turns upward and lateralward. It emerges from the upper end of the gland, crosses the root of the zygoma close to the posterior border of the superficial temporal artery, and divides into auricular and temporal terminal branches at the level of the tragus of the pinna (fig. 766).

Communications.—(*a*) Each of the two roots of the nerve receives a communication from the otic ganglion containing fibers derived from the glossopharyngeal nerve. These fibers have passed from the glossopharyngeal through the tympanic plexus and the small superficial petrosal nerve and through the otic ganglion.

(*b*) Sensory filaments pass from the auriculotemporal nerve to the temporofacial branch of the facial nerve.

(*c*) Filaments of connection with the sympathetic plexus on the internal maxillary artery.

(*d*) A communication to the inferior alveolar (dental) nerve.

Branches of the auriculotemporal nerve.—(*a*) An **articular branch** to the mandibular joint, given off as the nerve lies on the medial side of the capsule.

(*b*) **Branches to the external auditory meatus.** Two branches, as a rule, are given off in the parotid gland. They enter the meatus by passing between the cartilage and the bone and supply the upper part of the meatus and the membrana tympani by a fine branch, and occasionally the lower branch gives twigs to the skin of the lobule of the pinna.

(*c*) **Parotid branches** are distributed to the substance of the parotid gland. Sensory or trigeminal fibers for the gland spring either directly from the nerve or from the communicating branches previously given by it to the glossopalatine nerve. The parotid branches also contain fibers derived from the glossopharyngeal nerve which pass successively through its tympanic branch, the tympanic plexus, the small superficial petrosal nerve, the otic ganglion, and the communicating twigs from the otic ganglion to the roots of the auriculotemporal nerve. The parotid branches are later again mentioned as concerned chiefly with the *ganglialed cephalic plexus.*

(*d*) The **anterior auricular branches,** usually two in number, are distributed to the skin of the tragus and the upper and outer part of the auricle.

(*e*) The **superficial temporal branches** supply the integument of the greater part of the temporal region, and anastomose with the temporal branch of the facial nerve.

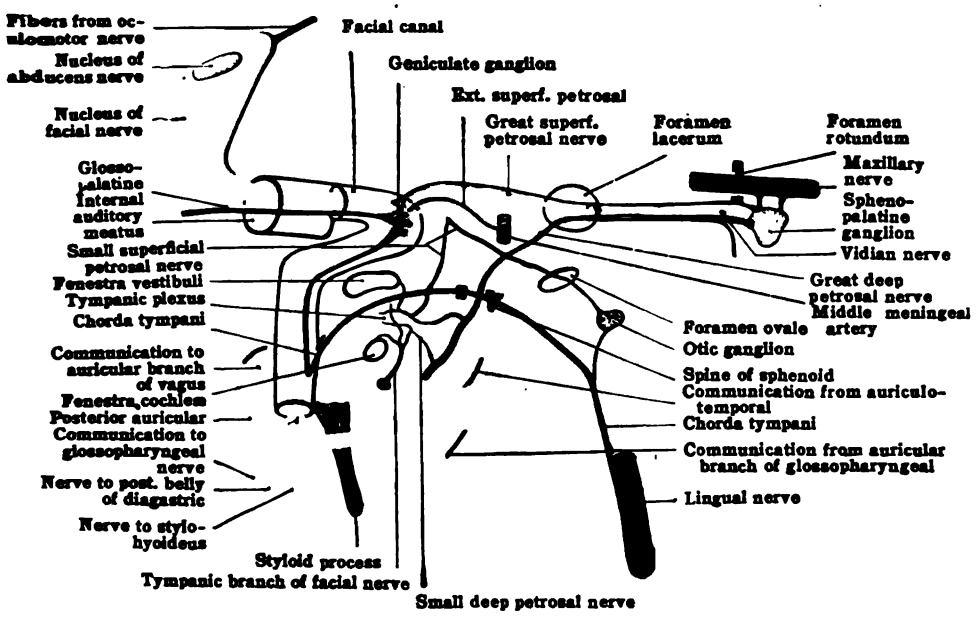
THE MASTICATOR NERVE (Fig. 767)

The masticator nerve (*motor root or portio minor of trigeminus*). The fibers of the masticator nerve spring from two nuclei, a slender upper or mesencephalic

the posterior wall to the stylomastoid foramen. As soon as it emerges from the stylomastoid foramen it turns forward around the lateral side of the base of the styloid process, and plunges into the substance of the parotid gland, where it divides into its cervicofacial and temporofacial terminal divisions. Before its terminal divisions, the nerve gives off three, and sometimes four, small branches: one, the nerve to the stapedius muscle, before it leaves the skull, the others after it leaves the skull.

The nerve to the stapedius is given off from the facial nerve as it descends in the posterior wall of the tympanum behind the pyramidal eminence. It is stated that filaments are also given off from the facial to the internal auditory artery (probably visceral motor from the glossopalatine) while the nerve is passing through the internal auditory meatus.

FIG. 768.—DIAGRAM OF THE FACIAL (YELLOW) AND GLOSSOPALATINE NERVE (BLUE).



After it leaves the skull the facial nerve (fig. 770) gives off two or three collateral branches and its two terminal divisions, the temporofacial and cervicofacial. The collateral branches are the posterior auricular nerve, a branch to the posterior belly of the digastric, and sometimes a lingual branch.

(1) The **posterior auricular nerve** is the first branch of the extracranial portion of the facial nerve. It passes between the parotid gland and the anterior border of the sternomastoid muscle and runs upward in the deep interval between the external auditory meatus and the mastoid process. In this situation it communicates with the auricular branch of the vagus. It supplies the auricularis posterior, sends a slender twig upward to the auricularis superior, and ends in a long slender branch, **the occipital branch,** which passes backward to supply the occipitalis muscle. It also receives filaments from the small occipital and great auricular nerves, and supplies the intrinsic muscles of the auricle (pinna).

(2) **The nerve to the posterior belly of the digastric** arises from the facial nerve close to the stylomastoid foramen and enters the muscle near its center, or sometimes near its origin. It usually gives off two branches: the **nerve to the stylohyoid,** which sometimes arises directly from the facial nerve and passes to the upper part of the muscle that it supplies, and the **anastomotic branch,** which joins the glossopharyngeal nerve below its petrous ganglion.

(3) **The lingual branch,** first described by Cruveilhier, is not commonly present. It arises a little below the nerve to the stylohyoideus and runs downward and medialward to the base of the tongue. In its course it passes to the medial sides of the styloglossus and stylopharyngeus, and runs downward along the anterior border of the latter muscle to the wall of the pharynx. It pierces the superior constrictor, insinuates itself between the tonsil and the anterior palatine arch, and it is stated that it gives filaments to the base of the tongue and to the styloglossus and glossopalatinus (palatoglossus) muscles.

The terminal divisions.—In the substance of the parotid gland the two terminal divisions of the facial nerve lie superficial to the external carotid artery and to the posterior facial (temporomaxillary) vein. The way in which these

The **deep temporal nerves,** usually two in number, posterior and anterior, pass betw bone and the upper border of the external pterygoid muscle, and turn upward around the temporal crest of the sphenoid bone to end in the deep surface of the temporalis (fig The posterior of the two often arises in common with the masseteric nerve. The a is frequently associated with the buccinator (long buccal) nerve till the latter has passed b the two heads of the pterygoideus externus. There is frequently a third branch, the a which passes lateralward above the pterygoideus externus, and turns upward close to th to enter the deep surface of that muscle. A small strand of masticator fibers accompa buccinator nerve to enter and end in the anterior part of the temporal muscle.

The **masseteric nerve,** which frequently arises in common with the posterior deep te nerve, passes between the bone and the pterygoideus externus, and accompanies the ma artery through the notch of the mandible to be distributed to the masseter (fig. 76 is easily traced through the deeper fibers nearly to the anterior border of the masset it emerges above the pterygoideus externus it gives off a twig to the mandibular artic

The **nerve to the external pterygoid,** after a course of about 3 mm., divides into twig enter the deep surface of the two heads of the muscle. It is usually adherent at its o the buccinator nerve.

The **mylohyoid branch,** carried in the posterior portion of the mandibular nerve, i off immediately before the inferior alveolar (dental) nerve enters the mandibular (infer tal) canal. It pierces the lower and back part of the sphenomandibular ligament a downward and forward in the mylohyoid groove between the mandible on the lateral s the internal pterygoid muscle and the lateral surface of the submaxillary gland on the me In the anterior part of the digastric triangle it is continued forward between the ante of the submaxillary gland and the mylohyoideus, and it breaks up into branches whic the mylohyoideus and the anterior belly of the digastric (fig. 766).

THE FACIAL NERVE

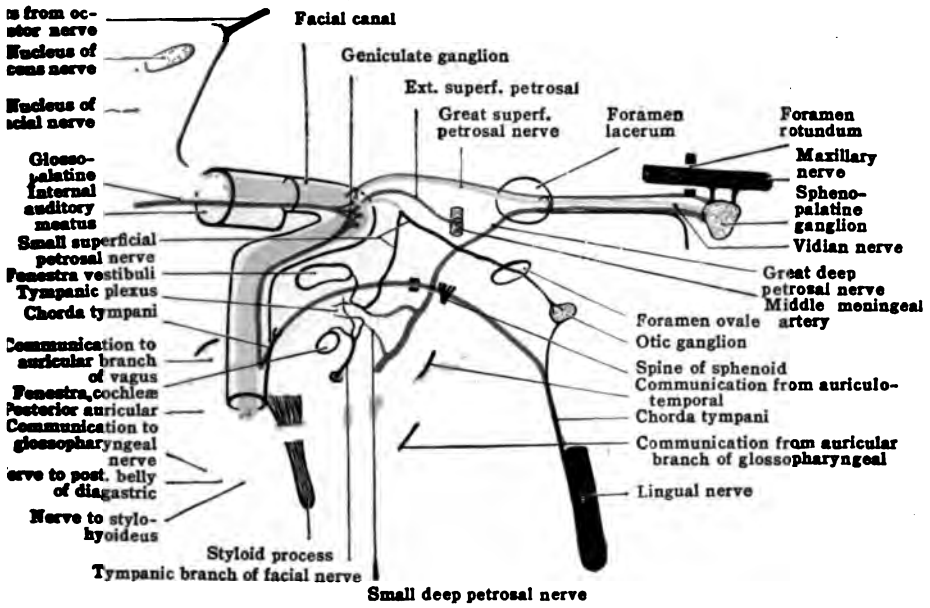
The facial (or seventh) nerve is purely motor. It is accompanied distance by a bundle usually called its *sensory root* or the *intermediat* This latter, however, on the basis of its origin, distribution, and mixed in sensory character, is described separately below as the *glossopalatin* It is smaller than the facial, is fused to the trunk of the facial, and the g giving rise to its sensory fibers is situated upon the external genu of th (figs. 768, 771).

The fibers of the facial nerve (fig. 768) spring from a nucleus of cells s laterally in the reticular formation at the level of the lower part of th dorsal to the superior olive, and between the root fibers of the abducens ne the laterally placed spinal tract of the trigeminus. From this nucleus th of the nerve passs medially and dorsalward to the floor of the fourth ventri just under the floor, they turn anteriorly, passing dorsal to the nucleu abducens (fig. 694). At the anterior end of this nucleus they turn sharp tralward and lateralward, and at this point it is claimed that fibers descer the near-by medial longitudinal fasciculus from the nucleus of the ocul nerve of the same side become intermingled with the fibers of the facial ne pass outward with them. This, however, is uncertain. Continuing vent through the reticular formation the fibers of the facial emerge from the bra at the inferior border of the pons, lateral to the superficial attachment abducens. At the point of its emergence, the facial nerve pierces the pia from which it receives a sheath, and then proceeds forward and late in the posterior fossa of the cranium to the internal auditory meatus, v enters in company with the glossopalatine nerve and with the cochl vestibular nerves. As it lies in the meatus it is situated above and in the latter nerves, from which it is separated by the glossopalatine, a surrounded, together with these three nerves, by sheaths of both the ar and the dura mater and by prolongations of the subarachnoid and s spaces. While it is still in the meatus it blends with the glossopalatine a the combined trunk is formed. At the outer end of the meatus the trunk the arachnoid and the dura mater and enters the facial canal (aqueduct c pius), in which it runs forward and slightly lateralward to the hiatus l where it makes an angular bend, the external genu [geniculum], arou anterior boundary of the vestibule of the inner ear; this bend is enlarged adhesion of the geniculate ganglion (of the glossopalatine) upon its border (fig. 769). From the geniculum the facial nerve runs backwar facial canal along the lateral wall of the vestibule and the medial wall of t panum, above the fenestra vestibuli (ovalis), to the junction of the me posterior walls of the tympanic cavity; then, bending downward, it des

posterior wall to the stylomastoid foramen. As soon as it emerges from stylomastoid foramen it turns forward around the lateral side of the base of the oid process, and plunges into the substance of the parotid gland, where it des into its cervicofacial and temporofacial terminal divisions. Before its inal divisions, the nerve gives off three, and sometimes four, small branch- one, the nerve to the stapedius muscle, before it leaves the skull, the others r it leaves the skull.

The nerve to the stapedius is given off from the facial nerve as it descends in the posterior of the tympanum behind the pyramidal eminence. It is stated that filaments are also n off from the facial to the internal auditory artery (probably visceral motor from the glosso- tine) while the nerve is passing through the internal auditory meatus.

IG. 768.—DIAGRAM OF THE FACIAL (YELLOW) AND GLOSSOPALATINE NERVE (BLUE).



After it leaves the skull the facial nerve (fig. 770) gives off two or three col- ral branches and its two terminal divisions, the temporofacial and cervico- al. The collateral branches are the posterior auricular nerve, a branch to the terior belly of the digastric, and sometimes a lingual branch.

1) **The posterior auricular nerve** is the first branch of the extracranial portion of the facial e. It passes between the parotid gland and the anterior border of the sternomastoid le and runs upward in the deep interval between the external auditory meatus and the toid process. In this situation it communicates with the auricular branch of the vagus. pplies the auricularis posterior, sends a slender twig upward to the auricularis superior, ends in a long slender branch, **the occipital branch,** which passes backward to supply the pitalis muscle. It also receives filaments from the small occipital and great auricular nerves, supplies the intrinsic muscles of the auricle (pinna).

2) **The nerve to the posterior belly of the digastric** arises from the facial nerve close to stylomastoid foramen and enters the muscle near its center, or sometimes near its origin. ually gives off two branches: the **nerve to the stylohyoid,** which sometimes arises directly the facial nerve and passes to the upper part of the muscle that it supplies, and the **anas- otic branch,** which joins the glossopharyngeal nerve below its petrous ganglion.

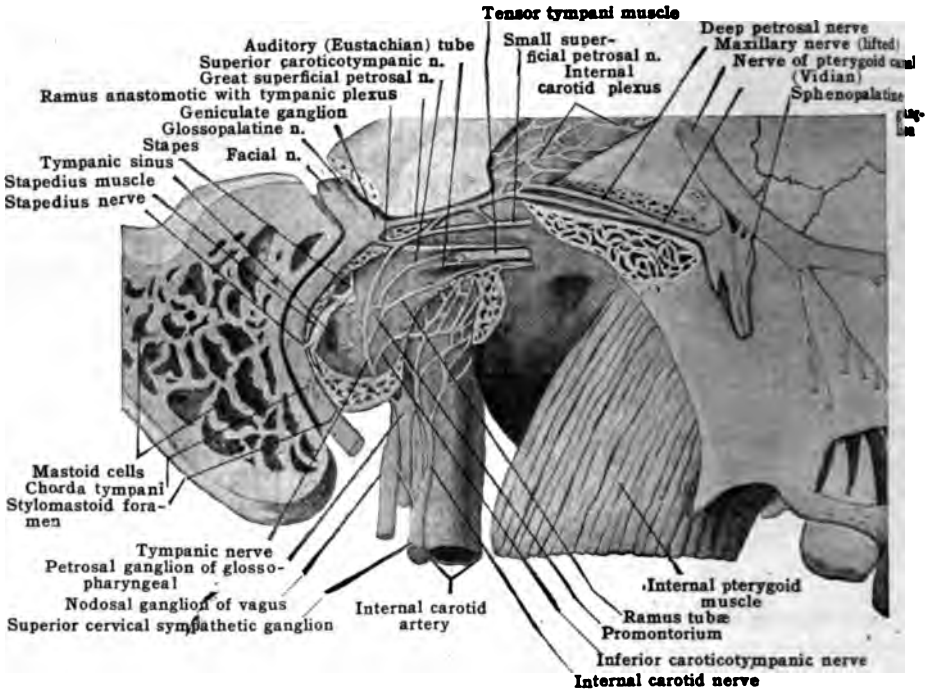
3) **The lingual branch,** first described by Cruveilhier, is not commonly present. It arises le below the nerve to the stylohyoideus and runs downward and medialward to the base he tongue. In its course it passes to the medial sides of the styloglossus and stylopharyn- s, and runs downward along the anterior border of the latter muscle to the wall of the ynx. It pierces the superior constrictor, insinuates itself between the tonsil and the rior palatine arch, and it is stated that it gives filaments to the base of the tongue and to styloglossus and glossopalatinus (palatoglossus) muscles.

The terminal divisions.—In the substance of the parotid gland the two inal divisions of the facial nerve lie superficial to the external carotid artery to the posterior facial (temporomaxillary) vein. The way in which these

terminal divisions give off their branches varies much in different subjects and often on the opposite sides of the same subject. One of the more common forms is here described.

The **temporofacial** or upper division runs upward and forward, and, after receiving communicating twigs from the auriculotemporal nerve, gives off temporal and zygomatic (malar) branches. The **cervicofacial** or lower division runs downward and forward, receives branches from the great auricular nerve, and gives off—(1) *buccal branches*, comprising what have been called infraorbital and buccal branches; (2) the *marginal mandibular* (supramandibular) branch; and (3) the *ramus colli* (inframandibular branch). These branches from the two terminal divisions anastomose freely to form the **parotid plexus** (pes anserinus).

FIG. 769.—THE RIGHT FACIAL NERVE, WITHIN THE SKULL, AND THE RELATIONS OF THE GLOSSOPALATINE AND GLOSSOPHARYNGEAL NERVES WITH THE TYMPANIC AND INTERNAL CAROTID PLEXUSES. (From Sobotta's Atlas, modified.)



The **temporal branches** passing upward communicate freely with each other and with the zygomatic branches. They also communicate with the zygomaticotemporal branch of the zygomatic nerve (the orbital branch of the maxillary nerve) and with the supraorbital nerve. They supply the frontalis, orbicularis oculi, corrugator supercilii, and auricularis anterior and superior (fig. 770).

The **zygomatic (malar) branches** passing upward and forward, communicate with the buccal branches of the facial nerve; with the zygomaticofacial branch of the zygomatic nerve (the orbital branch of the maxillary nerve); with the supraorbital and lacrimal branches of the ophthalmic nerve, and with the palpebral twigs of the maxillary. They supply both eyelids, the orbicularis oculi, and the zygomaticus (fig. 770).

The **buccal (infraorbital and buccal) branches** arise sometimes from the lower terminal division and sometimes from both the upper and the lower terminal divisions. The buccal branches, passing forward upon the masseter and underneath the zygomaticus and quadratus labii superioris, interlace with the zygomatic and marginal mandibular (supramandibular) branches of the facial nerve, with the buccinator (long buccal) branch of the trigeminus, and with the terminal branches of the maxillary nerve, forming with the last-named nerve the infraorbital plexus. They supply the zygomaticus, risorius, quadratus labii superioris, caninus, buccinator, incisivi, orbicularis oris, triangularis, quadratus labii inferioris, and the muscles of the nose (fig. 770).

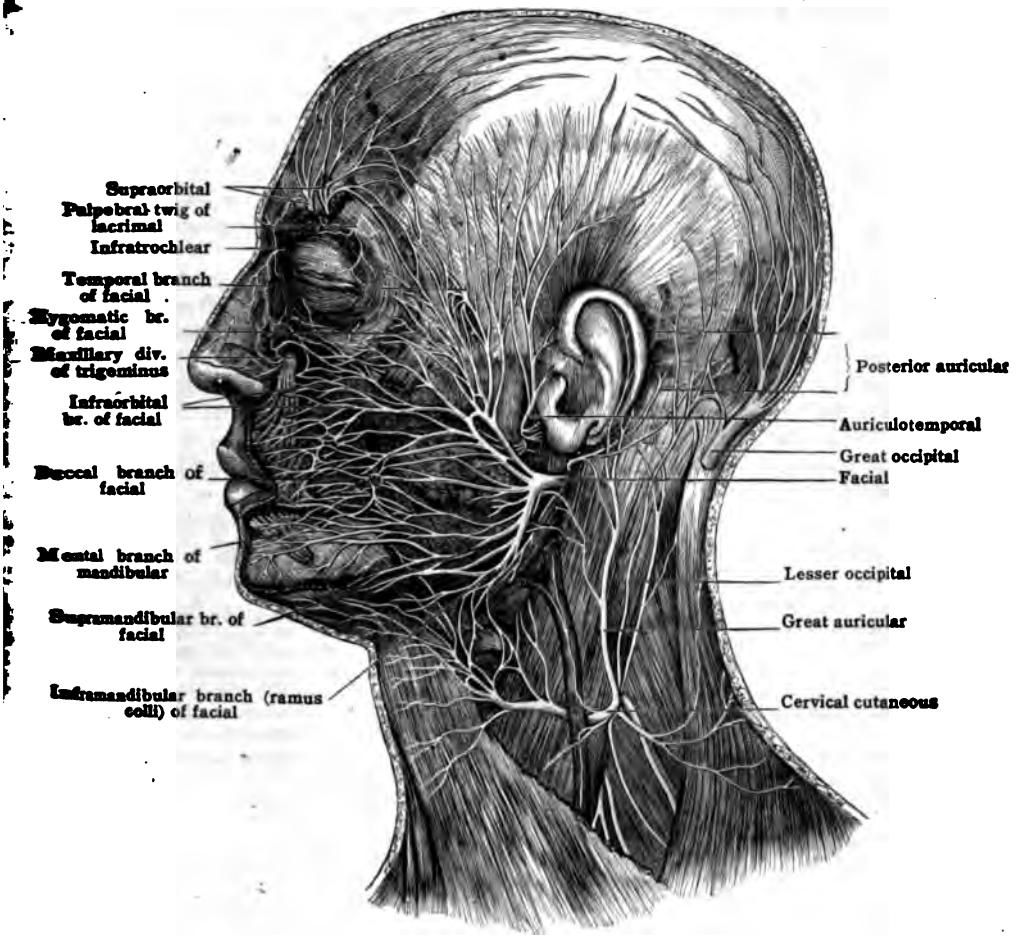
The **marginal mandibular (supramandibular) branch**, passing downward and forward under cover of the risorius and the depressors of the lower lip, communicates with the buccal branches and with the ramus colli of the facial nerve, and with the mental branch of the mandibular nerve. It supplies the quadratus labii inferioris and mentalis.

The **ramus colli (inframandibular branch)** runs downward and forward under cover of the platysma, which muscle it innervates (fig. 770). Beneath the platysma it forms one or

communicating loops, near its commencement, with the great auricular nerve, and longer , lower down, with the superficial cervical nerve.

Central connections.—The nucleus of origin of the facial in the rhombencephalon includes anterior and a posterior group of cells which give rise respectively to its upper and lower inal divisions. They are associated with the somesthetic area (lower third of the anterior al gyrus) by way of the pyramidal fasciculi of the opposite and same sides, and with the ei of the other cranial nerves, including the nucleus of termination of the trigeminus and opalatine, by way of the reticular formation and the medial longitudinal fasciculus.

FIG. 770.—SUPERFICIAL DISTRIBUTION OF THE FACIAL AND OTHER NERVES OF THE HEAD. (After Hirschfield and Leveillé.)



GLOSSOPALATINE NERVE

The **glossopalatine nerve** (*sensory root or pars intermedia of facial; nerve of Wrisberg*) contains both sensory and motor fibers. While it has a separate attachment to the medulla, it courses in close company with the facial and, in the internal auditory meatus, it is involved in the same sheath with the facial, which relation is maintained by its larger part thence through the facial canal till a short distance above the stylomastoid foramen (figs. 768, 769, 771). Here this larger part leaves the trunk of the facial as the *chorda tympani* nerve. The origin, central connections and peripheral distribution of the glossopalatine are similar to those of the glossopharyngeal nerve and suggest that it may be considered an aberrant portion of that nerve.

The **sensory portion** is much greater than the motor. Its fibers arise from cells situated in the geniculate ganglion which thus corresponds to a spinal ganglion. The *central processes* from these cells pass medialward in the facial canal (aqueduct of Fallopius) enclosed in the sheath of the facial nerve, which they

The **geniculate ganglion** is so named from the fact that it is embedded upo anterior border of the external genu (*geniculum*) of the facial nerve, behin hiatus Fallopii. It is somewhat triangular in form. From its superom angle leave the central processes of its cells, the root of the nerve; from its i lateral angle leave the fibers which later leave the sheath of the facial a chorda tympani, and its anterior angle is connected with the great supe petrosal nerve (figs. 769 and 771). The geniculate ganglion contains a rela large number of cell-bodies of sympathetic neurones many of whose pro run in this latter nerve, a relation mentioned below with the gangliated ce sympathetic plexus.

The **motor portion** of the glossopalatine consists for the most part of v efferent (autonomic) fibers, chiefly secretory. These arise in the medul longata from a small group of cells scattered in the reticular formation medial to the nucleus of the facial and in line with the dorsal efferent nuc the vagus below. It is called the *salivatory nucleus*. The fibers course v ward and lateralward to their exit, mingle with the entering sensory fibers glossopalatine in the sheath of the facial and, through the branches of the palatine, pass to terminate in sympathetic ganglia of the head, large and These ganglia send axones which terminate in the smooth muscle of vess about the cells of the glands of the lingual and palatine mucous membrane the salivary glands proper.

Some of the motor fibers of the nerve terminate in contact with the sympathetic maining in the geniculate ganglion and which give rise to sympathetic fibers issuing Most of the motor fibers pass into the great superficial petrosal nerve and the chorda to terminate in (chiefly) or pass through the sphenopalatine and submaxillary ganglia tively. Some may pass by the geniculotympanic branch and tympanic plexus to en otic ganglion. Many no doubt end in the smaller ganglia involved in the various sym plexuses. It is suggested that the motor part carries secretory impulses destined el the submaxillary and sublingual glands. A small gangliated plexus on the capsule of th side of the parotid gland has been frequently dissected and found to communicate fre twigs from the facial nerve and twigs concerned with the trigeminus. It is possible th glossopalatine visceral motor fibers terminate in these ganglia for secretory impulse parotid gland as well.

Central connections.—The nucleus of termination of the glossopalatine nerve (extension of the nucleus of termination of the sensory portion of the glossopharyn associated with the somesthetic area of the cerebral cortex of the opposite and same way of the medial lemniscus, and with the salivatory nucleus and motor nuclei of othe nerves by way of the reticular formation and medial longitudinal fasciculus. The nu origin of the motor portion (salivatory nucleus) may be associated not only with the of termination of the sensory part, but with the nuclei of termination of other cranial and perhaps with the motor area of the cortex of the opposite side by way of the py

'bipolar,' form. The *central processes* course with the cochlear nerve in the internal auditory meatus medialward, caudad and slightly downward, inferior to the accompanying facial and glossopalatine nerves, and, arching ventrally around the restiform body, they enter the medulla at the inferior border of the pons, lateral to the glossopalatine and facial and medial to the entrance of the cochlear nerve. They find their nucleus of termination spread in the floor of the fourth ventricle and grouped as the median, the lateral (Deiters'), the superior, and the nucleus of the spinal root of the vestibular nerve. In the internal auditory meatus, the vestibular nerve is connected by two small filaments of fibers with the glossopalatine nerve. These are either visceral motor fibers for the vessels of the domain of the vestibular or are aberrant fibers which course only temporarily with the vestibular and return to the glossopalatine.

The *peripheral processes* of the cells of the vestibular ganglion terminate in the neuroepithelium comprising the *maculæ* in the sacculus and the utriculus and the *cristæ* in the ampullæ of the three semicircular ducts. Thus there are five **terminal branches** of the nerve. None of its fibers terminates in the cochlea. The vestibular ganglion has a lobar form, one lobe giving rise to a superior **utriculoampullar** division which divides into three terminal branches; the other giving a **sacculoampullar** division which gives two terminals (fig. 772).

The superior or **utriculoampullar division** divides into the following terminal branches:

(1) The **utricular branch** passes through the superior macula cribrosa of the vestibule and terminates in the macula acustica of the utriculus.

(2) Accompanying the utricular branch through the superior macula cribrosa is a branch, the **superior ampullar,** to the crista acustica of the ampulla of the superior semicircular duct, and—

(3) A similar branch, the **lateral ampullar,** to the ampulla of the lateral semicircular duct.

The inferior or **sacculoampullar division** accompanies the cochlear nerve a short distance further than the superior, and divides into—

(4) A branch, the **posterior ampullar,** which passes through the foramen singulare and the inferior macula cribrosa and terminates in the ampulla of the posterior semicircular duct, and—

(5) A branch, the **saccular,** which passes through the middle macula cribrosa and terminates in the macula acustica of the sacculus.

The **central connections** of the vestibular nerve are described in detail on pp. 823, 860, 936. It large nucleus of termination, spread through the area acustica in the floor of the fourth ventricle, and divided into four sub-nuclei, is associated with the nuclei fastigii, globosus, and emboliformis of the cerebellum, with the nuclei of the eye-moving nerves, with the spinal cord, and with the cerebral cortex by way of the lemnisci.

THE COCHLEAR OR AUDITORY NERVE

The fibers of the cochlear nerve are distributed to the spiral organ (of Corti) in the cochlea, and so are considered as comprising the auditory nerve proper. They arise from the long, coiled **spiral ganglion** of the cochlea, the cells of which. like those of the vestibular ganglion, are bipolar. The *peripheral processes* of these cells are shorter than those of the vestibular ganglion. They terminate about the auditory or hair-cells of the spiral organ and thus collect impulses aroused by stimuli affecting these cells. The *central processes* of the ganglion cells continue through the modiolar canal and the tractus spiralis foraminosus of the cochlea, and thence, joining the vestibular nerve through the internal auditory meatus, accompanying the facial nerve and internal auditory artery, they course medialward and downward, approach and enclasp the restiform body (fig. 690) and enter the lateral aspect of brain-stem to terminate in their dorsal and ventral nuclei. A description of these nuclei and the further central connections of the cochlea with the superior olive, the nuclei of the eye-moving nerves, the inferior quadrigeminate bodies, the medial geniculate bodies, and with the cerebellum and temporal lobes of the cerebral hemispheres are given on pages 861, 877.

THE GLOSSOPHARYNGEAL NERVE

The glossopharyngeal or *ninth* cranial nerves are mixed nerves and each is attached to the medulla by several roots which enter the posterolateral sulcus, dorsal to the anterior end of the olivary body and in direct line with the facial nerve (fig. 761). Some of its sensory fibers are special sensory (taste) and many of its motor fibers are visceral motor (autonomic).

nerve and pass to the submaxillary ganglion, and others (sensory) continue forwar tongue, where, in company with fibers of the lingual nerve, they terminate in the ep covering the anterior two-thirds of the tongue. Some probably serve to convey sens taste, most of them are fibers of general sensibility. Before it joins the lingual nerve th tympani receives a communicating twig from the otic ganglion (figs. 768, 771).

THE VESTIBULAR NERVE

The vestibular nerve is purely sensory. With the peripheral process cells of origin terminating in the neuroepithelium of the semicircular ducts (and the vestibule, and their central processes conveying impulses to t substance of the medulla, cerebellum and spinal cord, the nerve comprises

FIG. 772.—THE LEFT MEMBRANOUS LABYRINTH OF A HUMAN FETUS OF 10 WEEKS (LATERAL ASPECT. Vestibular ganglion and nerve, red; cochlear nerve, yellow. (American Journal of Anatomy.)

a. 30mm. lateral.

important part of the apparatus for the equilibration of the body. It l customary to describe the vestibular [radix vestibularis] and the cochle cochlearis] nerves combined as the acoustic (auditory) or eighth crani While the two are blended in a common sheath from near the medul bottom of the internal auditory meatus, they are likewise partly enclos same sheath with the facial and glossopalatine nerves and the internal artery which accompany them in this meatus. At the bottom of the m vestibular and the cochlear are separate; they are separate at their entranc lateral aspect of the medulla oblongata; and their central connections, p distributions and functions are different.

The vestibular nerve arises as processes of the cells of the vestibular (ganglion of Scarpa), situated upon and blended within the nerve at th of the internal auditory meatus. Unlike the ordinary spinal ganglion t it corresponds, most of the cells of the vestibular ganglion retain an em

ganglion cells are those which are distributed to the mucous membrane (including taste-buds) of the tongue and pharynx, and the central processes pass medialward to the medulla. In the medulla they pass dorsalward and medianward through the reticular formation and, bifurcating into ascending and descending branches, they end in the nucleus of termination of the glossopharyngeal nerve, that is, in the superior part of the nucleus alæ cinereæ and of the nucleus of the tractus solitarius.

The motor fibers arise from the nucleus ambiguus in the lateral funiculus of the medulla, in line with the nucleus of origin of the facial nerve. From this nucleus they pass at first dorsalward and then, turning lateralward, they emerge and join the sensory fibers and run with them in the trunk of the nerve (fig. 687).

Van Gehuchten's observations point to the conclusion that one motor nucleus of the glossopharyngeal nerve is separate from and lies above and to the medial side of the nucleus ambiguus, and that a portion of the nucleus of the ala cinerea is also a motor nucleus common to the glossopharyngeal and vagus nerves. It is quite probable that the former motor nucleus is that now considered as the dorsal efferent nucleus of the vagus. An unknown number of the motor fibers are visceral motor and course in the various communications of the glossopharyngeal nerve with the cephalic (sympathetic) plexus.

Central connections.—The nuclei of termination of the glossopharyngeal nerve are associated with the motor nuclei of other cranial nerves by the medial longitudinal fasciculus, and with the somesthetic area of the cortex cerebri of the opposite side by the medial lemniscus fillet). The motor neurones of the nerve are associated with the somesthetic area by the pyramidal fibers.

THE HYPOGLOSSAL NERVE

The **hypoglossal nerves** are exclusively motor and probably exclusively somatic motor; they supply the geniohyoid and the extrinsic and intrinsic muscles of the tongue (except the glossopalatine). They are usually designated as the twelfth pair of cranial nerves. The fibers of each nerve issue from the cells of an elongated nucleus which lies in the floor of the central canal in the lower half of the medulla and in the floor of the fourth ventricle in the upper half beneath the trigonum hypoglossi. This nucleus is the upward continuation of the ventromedial group of cells of the ventral horn of the spinal cord. From their origin the fibers run ventralward and somewhat lateralward, probably joined in the medulla by a few fibers from the nucleus ambiguus which is a segment of the upward prolongation of the lateral group of cells of the ventral horn. The conjoined fibers issue from the medulla in the sulcus between the pyramid and the olivary body, in a series of from ten to sixteen root-filaments, which pierce the pia mater and unite with each other to form two bundles (fig. 761). These bundles pass forward and lateralward to the hypoglossal (anterior condyloid) foramen, where they pierce the arachnoid and dura mater. In the outer part of the foramen the two bundles unite to form the trunk of the nerve. At its commencement, at the base of the skull, the trunk of the hypoglossus lies on the medial side of the vagus, but as it descends in the neck it turns gradually around the dorsal and the lateral side of the latter nerve, lying between it and the internal jugular vein, and a little above the level of the hyoid bone it bends forward, and crosses lateral to the internal carotid artery, the root of origin of the occipital artery, the external carotid, and the loop formed by the first part of the lingual artery (fig. 773). After crossing the lingual artery it proceeds forward on the lateral surface of the hyoglossus, crossing to the medial side of the posterior belly of the digastric, and the stylohyoid muscles. It disappears in the anterior part of the submaxillary region between the mylohyoid and the hyoglossus, and divides into its terminal branches between the latter muscle and the genioglossus.

As it descends in the neck the trunk lies deeply between the internal jugular vein and the internal carotid artery under cover of the parotid gland, the styloid muscles, and the posterior belly of the digastric, and it is crossed superficially by the posterior auricular and the occipital arteries. As it turns forward around the root of the occipital artery the sternomastoid branch of that vessel hooks downward across the nerve, and as it turns forward on the hyoglossus muscle it lies immediately above the ranine vein. It is crossed by the posterior belly of the digastric and the stylohyoid muscle, and it is covered superficially, behind the mylohyoid, by the lower part of the submaxillary gland. Many of the twigs described as communications and branches contain few or no fibers of the hypoglossus proper.

Communications.—The hypoglossus is connected with the superior cervical ganglion of the sympathetic, with the ganglion nodosum of the vagus, with the loop between the first and second cervical nerves, and with the lingual nerve; the latter communication is established along the anterior border of the hyoglossus muscle (figs. 773 and 774).

The filaments, when traced lateralward, are seen to blend, in front of the flocculus, into a trunk which lies in front of the vagus nerve, but which passes through a separate opening through the arachnoid and the dura mater and through the jugular foramen. In the foramen this trunk lies in front, and lateral to the vagus nerve in a groove on the petrous portion of the temporal bone; and in this situation two ganglia are interposed in it, a superior or jugular, and an inferior or petrosal. After it emerges from the jugular foramen the glossopharyngeal nerve descends at first between the internal carotid artery and the internal jugular vein and to the lateral side of the vagus; then, bending forward and medialward, it descends medial to the styloid process and the muscles attached to it, and turning around the lower border of the stylopharyngeus it passes between the internal and the external carotid arteries, crosses the superficial surface of the stylopharyngeus, and runs forward and upward medial to the hyoglossus muscle and across the middle constrictor and the stylohyoid ligament, to the base of the tongue (fig. 773).

Ganglia.—The **superior or jugular ganglion** (ganglion of Ehrenritter), is a small, ovoid, reddish-gray body which lies on the back part of the nerve-trunk in the upper part of the jugular foramen. No branches arise from it. It is sometimes continuous with the petrosal ganglion or it may be absent.

The **inferior or petrosal ganglion** (ganglion of Andersch), is an ovoid gray body which lies in the lower part of the jugular foramen, and appears to include all the fibers of the nerve.

Branches and communications.—(1) The petrosal ganglion is connected with the superior cervical ganglion of the sympathetic by a fine filament.

(2) It also has a filament of communication with the auricular branch of the vagus which varies inversely in size with the latter branch and sometimes entirely replaces it. This filament may be absent.

(3) An inconstant communication with the ganglion of the root of the vagus.

(4) A short distance below the petrous ganglion the trunk of the nerve is connected by a twig with that branch of the facial nerve which supplies the posterior belly of the digastric muscle. There is also a small twig (probably sensory) to the stylohyoid.

(5) **From the petrosal ganglion: The tympanic branch** (nerve of Jacobson) arises from the petrosal ganglion and passes through a foramen, which lies in the ridge of bone between the carotid canal and the jugular fossa, into the tympanic canaliculus (**Jacobson's canal**), where it is surrounded by a small, fusiform mass of vascular tissue, the *intumescentia tympanica*. After traversing the tympanic canaliculus it enters the tympanum at the junction of its lower and medial walls, and, ascending on the medial wall, breaks up into a number of branches which take part in the formation of the **tympanic plexus** on the surface of the promontory (**fig. 769**). The continuation of the nerve emerges from this plexus as the *small superficial petrosal nerve*, which runs through a small canal in the petrous portion of the temporal bone, beneath the canal for the tensor tympani, and appears in the middle fossa of the cranium through a foramen which lies in front of the hiatus Fallopii. From this foramen it runs forward and passes through the foramen ovale, the canaliculus innominatus, or the sphenopetrosal suture, and enters the zygomatic fossa, where it enters the otic ganglion. While it is in the canal in the temporal bone the small superficial petrosal nerve is joined by a **geniculotympanic branch from the geniculate ganglion** of the glossopalatine nerve.

(6) **Branches from the tympanic plexus:** (*a*) The **tubal branch** (**ramus tubæ**), a delicate branch, which runs forward to the mucous membrane of the tuba auditiva (**Eustachian tube**) and sends filaments backward to the region of the fenestra vestibuli (**ovalis**) and the fenestra cochleæ (**rotunda**). (*b*) The **superior and inferior caroticotympanic (carotid) branches** pass medianward to the internal carotid plexus (figs. 769, 771).

The above communications carry fibers almost entirely concerned with the sympathetic plexuses of the head and they will be again mentioned below with the gangliated cephalic plexus.

Branches from the trunk of the nerve: (1) **Pharyngeal branches**, which may be two or three in number, arise from the nerve a short distance below the petrosal ganglion. The principal and most constant of these passes on the lateral side of the internal carotid artery, and after a very short independent course joins with the pharyngeal branch of the vagus and with branches of the superior cervical ganglion to form the **pharyngeal plexus** (**fig. 773**).

(2) A **muscular branch** is distributed to the **stylopharyngeus muscle**. This branch receives a communication from the facial nerve (fig. 773).

(3) The **tonsillar branches** are a number of small twigs which arise under cover of the hyoglossus muscle; they proceed to the tonsil, around which they form a plexus, the **circulus tonsillaris**. From this plexus fine twigs proceed to the glossopalatine arch and to the soft palate.

(4) The **lingual branches** are the terminal branches of the nerve and supply the mucous membrane of the posterior half of the dorsum of the tongue, where, chiefly as **taste-fibers**, they are distributed to the vallate papillæ. Some small twigs pass backward to the follicular glands of the tongue, and to the anterior surface of the epiglottis. Other twigs are distributed around the foramen cecum, where they communicate with the corresponding twigs of the opposite side.

The sensory fibers.—The sensory fibers of the glossopharyngeal nerve spring from the superior and petrosal ganglia and pass peripherally and centrally. **The peripheral processes of the**

(3) **The branches of the hypoglossus proper, the rami linguales,** supply the styloglossus hyoglossus, genioglossus, and the intrinsic muscular fibers of the tongue.

The nerve to the styloglossus is given off near the posterior border of the hyoglossus. It pierces the styloglossus, and its fibers pursue a more or less recurrent course within the muscle.

The nerves to the hyoglossus are several twigs which are supplied to the muscle as the hypoglossal nerve crosses it.

The nerve to the genioglossus arises under cover of the mylohyoid in common with the terminal branches to the intrinsic muscles of the tongue. It communicates freely with branches (sensory) of the lingual, forming long loops which lie on the genioglossus. From these loops twigs pass into the genioglossus and into the muscular substance of the tongue.

Central connections.—The nucleus of origin of the hypoglossus is associated with the somesthetic area (operculum) of the cortex cerebri of the opposite side by the pyramidal fibers, and it is correlated with the sensory nuclei (nuclei of termination) of other cranial nerves by way of the reticular formation and the medial longitudinal fasciculus.

THE VAGUS OR PNEUMOGASTRIC NERVE

The vagus or pneumogastric (tenth) nerves are the longest of the cranial nerves, and they are remarkable for their almost vertical course, their asymmetry, and their extensive distribution, for, in addition to supplying the lung and stomach, as the name 'pneumogastric' indicates, each nerve gives branches to the external ear, the pharynx, the larynx, the trachea, the esophagus, the heart, and the abdominal viscera.

Each nerve is attached to the side of the medulla, in the posterolateral sulcus, dorsal to the olivary body, by from twelve to fifteen root-filaments which are in linear series with the filaments of the glossopharyngeal nerve (fig. 761). The filaments contain both visceral and somatic sensory and motor fibers. They pierce the pia mater, from which they receive sheaths, and, traced outward, they pass into the posterior fossa of the cranium toward the jugular foramen and unite to form the trunk of the nerve, which passes through openings in the arachnoid and the dura mater which are common to it and to the spinal accessory nerve. In the jugular foramen a small spherical ganglion, the *jugular ganglion* (ganglion of the root), is interposed in the trunk which here turns at right angles to its former course and descends through the neck. As it leaves the jugular foramen it is joined by the internal or accessory portion of the spinal accessory nerve, and immediately below this junction occurs its large ovoid ganglion, the *ganglion nodosum* or ganglion of the trunk (fig. 773). As it descends through the neck the nerve passes ventral and somewhat lateral to the superior cervical sympathetic ganglion, and in front of the longus capitis and longus colli, from which it is separated by the prevertebral fascia. In the upper part of the neck it is placed between the internal carotid artery and the internal jugular vein, and in a plane dorsal to them, the artery being ventral and mesial, and the vein ventral and lateral. In the lower part of the neck it occupies a similar position in regard to the common carotid artery and the internal jugular vein, and the three structures are enclosed in a common sheath derived from the deep cervical fascia, but within the sheath each structure occupies a separate compartment (fig. 773). In the root of the neck and in the thorax the relations of the nerves of the two sides of the body differ somewhat, and they must, therefore, be considered separately (fig. 774).

The right vagus passes in front of the first part of the right subclavian artery in the root of the neck and then descends in the thorax, passing obliquely downward and backward on the right of the trachea, and behind the right innominate vein and the superior vena cava, to the back of the root of the right lung. Just before it reaches the right bronchus it lies close to the medial side of the vena azygos as the latter hooks forward over the root of the lung. At the back of the right bronchus the right vagus breaks up into a number of branches which join with the branches of the sympathetic to form the **right posterior pulmonary plexus,** and from this plexus it issues in the form of one or more cords, combined sensory, visceral motor and sympathetic, which descend on the esophagus and break up into branches which join with branches of the left vagus, forming the **posterior esophageal plexus.** At the lower part of the thorax fibers of this plexus become again associated in one trunk which passes through the diaphragm on the *posterior* surface of the esophagus, and is distributed to the *posterior* surface of the stomach and to the celiac (solar) plexus and its offsets.

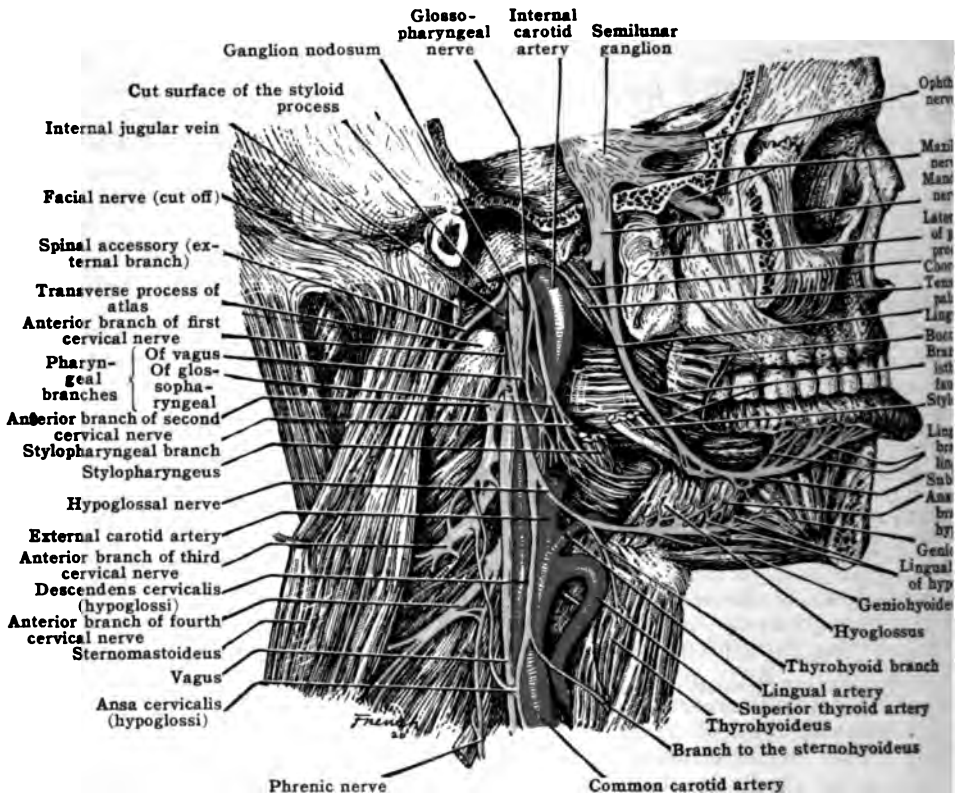
The left vagus descends through the root of the neck between the carotid and subclavian arteries and in front of the thoracic duct. In the upper part of the superior mediastinum it is crossed in front by the left phrenic nerve, and in the lower part of the same region it crosses in front of the root of the subclavian artery and the arch of the aorta and behind the left superior intercostal vein. Below the aortic arch it passes behind the left bronchus and divides into branches which unite with twigs of the sympathetic to form the **left posterior pulmonary plexus.**

Terminal branches.—These include (1) a meningeal branch; (2) branches from the cervical plexus; and (3) branches from the hypoglossus proper.

(1) A meningeal branch, frequently represented by two filaments, is given off in the hypoglossal (anterior condyloid) canal. It passes backward into the posterior fossa of the cranium and is distributed to the dura mater. It does not comprise fibers of the hypoglossus proper. It was believed at one time that the fibers of the meningeal branch were derived from the lingual nerve, but it is now deemed more probable that they are either sensory or visceral motor fibers from the cervical nerves, or from the vagus.

(2) **Branches which consist of fibers derived from the cervical plexus.**—The descendens cervicalis (hypoglossi) and the muscular twig to the thyrohyoid muscle, though apparently arising from the hypoglossal nerve, consists entirely of fibers which have passed into the hypoglossal nerve from the loop between the first two cervical nerves. Therefore, neither of these are branches of the hypoglossus proper. (See fig. 783).

FIG. 773.—THE HYPOGLOSSAL, GLOSSOPHARYNGEAL, AND LINGUAL NERVES. (From Spalteholz, modified.)



(a) The **descendens cervicalis (hypoglossi)** parts company with the hypoglossus at the where the latter hooks around the occipital artery (fig. 773). It runs downward and sl medialward on the sheath of the great vessels (occasionally within the sheath), and is at a variable level by branches from the second and third cervical nerves, forming with t loop, the cervical loop [ansa hypoglossi]. The cervical loop may be placed at any leve a point immediately below the occipital artery to about 4 cm. above the sternum. Fro loop all the muscles attached to the hyoid bone are supplied. A twig to the anterior b the omohyoid arises from the descendens cervicalis in the upper part of its course. The which supply the sternohyoid, sternothyroid, and posterior belly of the omohyoid are gi by the cervical loop. Twigs from the first two nerves pass downward in the muscles behi manubrium sterni and in rare cases communicate with the phrenic nerve within the t The nerve to the posterior belly of the omohyoid runs in a loop of the cervical fascia bel central tendon of the muscle.

(b) The **nerve to the thyrohyoid** leaves the hypoglossus near the tip of the great co the hyoid bone, and runs obliquely downward and medialward to reach the muscle. A fibers in (a) and (b) are derived from the first, second and third cervical nerves.

(c) The **nerve to the geniohyoid** arises under cover of the mylohyoid, where loo formed with the lingual nerve from which loops branches pass into the muscle. It pro *contains some* true hypoglossal fibers.

skull and in front of the upper part of the internal jugular vein. It is of flattened ovoid form and about 17 mm. long and 4 mm. broad (figs. 774 and 773). It is joined by the accessory part of the spinal accessory nerve, and is associated with the hypoglossal nerve, with the superior cervical ganglion of the sympathetic, and with the loop between the first two cervical nerves, and it gives off a pharyngeal, a superior laryngeal, and a superior cardiac branch. Both ganglia and especially the nodosal retain numerous cell-bodies of sympathetic neurones and the twigs issuing from the ganglia thus contain sympathetic fibers. The greater number of the cell-bodies are of sensory neurones.

It should be remembered that the visceral sensory fibers of the vagus arise in its ganglia and carry to the medulla impulses aroused in the viscera it supplies, chiefly the epithelium of the digestive and respiratory apparatuses; that its visceral motor fibers carry from the medulla efferent impulses which are transferred by synapses to sympathetic ganglion-cells and these in turn send fibers to the smooth and cardiac muscle and the glands of its domain, while its somatic motor fibers carry impulses from the medulla direct to skeletal muscle. Its somatic sensory fibers carry to the medulla impulses aroused, for the most part, in the skin.

Communications.—The vagus nerve is connected with the glossopharyngeal, spinal accessory and hypoglossal nerves, with the sympathetic, and with the loop between the first and second cervical nerves.

(1) Two communications exist between the vagus and glossopharyngeal nerves: one between their trunks, just below the base of the skull, and one, in the region of their ganglia, consisting of one or two filaments. When two filaments are present one passes from the jugular ganglion and the other from the auricular nerve to the petrosal ganglion of the glossopharyngeal nerve. Either or both of these filaments may be absent.

(2) Two twigs pass from the spinal accessory nerve to the ganglion nodosum, and at a lower level the accessory part of the spinal accessory nerve also joins the same ganglion (fig. 774). The majority of the fibers of the accessory part of the spinal accessory nerve merely pass across the surface of the ganglion and are continued into the pharyngeal and superior laryngeal branches of the vagus, but a certain number blend with the trunk of the vagus and are continued into its recurrent laryngeal and cardiac branches.

(3) Two or three fine filaments connect the ganglion nodosum with the hypoglossal nerve as the latter turns around the lower part of the ganglion (fig. 774).

(4) Fibers pass from the superior cervical ganglion of the sympathetic to both ganglia of the vagus (fig. 774).

(5) A twig sometimes passes from the loop between the first two cervical nerves to the ganglion nodosum (fig. 774).

Terminal branches of the vagus.—These are the meningeal, auricular, pharyngeal, superior laryngeal, recurrent (inferior laryngeal), cardiac, bronchial, pericardial, esophageal, and the abdominal branches.

(1) The **meningeal** or **recurrent branch** is a slender filament which is given off from the jugular ganglion. It takes a recurrent course through the jugular foramen, and is distributed to the dura mater around the transverse (lateral) sinus.

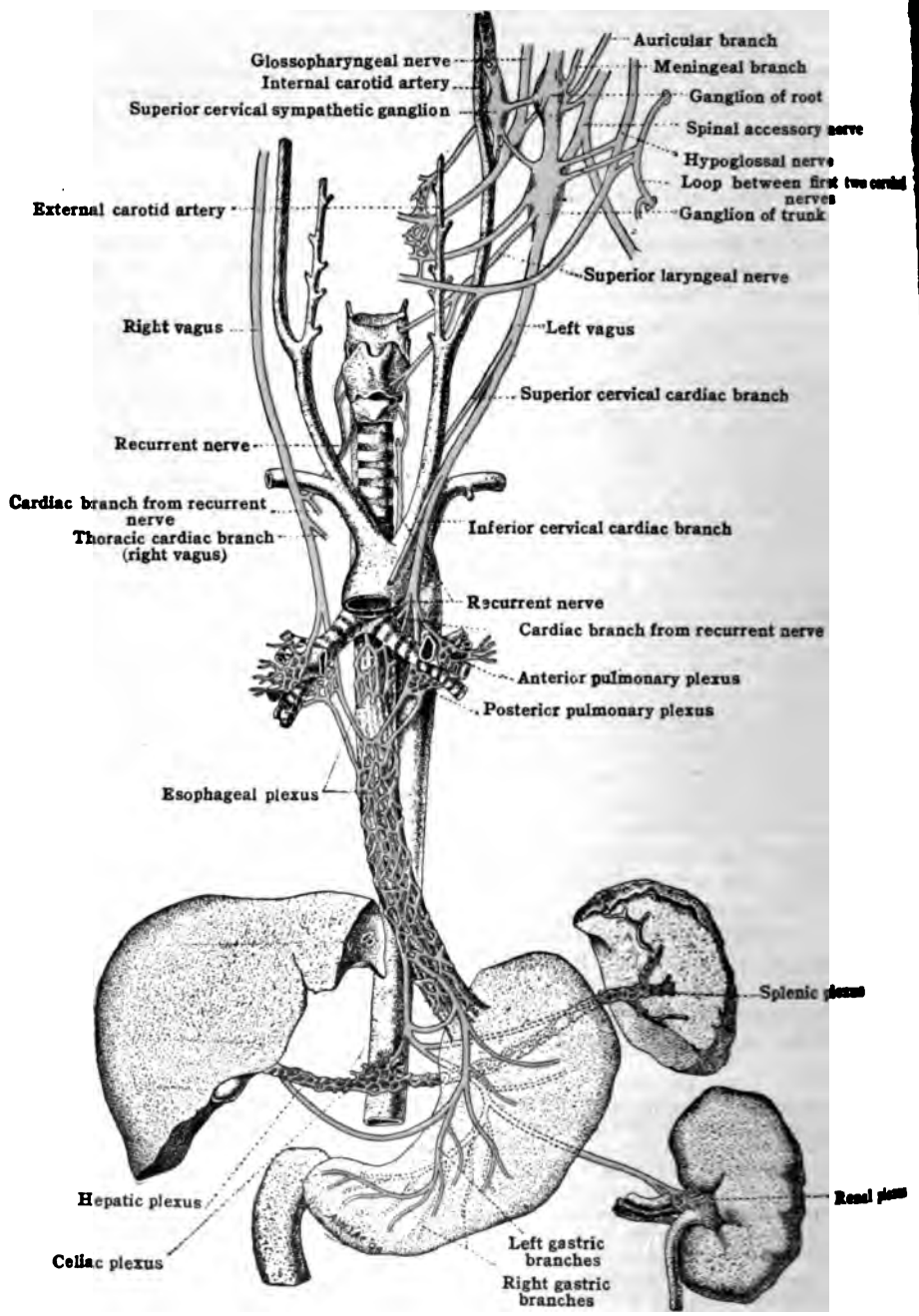
(2) The **auricular branch, or nerve of Arnold,** arises from the jugular ganglion in the jugular foramen. It receives a branch from the petrosal ganglion of the glossopharyngeal, enters the petrous part of the temporal bone through a foramen in the lateral wall of the jugular fossa, and communicates with the facial nerve or merely lies in contact with it as far as the stylomastoid foramen. It usually leaves the temporal bone by the stylomastoid foramen, but it may pass through the tympanomastoid fissure, and it divides, behind the auricle, into two branches, one of which joins the posterior auricular branch of the facial while the other supplies sensory fibers to the posterior and inferior part of the external auditory meatus and the back of the auricle. It also supplies twigs to the osseous part of the external auditory meatus and to the lower part of the outer surface of the tympanic membrane.

(3) The **pharyngeal branches** may be two or three in number. The principal of these joins the pharyngeal branch of the glossopharyngeal on the lateral surface of the internal carotid artery, and after passing with the latter medial to the external carotid artery it turns downward and medialward to reach the posterior aspect of the pharynx. Here the two nerves are joined by branches from the superior cervical ganglion of the sympathetic, with which they form the **pharyngeal plexus** (figs. 773, 774). Branches from this plexus supply sensory fibers to the mucous membrane of the pharynx, somatic motor fibers to the constrictores pharyngis, levator palatini, uvulæ, glossopalatinus, and pharyngopalatinus and probably visceral motor to sympathetic ganglion cells.

(4) The **superior laryngeal nerve** arises from the lower part of the ganglion nodosum, and passes obliquely downward and medialward, behind and medial to both the internal and external carotid arteries, toward the larynx. In this course it describes a curve with the convexity downward and lateralward and divides into (a) a larger internal and (b) a smaller external branch (fig. 774). Before its division it is joined by twigs with the sympathetic and with the pharyngeal plexus, and it gives a small branch to the internal carotid artery.

From this plexus the fibers of the left vagus issue as one or more cords that break up into anastomosing branches to form the anterior **esophageal plexus.** At the lower part of the thorax this plexus becomes a single trunk, which passes through the diaphragm on the *anterior* surface of the esophagus, and it is distributed to the *anterior* surface of the stomach and to the liver.

FIG. 774.—DIAGRAM OF THE BRANCHES OF THE VAGUS NERVES.



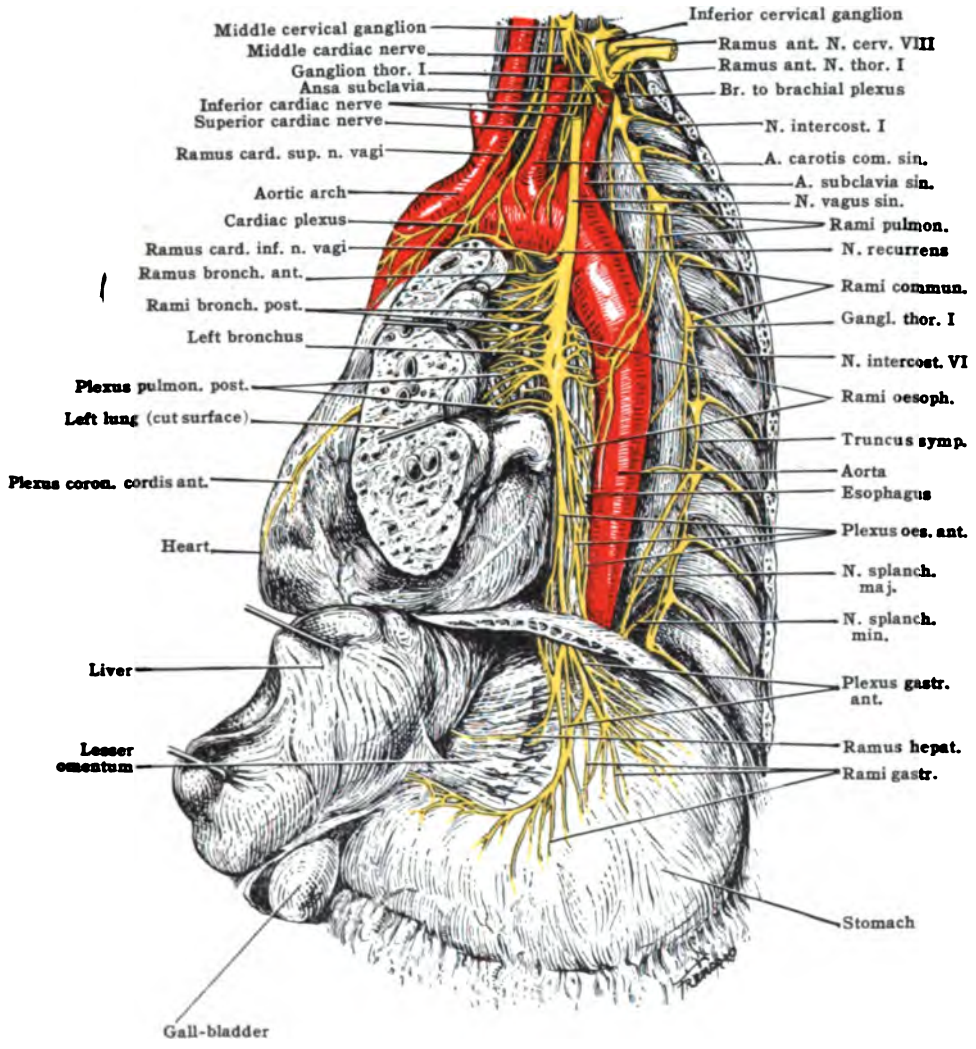
The **jugular ganglion** (ganglion of the root) is a **spherical gray mass** about 5 mm. in diameter which lies in the jugular foramen (**fig. 774**). It is connected with the spinal accessory nerve and with the superior cervical sympathetic ganglion, and it gives off an auricular branch, by means of which it becomes associated with the facial and glossopharyngeal nerves, and a recurrent meningeal branch.

The **ganglion nodosum** (ganglion of the trunk) lies below the base of the

(9) **Esophageal branches,** given off by the trunk of the nerve above the bronchial plexuses and from the esophageal plexuses lower down, pass to the wall of the esophagus.

(10) **Abdominal branches.**—The terminal part of the left vagus divides into many branches, some of which communicate freely along the lesser curvature of the stomach with filaments from the gastric plexus of the sympathetic, and to some extent with branches of the right vagus, to form the elongated **anterior gastric plexus** (figs. 774, 775). From this plexus as well as from the nerve-trunk, **gastric branches** are given to the anterior surface of the stomach. **Hepatic branches** from the trunk or from this plexus pass in the lesser omentum to the hepatic plexus (figs. 774, 775). The terminal part of the right vagus divides into many branches, and forms along the lesser curvature of the stomach an elongated **posterior gastric plexus** by communica-

FIG. 775.—THORACIC BRANCHES OF LEFT VAGUS AND OF ABDOMINAL PORTION OF LEFT SYMPATHETIC TRUNK. (After Spalteholz.)



tions with branches from the gastric plexus of the sympathetic and with branches from the right vagus. **Gastric branches** are given off by the trunk of the nerve and from this plexus. **Celiac branches** are given by the trunk to the celiac (solar) plexus, and **splenic** and **renal branches,** either directly or through the celiac (solar) plexus, are given to the splenic and renal plexuses (fig. 774).

Central connections.—The **sensory fibers** of the vagus are processes of the cells of the jugular ganglion and the ganglion nodosum. The peripheral fibers from these cells bring in sensory impulses from the periphery, and their central fibers convey the impulses to the brain. The latter fibers enter the medulla in the filaments of attachment in the posterolateral sulcus, and, in the reticular formation, they bifurcate into ascending and descending branches which end in the nuclei of termination of the vagus, namely, in the nucleus alæ cinereæ in the floor of the fourth ventricle and in the nucleus tractus solitarii. The tractus solitarius consists largely of the descending branches. These and the axones arising from the nuclei of termination of the vagus descend the spinal cord to terminate about ventral horn cells which give origin to the

phrenic nerve and to motor fibers supplying other muscles of respiration, and they al impulses which are distributed to visceral motor neurones along the spinal cord.

The **motor fibers** spring from the nucleus ambiguus and from the dorsal efferent motor) nucleus of the vagus, described on page 858. They join the sensory fibers in the formation. Some of the motor fibers, especially those from the dorsal efferent nu visceral motor fibers.

The central connections of the vagus are similar to those of the glossopharyng (fig. 688). Van Gehuchten's observations point to the conclusion that the chief t termination of the vagus nerve is that of the tractus solitarius.

THE SPINAL ACCESSORY NERVE

The spinal accessory (or eleventh) nerve [n. accessorius] is exclusively It consists of two parts, the accessory or superior, and the spinal or infer

The fibers of the **accessory or superior portion** [ramus internus] ('a vagus') spring chiefly from the inferior continuation of the nucleus ambi common with the motor fibers of the vagus above, and they pass thr reticular formation to the posterolateral sulcus of the medulla, where the as a series of filaments, below those of the vagus. The filaments pierc mater and unite, as they pass outward in the posterior fossa of the cra form a part of the nerve which enters the aperture in the dura mater co the vagus and spinal accessory nerves. In the aperture this trunk is join spinal portion of the nerve.

The **spinal** or **inferior portion** [ramus externus] arises from the cells of tral horn of the cord as low as the fifth, and rarely the seventh, cervic The fibers pass dorsalward and lateralward from their origins, chiefly fro eral part of the ventral horn, through the lateral funiculus of white subst they emerge from the lateral aspect of the cord behind the ligamentum d tum, along an oblique line, the lower fibers passing out immediately dor ligament. and the upper close to and sometimes in association with t roots of the upper two spinal nerves. As the spinal fibers pass out of th of the cord they unite to form an ascending strand (fig. 761) which e posterior fossa of the cranium, through the foramen magnum, and lateralward, blends more or less intimately with the accessory portio combined, the nerve enters the jugular foramen in company with the v here it is again separated into its two branches, which contain chiefly fibers as the original superior and inferior parts.

The **superior branch**, or accessory portion of the nerve, gives one or more filam jugular ganglion (ganglion of the root of the vagus), and then joins either the trunk o directly or its ganglion nodosum, the fibers of the branch being contributed to the p laryngeal, and cardiac branches of the vagus. Fibers corresponding to the white ram cantes, absent in the cervical nerves, probably enter the cervical sympathetic gangl this ramus of the spinal accessory nerve. The fibers which are accessory to the vag probably include visceral motor and cardioinhibitory fibers.

The **inferior branch** or the spinal portion runs backward and downward under c posterior belly of the digastric and the sternomastoid. It usually crosses in fro the lateral side of the internal jugular vein and between it and the occipital arte pierces the *sternomastoid*, supplies filaments to it, and interlaces in its substance wi of the second cervical nerve. It emerges from the posterior border of the ste slightly above the level of the upper border of the thyroid cartilage, passes obliquely and backward across the occipital portion of the posterior triangle, and disappears t trapezius at about the junction of the middle and lower thirds of the anterior border of (fig. 773). In the posterior triangle it receives communications from the third cervical nerves, and beneath the trapezius its fibers form a plexus with other bran same nerves. Its terminal filaments are distributed to the *trapezius* and they ca almost to the lower extremity of that muscle.

Central connections.—The nuclei of origin, like other motor nuclei, are connect somesthetic area of the cerebral cortex of the opposite side by the pyramidal fibers, a associated with the sensory nuclei of other cranial nerves by the medial longitudina and with sensations brought in by the spinal nerves directly and by the fibers of t proprii.

THE GANGLIATED CEPHALIC PLEXUS

The Sympathetic Ganglia of the Head and Their Associations with Cranial Nerves

The sympathetic system of the head, like that of the remainder of described below, is arranged in the form of a continuous gangliated ple vided into subplexuses. Unlike the great unpaired prevertebral plexu

oracic and abdominal cavities, all the larger sympathetic ganglia of the head are ired, ganglia corresponding to each other being found on either side. Thus, ssibly, they may be considered as an upward extension of the series of paired nbar, thoracic and cervical ganglia belonging to the sympathetic trunks lying ng either side of the vertebral column. Numerous small ganglia, many of em microscopic, occur in the subplexuses throughout the head. These are egular in size and position and those in the region of the median line are no ubt unpaired.

In origin, the ganglia of the cephalic plexus consist of cell-bodies which, in the early stages development, migrated from the fundaments of the ganglia of the vagus, glossopharyngeal d glossopalatine nerves, and most especially from that of the semilunar (Gasserian) ganglion the trigeminus—a developmental relation identical with that of the remainder of the sym thetic system to the ganglia of the spinal nerves. Just as is known for the spinal ganglia, me cell-bodies destined to develop into sympathetic neurones, instead of migrating, remained ithin the confines of the ganglia of the above nerves, in company with the cell-bodies of their nsory neurones. This is thought to be especially true for the geniculate, the petrosal and the gular ganglion. Therefore these ganglia must be considered as in small part sympathetic nglia.

The gangliated cephalic plexus could properly be included as a division of the general sym thetic system described later. However, because its larger ganglia are so intimately asso ated with branches of the oculomotor, trigeminal, masticator, glossopalatine, glossopharyngeal d vagus nerves, it is customary to describe it in connection with the cranial nerves.

The larger **ganglia,** one on either side of the head, comprise the ciliary ganglion, e sphenopalatine (Meckel's) ganglion, the otic and the submaxillary ganglion. o these must be added portions of the geniculate, petrosal, jugular and the gan - ion nodosum, and a part of the superior cervical sympathetic ganglion. The ief relations of the gangliated cephalic plexus to the cranial nerves are shown in g. 771.

The so-called **roots and branches of the ganglia** carry three varieties of fibers:) Sensory, visceral and somatic, (2) Motor (visceral motor or preganglionic), d (3) Sympathetic proper. Most roots and branches are mixed, the name of a ot being determined only by the variety of fibers predominating in it. Fibers sing from the cells of a ganglion and passing out of it, usually in one of its anches, are often referred to as postganglionic fibers (sympathetic proper).

A bundle of sensory fibers going to a ganglion is called its **sensory root.** Such, however, nnot comprise a true root since none of its fibers arises in the ganglion and very few or none ay terminate in it. The only sensory fibers terminating in a ganglion are the few which may proach it in any of the roots to terminate in its capsule or the capsules of its cells and convey pulses of general sensibility from the ganglion to the central nervous system. Almost all of e fibers of a 'sensory root' merely pass around or through a ganglion and into its branches yond, which they borrow as paths for reaching their allotted fields of distribution. In this lation it should be realized that while the ciliary, sphenopalatine, otic and submaxillary nglia are customarily described under the discussion of the trigeminus, this nerve has func onally less to do with them than any of the other cranial nerves with which they are associated. ndles of trigeminal (sensory) fibers, traceable in gross anatomy because medullated and of preciable size, pass to the ganglia, but only to pass through them as continuations of the ter inal branches of the trigeminus.

The so-called **motor root** of a ganglion may carry two kinds of fibers: (a) visceral motor reganglionic) fibers, arising in the nuclei of origin in the central system and passing in the unk and branches of a cranial nerve (oculomotor, masticator, etc.) to enter and terminate in ntact with the cell-bodies of the ganglion, which, in their turn, give fibers to the branches e ganglion; (b) fibers of the same origin, name and course but which may pass through the nglion to terminate in contact with the cells of a more distant ganglion. Any root, the motor pecially, may contain somatic motor fibers, that is, fibers of central origin which pass through e ganglion uninterrupted and into its branches to terminate directly upon the fibers of skeletal uscle.

A **sympathetic root** carries chiefly fibers conforming to the name: fibers arising in other nglia which pass through the ganglion in question to enter its branches and terminate upon eir allotted muscular or glandular elements. Obviously it may possibly also carry somatic otor and sensory and visceral sensory fibers. The larger ganglia of the head are described each possessing the three roots above mentioned.

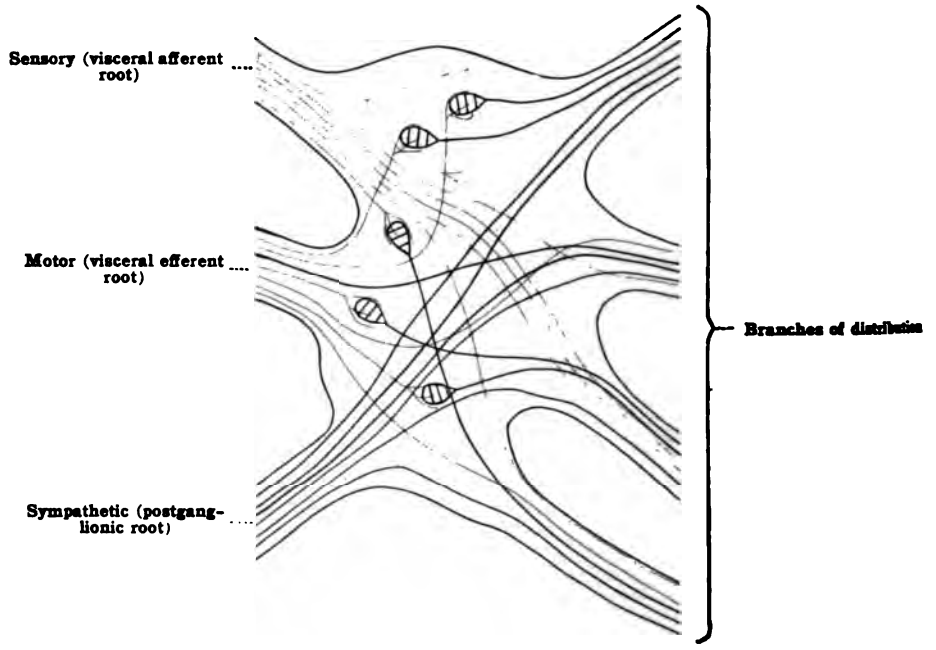
The **branches of distribution** of the ganglia, the larger of them often called nerves, are those ndles in which the fibers, both arising in or passing through the ganglia, course toward their rminations upon their allotted tissue elements of the head. In the branches pass fibers otor to the smooth muscle of the vessels of the head, to the intrinsic muscles of the eyeball, the lacrimal glands, the mucous membranes (gland cells) of the nasal and oral cavities and e salivary glands, and sensory fibers conveying impulses from these structures.

The **plexuses** into which the gangliated cephalic plexus is divided, including the roots and anches which connect the ganglia to form it, are numerous and vary greatly in size. They nderlie the mucous membranes and they surround all the vessels and glands. They are

named according to their locality. The largest of them are the tympanic plexus and the carotid and cavernous plexuses. They have been repeatedly referred to in their relations to the branches of the cranial nerves.

Of the numerous branches described from the superior cervical sympathetic ganglion, the two large ones which pass upward associate it especially with the gangliated cephalic plexus. That branch known as the internal *carotid nerve* may be considered as the direct continuation upward of the gangliated sympathetic trunk of the body. Through the branches of this nerve, the caroticotympanic and the deep petrosal nerves, and through the plexuses derived from it, the superior cervical ganglion may be associated with practically all the other sympathetic ganglia of the head (figs. 769 and 771). The other branch from the superior cervical ganglion, the *jugular nerve*, associates it with the ganglia of the glossopharyngeal and vagus nerves, with the petrosal ganglion by a direct branch and with the ganglia of the vagus through the nodosal plexus. These latter ganglia (and the nerves to which they belong) are connected chiefly by way of the tympanic nerve, which is from the petrosal ganglion, with the tympanic plexus (fig. 771).

FIG. 776.—DIAGRAM TO ILLUSTRATE THE STRUCTURAL RELATIONS OF THE ROOTS AND BRANCHES OF A CEPHALIC SYMPATHETIC GANGLION. Sensory fibers, blue; motor, red; sympathetic, black.



The tympanic plexus serves as a common point of distribution of fibers from the superior cervical spmpathetic ganglion, the ganglia of the vagus, the petrosal ganglion, and the geniculate ganglion, to the cavernous and carotid plexuses and to the sphenopalatine and otic ganglia. The superior cervical ganglion is associated with the cavernous and carotid plexuses direct by the internal carotid nerve and with the tympanic plexus by the inferior and superior caroticotympanic nerves. The tympanic plexus receives fibers from the geniculate ganglion by a small *geniculotympanic branch* and it is connected with the sphenopalatine ganglion by a small anastomotic or *tympanopetrosal branch* to the great superficial petrosal nerve, and it is connected with the otic ganglion by the small superficial petrosal nerve. It is not directly connected with either the ciliary or the submaxillary ganglion. However, these latter ganglia, as well as the sphenopalatine and otic, are connected with the carotid plexus either directly by named branches or indirectly by way of plexuses derived from the carotid. The geniculotympanic branch, the tympanic nerve, and twigs of the nodosal plexus may be considered as analogous to the rami communicantes of the spinal nerves.

The *parotid branches*, described above as branches of the auriculotemporal nerve (from the trigeminus) and as containing fibers from the glossopharyngeal, should be mentioned here as belonging to the gangliated cephalic plexus. These branches consist chiefly of sympathetic fibers arising in the otic ganglion (postganglionic) and passing as branches of the ganglion to the auriculotemporal in which they remain till this nerve enters the parotid gland and then they are distributed to the gland. The visceral motor or preganglionic fibers which terminate about their cells of origin in the otic ganglion are derived from the glossopharyngeal nerve and pass successively through the tympanic nerve, the tympanic plexus, and the small superficial petrosal nerve to the otic ganglion.

The *tympanic nerve* (tympanic branch of the glossopharyngeal, or nerve of Jacobson), the branch to the Eustachian tube (*ramus tubæ*), and the superior and inferior *caroticotympanic branches* are also described as branches of the glossopharyngeal nerve. These must likewise be considered as belonging to the gangliated cephalic plexus.

For purposes of dissection, it may be more expedient to consider separately, with its roots and branches, each of the larger ganglia of the gangliated cephalic plexus. Under this heading belong in part the *geniculate ganglion* of the glossopalatine nerve, and the *ganglia of the glossopharyngeal and vagus*, especially the petrosal ganglion of the former and the jugular ganglion of the latter, from the fact that these ganglia contain numerous cell-bodies of sympathetic neurones as well as those of the sensory neurones of their nerves.

These latter ganglia, however, have been described with their corresponding cranial nerves. The sensory and motor roots of their sympathetic portions are contained in the roots of their nerves. The geniculate probably has no sympathetic root. The sympathetic roots of the petrosal and jugular ganglia are contained in the branches of the jugular nerve. The chief branches of distribution of the geniculate are the geniculotympanic branch, the great superficial petrosal nerve, and the external superficial petrosal nerves. The branches of the petrosal ganglion are the tympanic nerve and its branches of the tympanic plexus. The chief branch of distribution from the jugular ganglion is contained in the auricular branch of the vagus, or nerve of Arnold, supplemented by sympathetic fibers in the trunk of the vagus itself.

The principal cephalic sympathetic ganglia are the ciliary, the sphenopalatine (Meckel's), the otic and the submaxillary.

The Ciliary Ganglion

The ciliary (lenticular, or ophthalmic) ganglion lies in the posterior part of the orbital cavity, about 6 mm. in front of the superior orbital (sphenoidal) fissure, to the lateral side of the optic nerve, and between the optic nerve and the external rectus muscle. It is a small, reddish, quadrangular body, compressed laterally, and it measures about 2 mm. from before backward (fig. 764).

Roots.—(*a*) Its motor or short (preganglionic) root enters its lower and posterior angle and is a visceral motor branch derived from the branch of the inferior division of the oculomotor nerve which supplies the inferior oblique muscle. The fibers of the motor root probably all terminate in the ciliary ganglion by synapses with the cell-bodies of its sympathetic neurones.

(*b*) The sensory or long root passes through the upper and back part of the ganglion. It is a branch of the nasociliary (nasal) nerve and is, therefore, composed of fibers from the trigeminus passing through the ganglion. This root also carries many sympathetic fibers, some of which arise from cell-bodies of the superior cervical sympathetic ganglion and gain the nasociliary nerve by way of the internal carotid nerve and the internal carotid and cavernous plexuses. All sympathetic fibers passing to the ganglion pass through it without interruption.

(*c*) The sympathetic root consists of fibers derived from the cavernous (and internal carotid) plexus of the sympathetic; it passes to the ganglion with the long root, and usually also as a separate sympathetic root carrying fibers similar to the sympathetic fibers of the long root.

Branches.—From three to six short ciliary nerves emerge from the anterior border of the ganglion; they divide as they pass forward and eventually form about twenty nerves which are arranged in an upper and a lower group, and the latter group is joined by the long ciliary branches of the nasociliary (nasal) nerve, now sensory and sympathetic (fig. 764). When they reach the eyeball, the ciliary nerves pierce the sclerotic around the optic nerve, and pass forward in grooves on the inner surface of the sclera. The sympathetic fibers contained are distributed as motor fibers to the ciliary muscle, the sphincter of the iris, and to the vessels of these and of the cornea. The dilator pupillæ or radial muscle of the iris is innervated by the fibers which arise in the superior cervical sympathetic ganglion and pass through the ciliary ganglion from either its long or its sympathetic root to enter the short ciliary nerves. These fibers are concerned in the '*skin-pupillary*') (*ciliospinal*) reflex chain by which the pupil dilates in response to stimulus of the skin (fig. 744).

The Sphenopalatine or Meckel's Ganglion

This ganglion is associated with the maxillary nerve (figs. 762, 765, 769). It is a small reddish-gray body of triangular form, which is flattened at the sides, and measures about 5 mm. from before backward. It lies deeply in the pterygopalatine (sphenomaxillary) fossa at the lateral side of the sphenopalatine foramen and in front of the anterior end of the pterygoid (Vidian) canal. It is attached to the maxillary nerve, from which it receives its sensory root, and it is connected with the Vidian nerve, which furnishes it with motor and sympathetic filaments.

The exact position of the ganglion depends upon the size and shape of the sphenoidal air-sinuses. When these are small, or high and narrow, the ganglion lies lateral to them; when they are large, or broad and flat, the ganglion lies inferior to them. Sometimes it may lie anterior to them if the sinuses are short from in front backward. The ganglion may be reached with ease by chipping away the bone around the sphenoidal air-sinuses after the skull is divided sagitally.

Roots.—(*a*) Its motor root, consisting of visceral motor fibers of the glossopalatine nerve, is contained in the great superficial petrosal nerve which is incorporated in the Vidian nerve.

It springs from the anterior angle of the geniculate ganglion and passes through the hiatus of the facial canal (hiatus Fallopii) into the middle fossa of the cranium, where it runs forward and medialward, in a groove on the upper surface of the petrous part of the temporal bone, to the foramen lacerum, and in this part of its course it passes beneath the semilunar (Gasserian) ganglion and the masticator nerve. In the foramen lacerum it joins with the great deep petrosal nerve to form the Vidian nerve (nerve of the pterygoid canal), which passes forward through the pterygoid (Vidian) canal, and its visceral motor fibers terminate in the sphenopalatine ganglion in the pterygopalatine (sphenomaxillary) fossa. The great superficial petrosal nerve contains sensory as well as sympathetic and motor fibers. The sensory fibers pass through the ganglion and, in the small palatine nerve, descend to the soft palate, where they terminate in the epithelium covering it and some are probably concerned with taste organs found there. They arise from the cells of the geniculate ganglion and therefore belong to the glossopalatine nerve.

(*b*) The **sympathetic root** is the great deep petrosal portion of the Vidian nerve. This root, which is of reddish color and of soft texture, springs from the carotid plexus which lies on the outer side of the internal carotid artery in the carotid canal. It enters the foramen lacerum through the apex of the petrous portion of the temporal bone, and unites with the great superficial petrosal branch of the glossopalatine nerve to form the Vidian nerve. The great superficial petrosa nerve also carries sympathetic fibers derived from the geniculate ganglion and from the tympanic plexus as well as from the carotid plexus.

The **Vidian nerve** [**n. canalis pterygoidei**] commences by the union of the great superficial and deep petrosal nerves in the foramen lacerum, and runs forward through the pterygoid (Vidian) canal into the pterygopalatine (sphenomaxillary) fossa to the sphenopalatine ganglion. The Vidian nerve often may be seen in a ridge of bone along the floor of the sphenoidal cells and its direction there depends upon the position of the sphenopalatine ganglion. While it is in the pterygoid canal the Vidian nerve is joined by a sphenoidal filament from the otic ganglion, and it gives branches to the upper and back part of the roof and septum of the nose, and to the lower end of the Eustachian tube.

(*c*) The **sensory roots** consist of the sensory fibers mentioned above in the great superficial petrosal nerve and of (usually) two sphenopalatine branches from the maxillary nerve. The majority of the fibers of these roots do not join the ganglion, but pass by its medial side and enter the palatine branches.

Branches.—The branches of the ganglion, containing sensory and vasomotor and secretory fibers, are orbital or ascending, internal or nasal, descending or palatine, and posterior or pharyngeal.

Ascending branches.—The **orbital** or **ascending branches** are two or three small twigs which enter the orbit through the inferior orbital (sphenomaxillary) fissure and proceed, within the periosteum, to the inner wall of the orbit, where they pass through the posterior ethmoidal foramen and through the foramina in the suture behind that foramen to be distributed to the mucous membrane which lines the posterior ethmoidal cells and the sphenoidal sinus.

Internal branches.—The internal or nasal branches are derived in part from the medial side of the ganglion, but are also largely made up of sensory fibers which pass from the sphenopalatine branches of the maxillary nerve without traversing the ganglionic substance. They are disposed in two sets, the lateral and the medial (septal) posterior superior nasal branches.

The **lateral posterior superior nasal branches** are six or seven small twigs which pass through the sphenopalatine foramen, and are distributed to the mucous membrane covering the posterior parts of the superior and middle nasal conchæ (turbinated bones) (**fig. 762**). They also furnish twigs to the lining membrane of the posterior ethmoidal cells.

The **medial posterior superior nasal (septal) branches**, two or three in number, pass medialward through the sphenopalatine foramen. They cross the roof of the nasal fossa to reach the back part of the nasal septum, where the smaller twigs terminate. The largest nerve of the set, the **nasopalatine nerve**, or **nerve of Cotunnius**, runs downward and forward in a groove in the vomer between the periosteum and the mucous membrane to the incisive (anterior palatine) canal, where it communicates with the nasal branch of the anterior superior alveolar nerve. The two nasopalatine nerves then pass through the foramina of Scarpa in the intermaxillary suture, the left nerve passing through the anterior of the two foramina. In the lower part of the incisive (anterior palatine) canal the two nerves form a plexiform communication (formerly described as Cloquet's ganglion) and they furnish twigs to the anterior or premaxillary part of the hard palate behind the incisor teeth. In this situation they communicate with the anterior palatine nerves.

Descending branches.—The descending branches are the great or anterior, the posterior, and the middle (external) palatine nerves. Like the internal set of branches, they are in part derived from the ganglion and in part are directly continuous with the sphenopalatine nerve (fig. 762)

The **great** or **anterior palatine** nerve, its sensory fibers derived from the maxillary nerve, arises from the inferior angle of Meckel's ganglion, and passes downward through the pterygopalatine canal, accompanied by the descending palatine artery. Emerging from the canal at the greater (posterior) palatine foramen it divides into two or three branches, which pass forward in grooves in the hard palate and supply the glands and mucous membrane of the hard palate and the gums on the inner aspect of the alveolar border of the upper jaw. During its course through the pterygopalatine canal the anterior palatine nerve gives off the **posterior inferior nasal nerves**. These nerves pass through small openings in the perpendicular plate of the palate bone to supply the mucous membrane covering the posterior part of the inferior nasal concha (turbinated bone) and the adjacent portions of the middle and inferior meatuses of the nose.

The **posterior** or **small palatine nerve** passes downward through a lesser palatine foramen (accessory palatine canal), and enters the soft palate, distributing branches to that organ, to the uvula, and to the tonsil. Its sensory fibers are derived from the glossopalatine nerve,

through the great superficial petrosal nerve, and pass through the sphenopalatine ganglion. It was formerly believed to convey motor fibers from the facial nerve to the levator veli palatini and azygos uvulæ, but it is now believed that these muscles are supplied by the spinal accessory nerve through the pharyngeal plexus.

The **middle (external) palatine nerve,** the smallest of the three, in part, likewise from the glossopalatine nerve, traverses a lesser palatine foramen and supplies twigs to the tonsil and to the adjacent part of the soft palate (fig. 762).

Posterior branch.—The small **pharyngeal branch** of the ganglion passes backward and somewhat medialward through the pharyngeal canal accompanied by a pharyngeal branch of the sphenopalatine artery. It is distributed to the mucous membrane of the uppermost part of the pharynx, to the upper part of the choanæ, to the opening of the Eustachian tube, and to the lining of the sphenoidal sinus. Its sensory fibers are derived from the maxillary nerve.

The Otic Ganglion

The otic (Arnold's) ganglion is a small reddish-gray body which is associated with the mandibular nerve. It lies deeply in the zygomatic fossa, immediately below the foramen ovale, on the inner side of the trunk of the mandibular nerve. It is in relation medially with the tensor veli palatini, which separates it from the Eustachian tube. In front of it is the posterior border of the pterygoideus internus, and behind it lie the middle and small meningeal arteries. It is compressed laterally, and its greatest diameter, which lies anteroposteriorly, is about 3 mm.

Roots.—The ganglion is closely connected with the nerve to the pterygoideus internus, through which it may receive a motor root from the masticator nerve. Through the small superficial petrosal nerve, which joins the upper and back part of the ganglion, it receives a motor root from the glossopalatine nerve and sensory and motor fibers from the glossopharyngeal nerve. It receives also a slender *sphenoidal filament* from the Vidian nerve. The **sympathetic roots** are derived from the small supe ficial petrosal nerve and from the sympathetic plexus on the middle meningeal artery.

Branches.—The communicating branches which pass from the ganglion are: (1) The filaments to the chorda tympani, some of whose fibers probably pass through the otic to terminate in the submaxillary ganglion; (2) filaments to the auriculotemporal nerve; (3) filaments to the spinous nerve (the recurrent branch of the mandibular nerve). The branches of distribution are sympathetic to the vessels and somatic motor branches to the tensor tympani, and tensor veli palatini, with sensory fibers (probably) to all of these.

The Submaxillary Ganglion

The submaxillary ganglion is suspended from the lingual division of the mandibular nerve by anterior and posterior branches. It is a small reddish body, of triangular or fusiform shape, which lies between the mylohyoideus and hyoglossus and above the duct of the submaxillary gland.

Roots.—The **sensory root** is received from the lingual nerve. The **motor root** (preganglionic) is from both the masticator nerve by way of the lingual nerve, and from the glossopalatine nerve by way of the chorda tympani. The motor fibers pass from the chorda tympani after it has joined the lingual, and the sensory fibers come directly from the lingual nerve. The **sympathetic root** is formed by filaments from the sympathetic plexus on the facial artery.

Branches.—(*a*) Five or six glandular (postganglionic) branches are given to the submaxillary gland and to Wharton's duct. (*b*) Branches to the lingual nerve and the sublingual gland. (*c*) To the mucous membrane of the floor of the mouth.

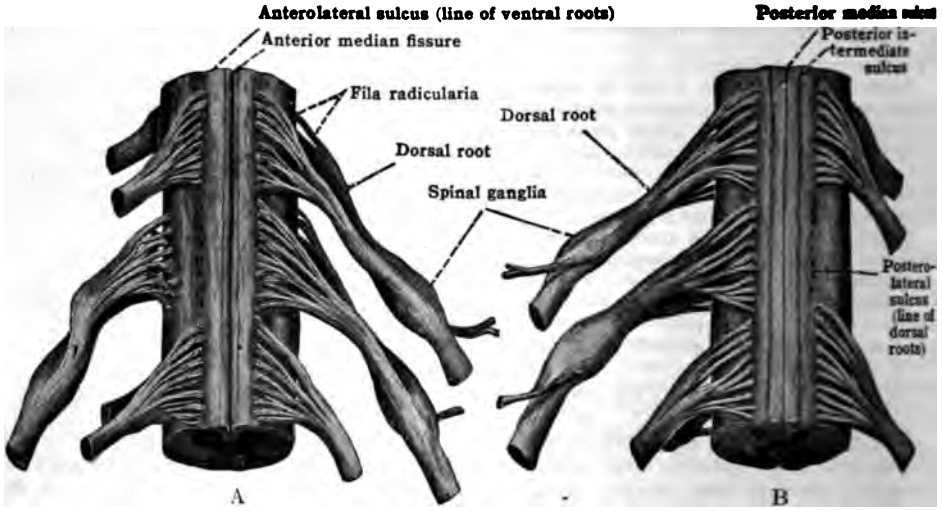
II. THE SPINAL NERVES

The spinal nerves are arranged in pairs, the nerves of each pair being symmetrical in their attachment to either side of their respective segment of the spinal cord, and, in general, symmetrical in their course and distribution. There are usually thirty-one pairs of functional spinal nerves. For purposes of description these are topographically separated into *eight* pairs of *cervical* nerves, *twelve* pairs of *thoracic* nerves, *five* pairs of *lumbar*, *five* pairs of *sacral*, and *one* pair of *coccygeal* nerves. Occasionally the coccygeal or thirty-first pair is rudimentary, while, on the other hand, there may be found small filaments representing one or even two additional pairs of coccygeal nerves below the thirty-first pair. These **rudimentary coccygeal nerves** are probably not functional. They never pass outside the vertebral canal, and often even remain within the tubular portion of the filum terminale. There sometimes occurs an increase in the number of vertebræ in the vertebral column and in such cases there is always a corresponding increase in the number of the spinal nerves.

Origin and attachment.—Each spinal nerve (unlike the cranial nerves) is attached to the spinal cord by two roots: a sensory or afferent **dorsal root** [radix posterior] and a motor or efferent **ventral root** [radix anterior]. Each dorsal root has interposed in its course an ovoid mass of nerve-cells, the **spinal ganglion**, and the nerve-fibers forming the root arise from the cells of this ganglion and are thus of peripheral origin. The fibers composing the ventral root, on the other hand, are of central origin; they arise from the large motor cells of the ventral horn of the gray column within the spinal cord (figs. 777, 779).

Each dorsal root-fiber upon leaving its cell of origin pursues a short tortuous course within the spinal ganglion and then undergoes a T-shaped bifurcation, one product of which passes toward the periphery, where it terminates for the collection of sensations and is known as the *peripheral branch*, or, since it conveys impulses toward the cell-body, the *dendrite* of the spinal ganglion neurone. It is more correct, however, to consider the T-fiber as a bifurcated axone. The other product of the bifurcation, the *central branch*, passes into the spinal cord and in its course toward the cord contributes to form the dorsal root proper.

FIG. 777.—VENTRAL AND DORSAL VIEWS OF SPINAL CORD SHOWING MANNER OF ATTACHMENT OF DORSAL AND VENTRAL ROOTS.



The central branches, upon emerging from the spinal ganglia, form a single compact bundle at first, which passes through the dura mater of the spinal cord and then breaks up into a series of root-filaments [fila radicularia]. These thread-like bundles of fibers spread out vertically in a fan-like manner and enter the cord in a direct linear series along its posterolateral sulcus. The fibers of the ventral root emerge from the cord in a series of more finely divided root filaments, which, unlike the entering filaments of the dorsal root, are not arranged in direct linear series, but make their exit over a strip of the ventrolateral aspect of the cord in some places as much as 2 mm. wide.

As they enter the spinal cord the fibers of the dorsal roots undergo a Y-shaped division, both products of which course in the cord longitudinally, an ascending and a descending branch. The descending or caudal branches are usually shorter than the ascending, and soon enter and terminate about the cells within the gray column of the cord, forming either associational, commissural, or immediate reflex connections, or about cells whose fibers form cerebellar or cerebral connections. The ascending or cephalic branches are either short, intermediate, or long. The short and intermediate branches are similar in function to the descending branches, save that they transfer impulses to the gray substance of segments of the cord above rather than below the level of their entrance. The long branches convey impulses (chiefly proprioceptive) destined for the structures of the brain, and pass upward in the fasciculus gracilis or fasciculus cuneatus of the cord, and terminate in the nuclei of these fasciculi in the medulla oblongata (figs. 660 and 662).

Aberrant spinal ganglia.—In serial sections on either side of the spinal ganglion of a nerve there may often be found outlying cells either scattered or in groups of sufficient size to be called small ganglia. Such are more often found in the dorsal roots of the lumbar and sacral nerves. These cells are nothing more than spinal ganglion-cells displaced in the growth processes, and have the same origin and function as those in the ganglion. In some animals occasional cells very rarely have been found in the outer portion of the ventral root. These probably represent afferent fibers which enter the cord by way of the ventral root. Likewise, especially in the birds and amphibia, it has been shown that occasional efferent fibers may pass from the gray substance of the cord to the periphery by way of the dorsal instead of the ventral root.

Relative size of the roots.—The sensory or dorsal root, with one constant exception, is larger than the ventral root, indicating that the sensory area to be supplied is greater and perhaps more abundantly innervated than the area requiring motor fibers.

It has been shown that in the entire thirty-one spinal nerves of one side of the body of man the dorsal root-fibers number 653,627, while all the corresponding ventral roots contain but 233,700 fibers, a ratio of 3.2 : 1. (Ingbert.) In the increase in the size of the nerves for the supply of the limbs the gain of dorsal root or sensory fibers is far greater than the gain of ventral root-fibers. The first cervical or the suboccipital nerve is always an exception to the rule; its dorsal root is always smaller than its ventral, and in rare cases may be rudimentary or entirely absent. The spinal ganglion and, therefore, the sensory root of the coccygeal nerve, is also quite frequently absent.

The dorsal and ventral root-fibers of each spinal nerve proceed outward from their segment of attachment to the spinal cord, pierce the pia mater and arachnoid, collect to form their respective roots, and pass into their respective intervertebral foramina. On the immediate peripheral side of the spinal ganglion the two roots blend, giving origin to the thus mixed **nerve-trunk.** As the trunk, the sensory and motor fibers make their exit rom the vertebral canal through the intervertebral foramen.

Relation to the meninges.—The root-filaments of each nerve receive connective tissue support from the pia mater and arachnoid in passing through them. In the subarachnoid cavity they become assembled into their respective nerve-roots; and the roots, closely approaching each other, pass into the dura mater, from which they receive separate sheaths at first, but at the peripheral side of the ganglion these sheaths blend into one, which, with the subsequent blending of the roots, becomes the sheath or epineurium of the nerve-trunk. By means of the sheaths derived from the meninges, especially the dura, the nerve-roots and the trunk are attached to the periosteum of the margins of the intervertebral foramina and thus are enabled to give some lateral support to the spinal cord in the upper portion of the canal.

The majority of the spinal ganglia lie in the intervertebral foramina, closely ensheathed, and thus outside the actual sac or cavity of the dura mater. The ganglia of the last lumbar and first four sacral nerves lie inside the vertebral canal, but since the sheath derived from the dura mater closely adheres to them, they are still outside the sac of the dura mater. The ganglia of the last sacral and of the coccygeal nerves (when present) lie in tubular extensions of the subdural cavity, and thus not only within the vertebral canal, but actually within the sac of the dura mater. The trunk of the first cervical nerve is assembled within the sac of the dura mater, and, therefore, the spinal ganglion of this nerve, when present, may lie within the sac.

Course and direction of emergence.—Invested with the connective tissue sheath derived from the meninges, each thoracic, lumbar and sacral nerve emerges from the vertebral canal through the intervertebral foramen below its corresponding vertebra, and all the nerves are in relation with the spinal rami of the arteries and veins associated with the blood-supply of the given localities of the spinal cord.

The first cervical nerve does not pass outward in an intervertebral foramen proper, but between the occipital bone and the posterior arch of the atlas and beneath the vertebral artery. Thus the eighth or last cervical nerve emerges between the seventh cervical and the first thoracic vertebra.

The first and second pairs of cervical nerves pass out of the vertebral canal almost at right angles to the levels of their attachment to the spinal cord. During the early periods of development the level of exit of each pair of spinal nerves is opposite the level of its attachment to the cord, but, owing to the fact that in the later periods the vertebral column grows more rapidly than the cord and increases considerably in length after the cord has practically ceased growing, all the spinal nerve roots, with the exception of the first two pairs, pass downward as well as outward. The obliquity of their course from the level of attachment to the level of exit increases progressively from above downward, and, as the cord ends at the level of the first or second lumbar vertebra, the roots of the lower lumbar and of the sacral nerves pass at first vertically downward within the dura mater, and form around the filum terminale a tapering sheaf of nerve-roots, the **cauda equina** (horse's tail) (fig. 655).

Topography of attachment.—The relations between the levels of attachment of the spinal nerves to the cord and the spinous processes of the vertebræ situated opposite these levels have been investigated by Nuhn and by Reid. The following table compiled by Reid gives the extreme limits of attachment as observed in six subjects.

TABLE OF TOPOGRAPHY OF ATTACHMENT OF SPINAL NERVES TO THE SPINAL CORD. (

(A) signifies the highest level at which the root filaments of a given nerve are at to the cord, and (B) the lowest level observed. For example, the root filaments of th thoracic nerve *may* be attached as high as the lower border of the spinous process of the thoracic vertebra, or some may be attached as low as the upper border of the spinous pro the fifth thoracic vertebra, but in a given subject they do not necessarily extend either or as low as either of the levels indicated.

Nerves		
Second cervical	(A)	A little above the posterior arch of atlas.
	(B)	Midway between posterior arch of atlas and spine of epistropheus.
Third "	(A)	A little below posterior arch of atlas.
	(B)	Junction of upper two-thirds and lower third of spine of epistroph
Fourth "	(A)	Just below upper border of spine of epistropheus.
	(B)	Middle of spine of third cervical vertebra.
Fifth "	(A)	Just below lower border of spine of epistropheus.
	(B)	Just below lower border of spine of fourth cervical vertebra.
Sixth "	(A)	Lower border of spine of third cervical vertebra.
	(B)	Lower border of spine of fifth cervical vertebra.
Seventh "	(A)	Just below upper border of spine of fourth cervical vertebra.
	(B)	Just above lower border of spine of sixth cervical vertebra.
Eighth "	(A)	Upper border of spine of fifth cervical vertebra.
	(B)	Upper border of spine of seventh cervical vertebra.
First thoracic	(A)	Midway between spines of fifth cervical and sixth cervical vertebr
	(B)	Junction of upper two-thirds and lower third of interval between cervical and first thoracic vertebra.
Second "	(A)	Lower border of spine of sixth cervical vertebra.
	(B)	Just above lower border of spine of first thoracic vertebra.
Third "	(A)	Just above middle of spine of seventh cervical vertebra.
	(B)	Lower border of spine of second thoracic vertebra.
Fourth "	(A)	Just below upper border of spine of first thoracic vertebra.
	(B)	Junction of upper third and lower two-thirds of spine of third vertebra.
Fifth "	(A)	Upper border of spine of second thoracic vertebra.
	(B)	Junction of upper quarter and lower three-quarters of spine of fou racic vertebra.
Sixth "	(A)	Lower border of spine of second thoracic vertebra.
	(B)	Just below upper border of spine of fifth thoracic vertebra.
Seventh "	(A)	Junction of upper third and lower two-thirds of spine of fourth vertebra.
	(B)	Just above lower border of spine of fifth thoracic vertebra.
Eighth "	(A)	Junction of upper two-thirds and lower third of interval betwee of fourth thoracic and fifth thoracic vertebra.
	(B)	Junction of upper quarter and lower three-quarters of spine thoracic vertebra.
Ninth "	(A)	Midway between spines of fifth thoracic and sixth thoracic vertel
	(B)	Upper border of spine of seventh thoracic vertebra.
Tenth "	(A)	Midway between spines of sixth thoracic and seventh thoracic ve
	(B)	Middle of the spine of eighth thoracic vertebra.
Eleventh "	(A)	Junction of upper quarter and lower three-quarters of spine of thoracic vertebra.
	(B)	Just above spine of ninth thoracic vertebra.
Twelfth "	(A)	Junction of upper quarter and lower three-quarters of spine of thoracic vertebra.
	(B)	Just below spine of ninth thoracic vertebra.
First lumbar	(A)	Midway between spines of eighth thoracic and ninth thoracic ver
	(B)	Lower border of spine of tenth thoracic vertebra.
Second "	(A)	Middle of spine of ninth thoracic vertebra.
	(B)	Junction of upper third and lower two-thirds of spine of eleventh vertebra.
Third "	(A)	Middle of spine of tenth thoracic vertebra.
	(B)	Just below spine of eleventh thoracic vertebra.
Fourth "	(A)	Just below spine of tenth thoracic vertebra.
	(B)	Junction of upper quarter and lower three-quarters of spine of thoracic vertebra.
Fifth "	(A)	Junction of upper third and lower two-thirds of spine of eleventh vertebra.
	(B)	Middle of spine of twelfth thoracic vertebra.
First sacral	(A)	Just above lower border of spine of eleventh thoracic vertebra.
Fifth "	(B)	Lower border of spine of first lumbar vertebra.
Coccygeal	(A)	Lower border of spine of first lumbar vertebra.
	(B)	Just below upper border of spine of second lumbar vertebra.

Relative size of the nerves.—The size of the different spinal nerves greatly. Just as the spinal cord shows marked enlargements in the cervi lumbar regions necessitated by the greater amount of innervation required o

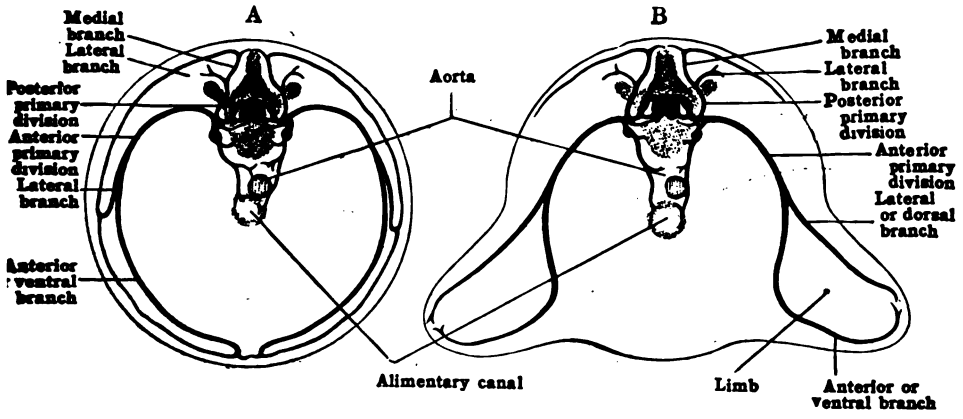
gions for the structures of the upper and lower limbs, so the nerves attached to ese regions are considerably larger than elsewhere.

The smaller nerves are found at the two extremities of the cord and in the midthoracic gion. The smallest nerve is the coccygeal, and the next in order of size are the lower sacral d the first two or three cervical nerves. The largest nerves are those which contribute ost to the great nerve trunks for the innervation of the skin and muscles of the limbs:—the wer cervical and first thoracic for the upper limbs and the lower lumbar and first sacral for e lower limbs. The nerves gradually increase in the series in passing from the smaller toward e larger.

The primary divisions of the nerve-trunk (figs. 778, 793).—A typical spinal erve (middle thoracic, for example), just as it emerges from the intervertebral oramen, divides into four branches;—the two large primary divisions; viz., **he posterior primary division** [ramus posterior] and the **anterior primary division** amus anterior]; third, the small **ramus communicans,** by which it is connected

FIG. 778.—DIAGRAMS ILLUSTRATING THE ORIGIN AND DISTRIBUTION OF A TYPICAL SPINAL NERVE.

A, in thoracic region; B, in region of a limb (highly schematic).



ith the sympathetic; and fourth, the smaller, **ramus meningeus** (*recurrent anch*), which immediately turns centralward for the innervation of the membranes and vessels of the spinal cord.

In general, **the posterior primary division** passes dorsalward between the arches r transverse processes of the two adjacent vertebræ in relation with the anterior ostotransverse ligament, and then divides (with the exception of the first cervical, the fourth and fifth thoracic, and the coccygeal nerves) into **a medial anch** and **a lateral branch.** The medial branch turns toward the spinous rocesses of the vertebræ, and supplies the bones and joints and the muscles about hem, and may or may not supply the skin overlying them. The lateral branch urns dorsalward and also supplies the adjacent muscles and bones, and, if the nedial branch has not supplied the overlying skin, it also terminates in cutaneous wigs.

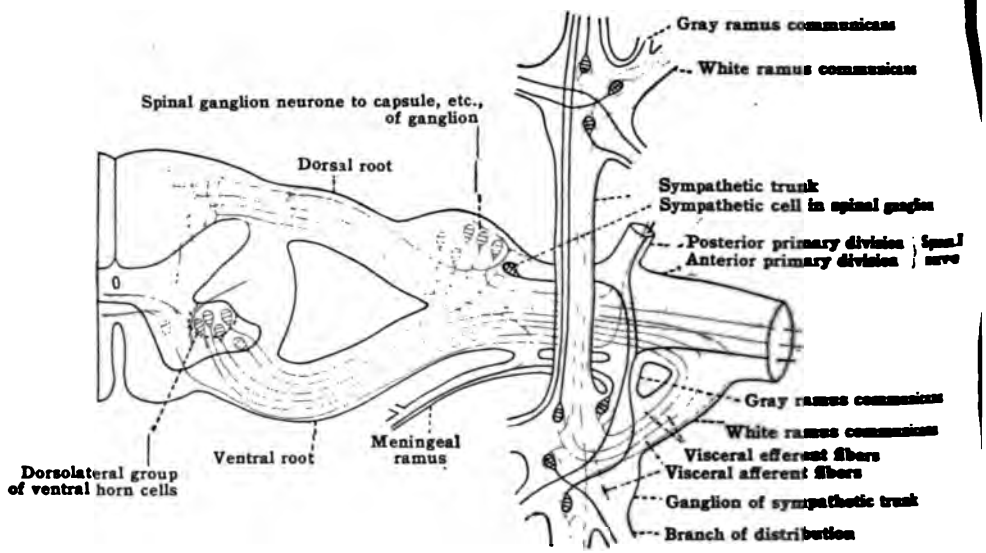
In the upper half of the spinal nerves the medial branches supply the skin; in the lower half, is the lateral branches which do so. Both branches of almost all the posterior divisions, specially those of the lower nerves, show a tendency to run caudalward and thus are distributed muscles and skin below the levels of their respective intervertebral foramina. They never pply the muscles of the limbs, though their cutaneous distribution extends upon the buttock, e shoulder, and the skin of the back of the head as far upward as the vertex. The posterior rimary divisions, with the exception of those of the first three cervical nerves, are much smaller han the anterior primary divisions.

As their mixed function suggests, the posterior primary divisions contain nerve-fibers both om the ventral roots and peripheral processes of the spinal ganglion-cells. If the nerve-trunk n the immediate peripheral side of the spinal ganglion be teased, bundles of ventral root-fibers ay be seen crossing the trunk obliquely to enter the posterior division, and fibers from the pinal ganglion may be also traced into it. Also the sympathetic fibers, derived chiefly by ay of the ramus communicans, are known to course in it for distribution in the walls of the lood-vessels, etc., of the area it supplies (fig. 779).

The anterior primary divisions run lateralward and ventralward. With the xception of those of the first two cervical nerves, which contribute the hypoglos-

sal loop, they are larger than the posterior primary divisions, and appear as direct continuations of the nerve-trunks. Only in case of most of the thoracic nerves do they remain independent in their course. In these they run lateralward and ventralward in the body-wall. In general, these divisions supply the lateral and ventral parts of the body, the limbs, and the perineum. In the cervical, lumbar, and sacral regions they lose their anatomical identity by dividing, subdividing, and anastomosing with each other so as to give rise to the three great spinal plexuses of the body—the **cervical**, the **brachial**, and the **lumbosacral plexuses**. The majority of the thoracic nerves retain the typical or primitive character in both their anterior and posterior primary divisions. In them the anterior division (intercostal nerve) divides into a **lateral** and an **anterior** (or ventral) branch, both of which subdivide. The lateral branch is chiefly cutaneous; it pierces the superficial muscles and, in the subcutaneous connective tissue, divides into a smaller posterior and a larger anterior **ramus**, which respectively supply the skin of the sides and the lateral part of the ventral surface of the

FIG. 779.—DIAGRAM ILLUSTRATING THE ORIGIN OF THE COMPONENT NERVE-FIBERS OF THE PRIMARY DIVISIONS OF A TYPICAL THORACIC OR LUMBAR SPINAL NERVE.



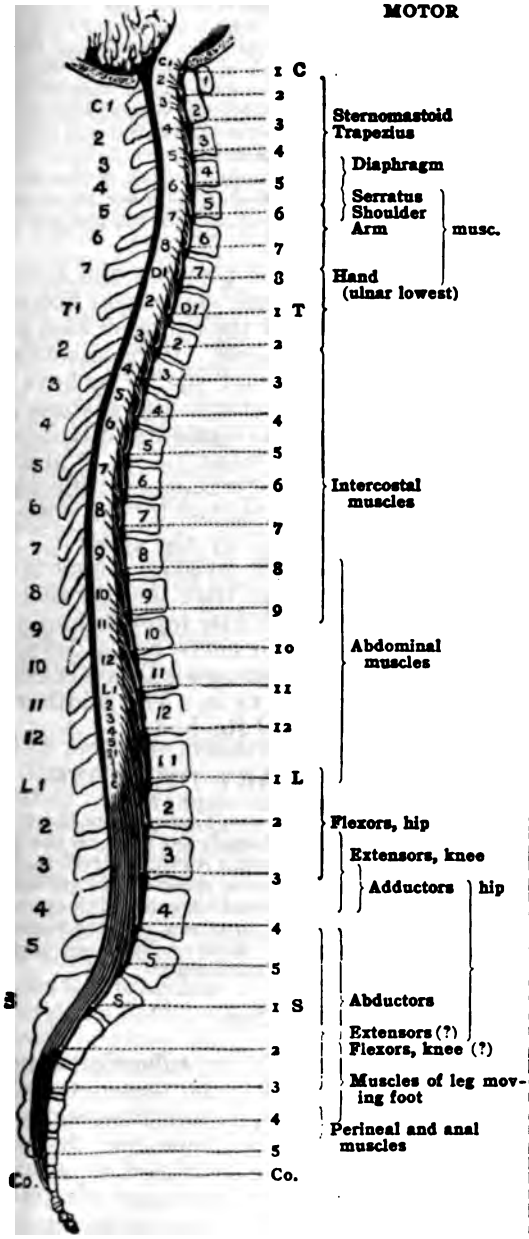
body. The anterior branch continues ventralward in the body-wall, giving off twigs along its course to the adjacent muscles and bones, and, as it approaches the ventral midline of the body, it turns sharply lateralward and sends rami medialward and lateralward to supply the skin of the ventral aspect of the body. In the region of the limbs the typical arrangement is interfered with in that what corresponds to the lateral and anterior branches of the division are carried out into the limbs for the skin and muscles there, instead of supplying the lateral and ventral parts of the body-wall.

Nerve-fibers arising in the spinal ganglion and fibers from the ventral root pass directly from the nerve-trunk into the anterior primary division of the spinal nerve. This division also receives sympathetic nerve-fibers by way of the ramus communicans. These latter accompany the division and are distributed to their allotted elements in the territory it supplies.

The rami communicantes are small, short, thread-like branches by which the nerve-trunks are connected with the nearest ganglion of the vertically running gangliated cord of the sympathetic (sympathetic trunk). The trunk or anterior primary division of every spinal nerve has at least one ramus; most of the nerves have two, and sometimes there are three. The nerves of the cervical region usually have but one, and this is composed largely of sympathetic fibers (gray ramus). Where there are two, one usually contains medullated fibers, chiefly visceral motor from the ventral root, sufficient to give it a whiter appearance (white ramus).

In the upper cervical and in the sacral regions one sympathetic ganglion may be connected h two or more spinal nerves, and sometimes one nerve is connected with two ganglia. The ai communicantes of the spinal nerves are equivalent to the communicating rami connecting tain of the cranial nerves with the sympathetic system (trigeminus, glossopharyngeal, vagus). e medullated fibers of the rami and, therefore, the white rami consist chiefly of fibers from spinal nerves, viz,, fibers from the spinal ganglion-cells which enter and course to their dis-

p. 780.—TABLE GIVING THE APPROXIMATE AREAS OF DISTRIBUTION OF THE DIFFERENT SPINAL NERVES WITH A DIAGRAM SHOWING THEIR RESPECTIVE LEVELS OF EXIT FROM THE VERTEBRAL COLUMN. (Arranged by Dr. Gowers.)



bution through branches of the sympathetic nerves, **visceral afferent fibers,** and fibers from e ventral roots of the spinal nerves which terminate in the sympathetic ganglia, **visceral erent** (preganglionic) **fibers.** Thus the white rami have been termed the **visceral divisions** the spinal nerves. The gray rami consist chiefly of sympathetic fibers, most of which are n-medullated or partially medullated, and which course to their distribution by way of the inal nerves. The usual absence of white rami communicantes from the cervical nerves is plained on the grounds—(1) that probably relatively fewer visceral efferent fibers are given the sympathetic from this region of the cord; (2) that many of the visceral efferent fibers

which do arise from this region of the cord probably join the rootlets of the spinal ac nerve and pass to the sympathetic system through the trunk of this nerve, and throu yagus with which it anastomoses; and (3) that such of these fibers, as are given off, es from the lower segments of the cervical region, descend the cord and pass out by the upper thoracic nerves which give very evident white rami to the sympathetic. In the white rami (visceral efferent fibers) of the thoracic and lumbar nerves terminat ganglia of the sympathetic trunk, while such fibers of the cranial and sacral nerves strea the trunk to terminate in more distant sympathetic ganglia.

The meningeal or recurrent branch (figs. 778, 777, and 793) is very small and v and is often difficult to find in ordinary dissections. It is given off from the nerve-tr before its anterior and posterior primary divisions are formed. It consists of a few p branches of spinal ganglion cells (senosry fibers) which leave the nerve-trunk and re-e vertebral canal for the sensory innervation of the meninges, and which are joined b from the gray ramus or directly from the nearest sympathetic ganglion (vasomoto There is considerable evidence, both physiological and anatomical, obtained chiefly animals, which shows that at times certain of the peripheral spinal ganglion or sens may turn backward in the nerve-trunk and pass to the meninges within the ventral ro of contributing to a recurrent branch. The occurrence of such fibers in the ventral roo the physiological phenomenon known as '*recurrent sensibility*.' Likewise, sympathe entering the trunk through the gray ramus may pass to the meninges by way of th root, and at times the recurrent branch is probably absent altogether, its place be entirely by the meningeal fibers passing in the ventral root. Possibly, some reach the by way of the dorsal root.

Areas of distribution of the spinal nerves.—Both the posterior and primary divisions divide and subdivide repeatedly, and their component f distributed to areas of the body more or less constant for the nerves of e but the distribution of the different nerves is very variable. Correspo their attachment, each to a given segment of the spinal cord, the nerves marily a segmental distribution, but, owing to the developmental cha displacement of parts during the growth of the body, the segmental dis becomes greatly obscured and in some nerves practically obliterated. N it is more retained by the nerves supplying the trunk than by those contri the innervation of the limbs and head, and the areas supplied by the primary divisions are less disturbed than those supplied by the anteri segmental areas of cutaneous distribution of the posterior divisions are n dent than the areas of muscle supplied by these divisions, from the fact segmental myotomes from which the dorsal muscles arise fuse together a lap each other considerably during development. No nerve has a d prescribed area of distribution, cutaneous or muscular, for its area is always ably overlapped by the areas of the nerves adjacent to it. The mid nerves more nearly supply a definitely prescribed belt of the body.

A. DISTRIBUTION OF POSTERIOR PRIMARY DIVISION

As above stated, the posterior primary divisions of the spinal nerves spring from t immediately outside the intervertebral foramina, and they pass dorsalward between cent transverse processes. With the exceptions of the first and second cervical nerve smaller than the corresponding anterior primary divisions, which in these nerves a from the fact that a large portion of them go over into the hypoglossal (or cervical) lo posterior primary divisions, after passing between the transverse processes into the the back, divide into medial and lateral branches. This division, however, does no the cases of the first cervical, the last two sacral, and the coccygeal nerves.

1. Cervical Nerves (Figs. 781, 782)

The posterior primary division of the first cervical or suboccipit springs from the trunk, between the vertebral artery and the posterior the atlas, passes dorsalward into the suboccipital triangle, and breaks branches which supply the superior oblique, the inferior oblique, and tl rectus capitis posterior muscles, which form the lateral boundaries of the It also gives a branch across the posterior surface of the major rectus ca terior to the minor rectus capitis posterior, and a branch to the sem capitis (complexus) in the roof of the triangle.

It communicates with the medial branch of the posterior primary division of t cervical nerve, either through or over the inferior oblique muscle, and it occasionall cutaneous branch to the skin of the upper part of the back of the neck and the low the scalp.

The posterior primary division of the second cervical nerve is the lar [redacted]erior division of all the cervical nerves. It divides into a small lateral br

very large medial branch. The **lateral branch** gives a twig to the inferior oblique and terminates in branches which supply the splenius and longissimus capitis (trachelomastoid) muscles. The **medial branch** is the **great occipital nerve** (fig. 784). It turns around the lower border of the inferior oblique, crosses the suboccipital triangle obliquely, pierces the semispinalis capitis (complexus), the tendon of the trapezius, and the deep cervical fascia, passing through the latter immediately below the superior nuchal line of the occipital bone, and it divides into several terminal sensory branches which ramify in the superficial fascia of the scalp.

It gives one or two motor twigs to the semispinalis capitis (complexus), and its terminal branches, which are accompanied by branches of the occipital artery, supply the skin of the scalp, above the superior nuchal line, as far forward as the vertex. Occasionally one branch reaches the pinna and supplies the skin on the upper part of its medial aspect. As it turns around the inferior oblique it gives branches which join with the medial branches of the posterior primary divisions of the first and third cervical nerves, and in this manner a small looped plexus is formed beneath the semispinalis capitis (complexus) muscle, the *posterior cervical plexus of Cruveilhier*.

The posterior divisions of the third, fourth, and fifth cervical nerves divide at the lateral border of the semispinalis colli into medial and lateral branches. **The medial branches** of the third, fourth, and fifth nerves run backward between the semispinalis colli and capitis (complexus), supplying both muscles. Then, after passing backward between the semispinalis capitis and the ligamentum nuchæ, they pierce the origin of the trapezius and supply the skin of the back of the neck. The greater part of the medial branch of the third nerve, which runs upward in the superficial fascia to the scalp, is an inconstant branch called the **third occipital nerve**; it interlaces with the great occipital nerve, and it supplies the skin of the upper part of the back of the neck, near the midline, and the skin of the scalp in the region of the external occipital protuberance.

The medial branches of the posterior primary divisions of the **sixth, seventh, and eighth cervical nerves** pass to the medial side of the semispinalis cervicis, between it and the subjacent multifidus spinæ, and they end in the neighboring muscles. The **lateral branches** of the posterior primary divisions of the **last five cervical nerves** are small and they are distributed to the longissimus capitis (trachelomastoid), the iliocostalis cervicis (cervicalis ascendens), the longissimus cervicis (transversalis cervicis), the semispinalis capitis (complexus), and the splenius muscles.

2. Thoracic Nerves

The **posterior primary divisions of all the thoracic nerves** divide into medial and lateral branches while in the vertebral groove (fig. 781). **The medial branches of the upper six thoracic nerves** pass dorsalward between the semispinalis dorsi and the multifidus spinæ; they supply the spinalis dorsi, the semispinalis dorsi, the multifidus spinæ, the rotatores spinæ, the intertransversales, and the interspinales muscles; and they end in cutaneous branches which, after piercing the trapezius, turn lateralward in the superficial fascia of the back, and supply the skin as far as the middle of the scapula. The cutaneous branch of the second nerve is the largest; it can be traced lateralward as far as the acromion process. **The medial branches of the lower six thoracic nerves** run dorsalward, between the longissimus dorsi and the multifidus spinæ; they chiefly end in twigs to the adjacent muscles, but not uncommonly they give small cutaneous twigs which pierce the latissimus dorsi and the trapezius and end in the skin near the midline of the back.

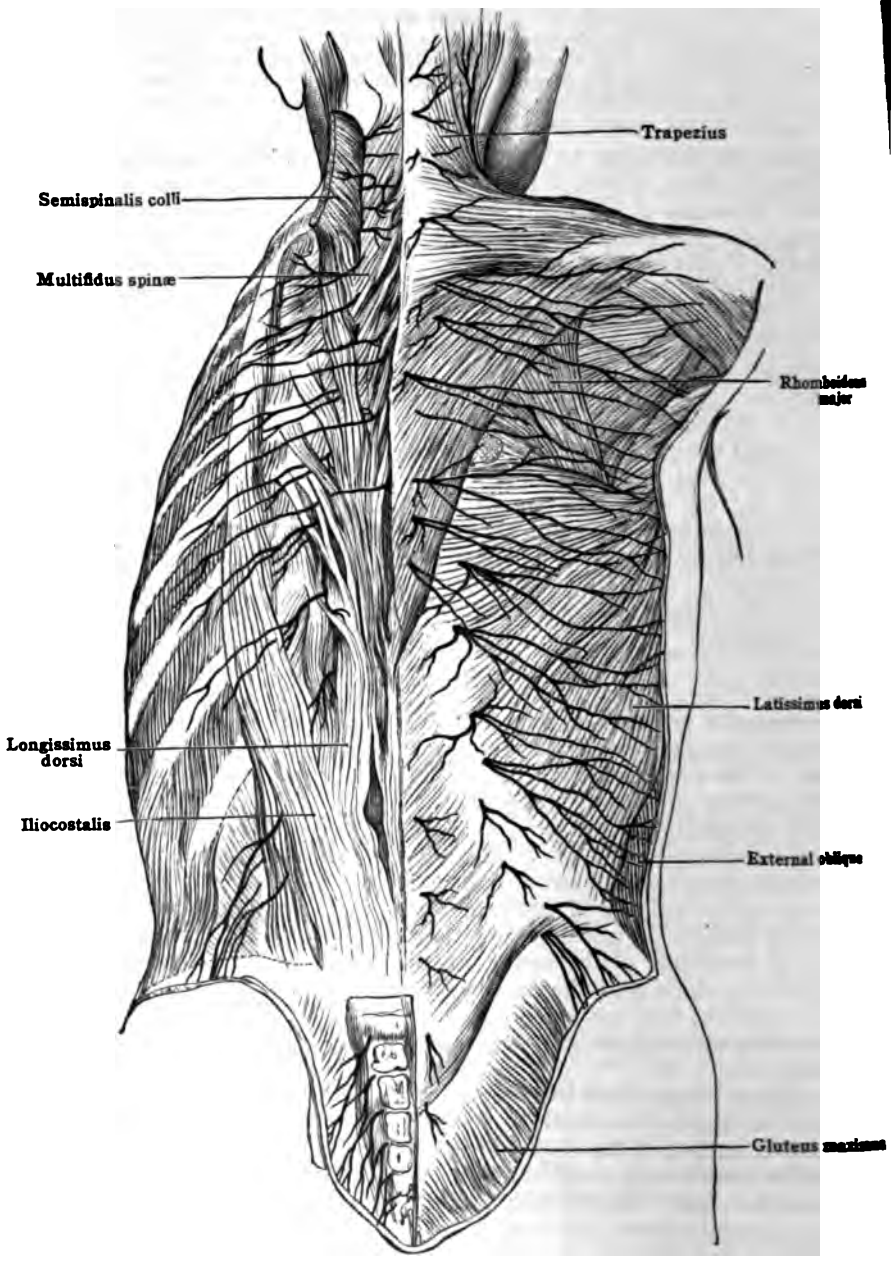
The lateral branches of the upper six thoracic nerves pass between the longissimus dorsi and the iliocostalis dorsi (accessorius) and end in those muscles, but **the lateral branches of the six lower nerves** are longer; they pass into the interval between the longissimus dorsi and the iliocostalis dorsi and give branches to them, and then they pierce the latissimus dorsi and are distributed to the skin of the lower and lateral part of the back.

3. Lumbar Nerves (Fig. 781)

The **medial branches** of the posterior primary divisions of all the lumbar nerves end in the multifidus spinæ and those of the three lower nerves send very small branches to the skin of the sacral region.

The **lateral branches of the upper three nerves** pass obliquely lateralward, supplying twigs to the adjacent muscles, pierce the posterior layer of the lumbar aponeurosis at the lateral border of the sacrospinalis (erector spinæ) and enter the subcutaneous tissue. They are, for the most part, cutaneous, forming the **superior clunial nerves,** which cross the crest of the ilium and pass downward to occupy different planes in the thick superficial fascia which covers the upper part of the gluteus medius.

FIG. 781.—DISTRIBUTION OF THE POSTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES. (Henle.)



The branch from the first lumbar nerve is comparatively small, and occupies the most superficial plane. The second occupies an intermediate position. The lateral branch from the third nerve is the largest of the three, and occupies the lowest position; it distributes branches over the gluteus maximus as far as the great trochanter. The three branches anastomose with one another and also with the cutaneous branches from the posterior primary divisions of the two upper sacral nerves.

The lateral branch of the fourth lumbar nerve is of small size and ends in the lower part of the sacrospinalis (erector spinæ). That of the **fifth lumbar** is distributed to the sacrospinalis and communicates with the first sacral nerve.

4. Sacral Nerves (Fig. 781)

The posterior primary divisions of the upper four sacral nerves escape from the vertebral canal by passing through the posterior sacral foramina; those of the fifth sacral nerve pass out through the hiatus sacralis between the posterior sacrococcygeal ligaments. Those of the upper three sacral nerves divide in the ordinary manner into medial and lateral branches. Those of the lower two sacral nerves remain undivided.

The medial branches of the upper three sacral nerves are of small size, and are distributed to the multifidus spinæ. The **lateral branches** anastomose with one another and with the lateral branch of the last lumbar nerve, forming loops on the posterior surface of the sacrum from which branches proceed to the posterior surface of the sacrotuberous (great sacrosciatic) ligament, where they anastomose and form a second series of loops, from which loops two or three branches are given off. These branches pierce the gluteus maximus and come to the surface of that muscle in a line between the posterior superior spine of the ilium and the tip of the coccyx. Then, as the **middle clunial nerves,** they are distributed to the integument over the medial part of the gluteus maximus, and communicate, in their course through the superficial fascia, with the posterior branches of the lumbar nerves.

The posterior primary divisions of the **lower two sacral nerves** unite with one another, with the posterior division of the third sacral, and with the coccygeal nerve, forming loops from which twigs pass to the integument over the lower end of the coccyx.

The posterior primary division of the coccygeal nerve is also undivided. It separates from the anterior division in the sacral canal and emerges through the hiatus sacralis, pierces the ligaments which close the lower part of that canal, receives a communication from the posterior division of the last sacral nerve, and ends in the skin over the dorsal aspect of the coccyx.

B. ANTERIOR PRIMARY DIVISIONS

The anterior primary divisions of the spinal nerves are larger than the posterior primary divisions, and each is joined near its origin by a gray ramus communicans from the sympathetic trunk (figs. 782, 783, 793). Beginning with the first thoracic nerve and ending with the second or third lumbar nerve, each anterior division sends to the sympathetic trunk a white ramus communicans. The same is true of the second and third or of the third and fourth sacral nerves. These white rami are appropriately designated the **visceral branches** of the spinal nerves, being composed chiefly of visceral efferent (preganglionic) and some visceral afferent fibers. The anterior primary divisions of the cervical, lumbar, sacral, and coccygeal nerves unite with one another to form **plexuses,** but the anterior primary divisions of the thoracic nerves, except the first and last, remain separate, pursue independent courses, and each divides, in a typical manner, into a lateral and an anterior or ventral branch. The separation of the anterior primary division into lateral and anterior branches is not confined to the thoracic nerves, however, it occurs also in the lower cervical, the lumbar, and the sacral nerves. But such a separation cannot be clearly distinguished either in the upper cervical nerves or in the coccygeal nerve.

1. CERVICAL NERVES

The anterior primary divisions of the **upper four cervical nerves** unite to form the **cervical plexus,** and each receives a communicating branch from the superior cervical sympathetic ganglion. The anterior divisions of the **lower four cervical nerves** are joined by the greater part of the first thoracic nerve and they unite to form the **brachial plexus** (figs. 782, 785, 786). The fifth and sixth cervical nerves receive communicating branches from the middle cervical sympathetic ganglion, and the seventh and eighth from the inferior cervical ganglion, while the first thoracic nerve is connected with the first thoracic sympathetic ('stellate') ganglion by a gray ramus (figs. 782, 814) and also by one or two white rami communicantes (Johnson and Mason).

THE CERVICAL PLEXUS

The cervical plexus (figs. 782,—784) is formed by the anterior primary divisions of the upper four cervical nerves which constitute the roots of the plexus. It

lies in the upper part of the side of the neck, under cover of the sternomastoid, and upon the levator scapulæ and the scalenus medius. It is a looped plexus, consisting of three loops.

A large part of the anterior primary division of the **first cervical nerve** is given to the hypoglossal (or cervical) loop; the remainder passes to the cervical plexus and in doing so it runs lateralward on the posterior arch of the atlas beneath the vertebral artery, then it turns forward, between the vertebral artery and the outer side of the upper articular process of the atlas, and finally it descends, in front of the transverse process of the atlas, and unites with the upper branch of the second nerve, forming with it the first loop of the plexus. It gives branches to the rectus capitis lateralis, longus capitis (major rectus capitis anterior), and to the rectus capitis anterior (minor). The division communicates with the ganglion of the trunk of the vagus and with the superior cervical ganglion of the sympathetic system (fig. 783). From the first loop of the plexus, two branches of the division pass over into the sheath of the hypoglossal nerve and descend with it to contribute to the **hypoglossal loop** [ansa hypoglossi] or better, the *cervical loop*. The fibers entering the sheath of the hypoglossus, after giving a few twigs to the geniohyoid and thyrohyoid muscles, leave the sheath as the **descendens cervicalis** (*hypoglossi*) and this latter joins the *communicans cervicalis*, (the portion of the loop from the second and third cervical nerves) and thus completes the hypoglossal (cervical) loop.

This loop usually may be found between the sheaths of the sternomastoid muscle and the carotid artery, superficial to the internal jugular vein; sometimes it may lie in the carotid sheath between the carotid artery and the internal jugular vein; rarely it may lie dorsal to both the artery and vein. Sometimes it is relatively long, descending toward the sternum below the level of the thyroid cartilage; again it is quite short and occurs near the level of the hyoid bone. The descendens cervicalis (hypoglossi) parts company with the hypoglossal nerve at the level at which the nerve curves around the occipital artery. It runs downward and slightly medialward on the sheaths of the great vessels and occasionally within the sheath of one of them.

The **second cervical nerve** (anterior primary division) passes behind the upper articular process of the axis and the vertebral artery, and between the intertransverse muscles extending from the first to the second cervical vertebræ, to the interval between the scalenus medius and the longus capitis (rectus capitis anterior major), where it divides into two parts. The upper part ascends and unites with the first nerve to form the first loop of the plexus, and the lower branch passes downward and dorsalward and joins the upper branch of the third nerve in the second loop of the plexus (figs. 782, 783). This branch gives off the small occipital nerve and a filament to the sternomastoid, which communicates with the spinal accessory nerve in the substance of the muscle, and it gives branches which assist in forming the hypoglossal or cervical loop [ansa hypoglossi] the cervical cutaneous and the great auricular nerves.

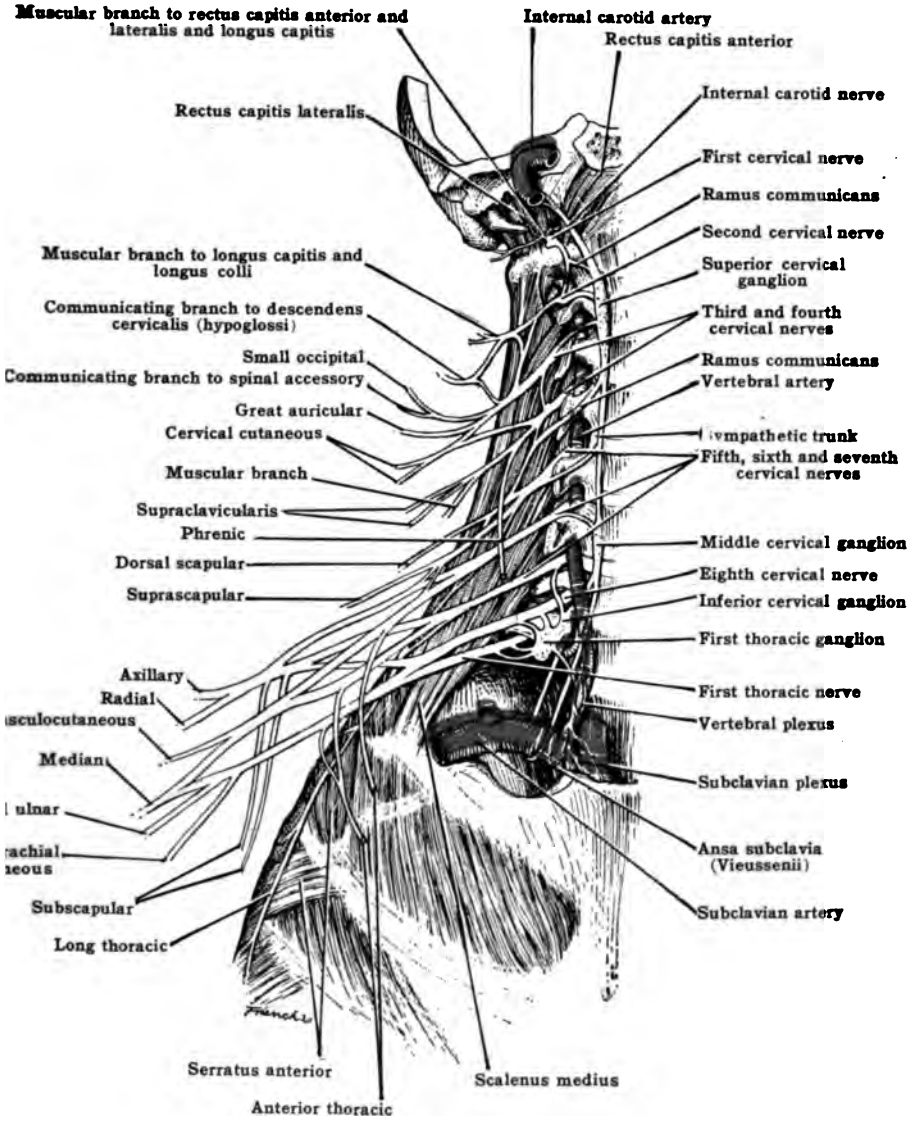
The anterior primary divisions of the **third** and **fourth cervical nerves** are about double the size of the preceding. They pass behind the vertebral artery (fig. 782) and between the intertransverse muscles to the interval between the scalenus medius and the longus capitis (rectus capitis anterior major), where the third unites with the second and fourth nerves and completes the lower two loops of the plexus. The third gives off branches to the hypoglossal loop, to the larger part of the great auricular and cervical cutaneous nerves, a branch to the phrenic, a branch to the supraclavicular nerves, and muscular branches to the scalenus medius, levator scapulæ, longus capitis, and trapezius (fig. 783). The trapezius branch joins the spinal accessory nerve beneath the muscle. The fourth nerve gives a branch to the phrenic, a branch to the supraclavicular nerves, and muscular branches to the scalenus medius, levator scapulæ, longus colli, and trapezius. The branch to the trapezius unites with the one from the third nerve and joins the spinal accessory nerve beneath the muscle.

The fibers forming the hypoglossal (cervical) loop innervate all the muscles of the infrahyoid group, though twigs to the geniohyoid and thyrohyoid seemingly enter these muscles from the trunk of the hypoglossus (fig. 783).

The nerve to geniohyoid is given off from the trunk of the hypoglossus under cover of the mylohyoid in common with the terminal branches of the hypoglossus proper going to the intrinsic muscles of the tongue. The nerve to the thyrohyoid muscle leaves the trunk of the hypoglossus near the tip of the great cornu of the hyoid bone, running obliquely downward and

anward to reach its muscle. A twig to the anterior belly of the omohyoid is given from the r part of the descendens cervicalis and the nerves for the sternohyoid, the sternothyroid the posterior belly of the omohyoid are supplied from the turn of the loop (fig. 783). nerves to the sternohyoid and sternothyroid send twigs downward in the muscles behind the ibrium sterni and fibers from these in rare cases join the phrenic nerve in the thorax. The to the posterior belly of the omohyoid courses as a loop in the cervical fascia below the al tendon of its muscle.

782.—Origin of the Cervical and Brachial Plexuses. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



ach root of the cervical plexus receives a communicating gray ramus from uperior cervical ganglion of the sympathetic, and from the roots and loops of lexus a number of branches arise which form two main groups, the superficial he deep.

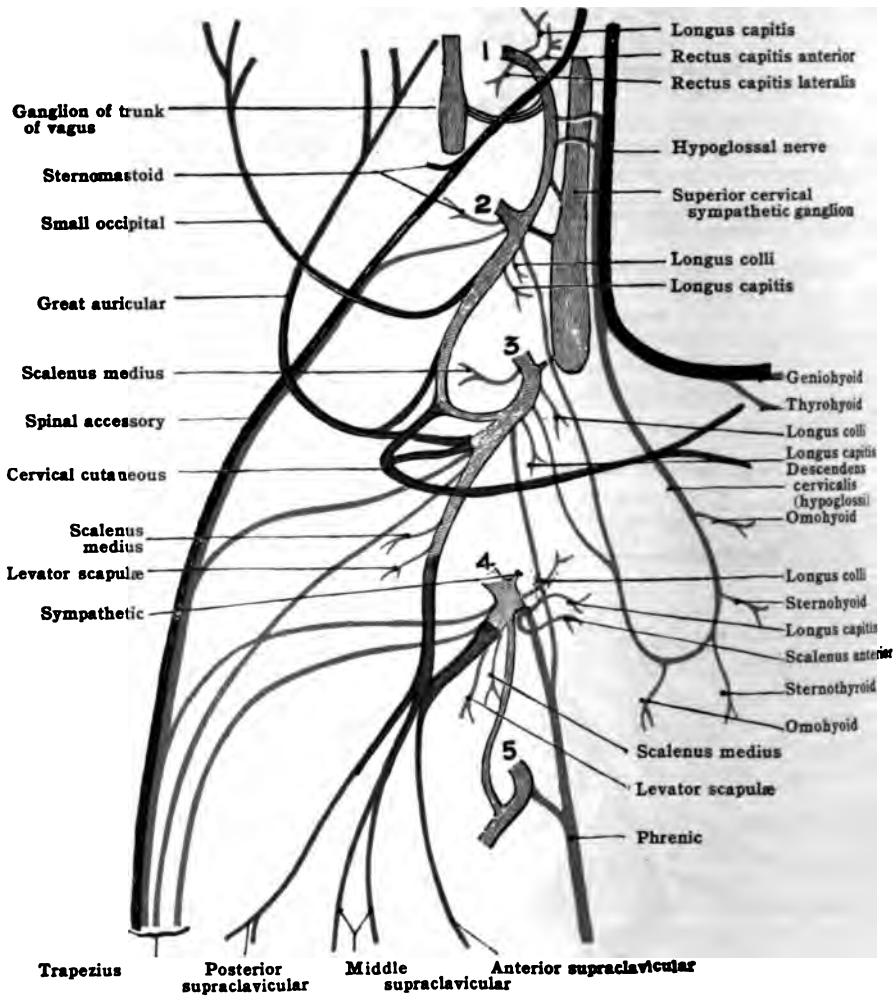
Superficial Branches of the Cervical Plexus

he superficial branches are described, according to the direction in which run, as ascending, transverse, and descending branches (fig. 784). The

ascending branches are the small occipital and the great auricular nerves. The is only one *transverse branch*, the superficial cervical cutaneous (transverse cervical) nerve. The *descending branches* are distinguished as the supraclavicular nerves and the cervical (hypoglossal) loop.

The ascending branches.—(1) The **small occipital nerve** (figs. 783, 784) arises from the second and third cervical nerves, or from the loop between them, and runs upward and dorsalward to the posterior border of the sternomastoid, where

FIG. 783.—DIAGRAM OF THE CERVICAL PLEXUS.



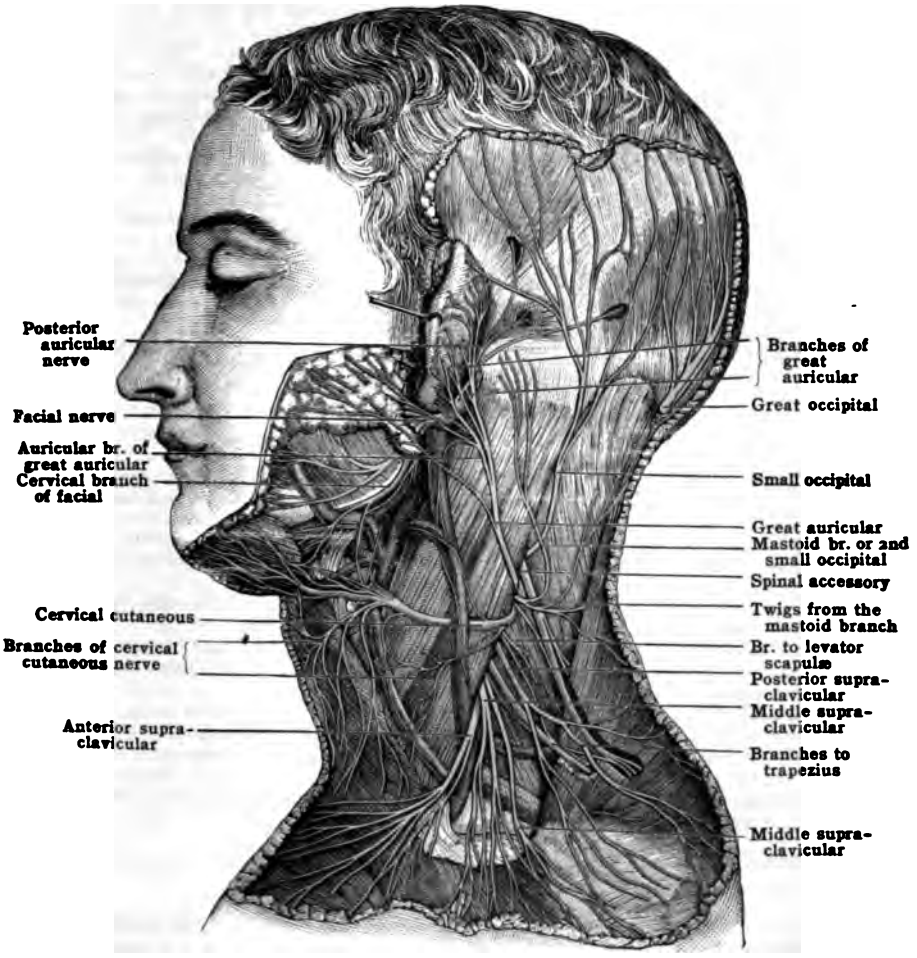
hooks around the lower border of the spinal accessory nerve and then ascends along the posterior border of the muscle to the mastoid process. It pierces the deep cervical fascia and passes across the posterior part of the insertion of the sternomastoid into the superficial fascia of the scalp, in which it breaks up into auricular, mastoid, and occipital terminal branches.

(*a*) The **auricular branch** runs upward and slightly forward to reach the integument of the upper median part of the auricle (pinna), which it supplies. (*b*) **The mastoid branch** is distributed to the skin covering the base of the mastoid process. (*c*) **The occipital branches** run over the occipitalis muscle and are distributed to the skin of the scalp; they communicate with one another and with the great occipital nerve. The branches of the small occipital anastomose with twigs of the posterior auricular, great auricular, and great occipital nerves (fig. 784).

(2) The **great auricular nerve** arises from the second and third cervical nerves (figs. 783, 784). It accompanies the small occipital to the posterior border of the sternomastoid, but at that point it diverges from the small occipital and runs upward and forward across the sternomastoid toward the angle of the mandible. When it is about half-way across the muscle it begins to break up into its terminal branches, which are named, according to the area of their distribution, mastoid, auricular, and facial.

As the nerve ascends obliquely across the sternomastoid it is embedded in the deep cervical fascia, is covered by superficial fascia and the platysma, and it lies parallel with and slightly dorsal to the external jugular vein. (*a*) The **mastoid branch** is small, and is distributed to the integument covering the mastoid process. It anastomoses with the posterior auricular and

FIG. 784.—SUPERFICIAL BRANCHES OF THE CERVICAL PLEXUS.
(After Hirschfeld and Leveillé.)



small occipital nerves. (*b*) The **auricular branches** are three or four stout twigs which interlace with the branches of the posterior auricular nerve; they cross the superficial surface of the posterior auricular branch of the facial, and are distributed to the skin on the back of the auricle with the exception of its uppermost part. One or two twigs pass through fissures in the cartilage of the auricle, and are distributed to the integument on the lateral surface of the lobule and the lateral surface of the lower part of the helix and anthelix. (*c*) The **facial branches** pass upward and forward among the superficial lobules of the parotid gland, and supply the skin over that gland and immediately in front of it, and they anastomose in the substance of the gland with the cervicofacial division of the facial nerve. In some cases fine twigs may be traced forward nearly to the angle of the mouth.

Transverse branch.—The **cervical cutaneous nerve** [n. cutaneus colli] arises from the second and third cervical nerves (figs. 782, 783), and appears at the posterior border of the sternomastoid, a little below the great auricular nerve.

It passes transversely across the sternomastoid under cover of the integument, platysma, and external jugular vein, and divides into a number of twigs which spread out after the manner of a fan, and, as they approach the middle line, extend from the chin to the sternum (fig. 784).

The upper two or three of these twigs unite, beneath the platysma, with the cervical (infra-mandibular) branch of the facial and thus form loops. From the terminal branches of the nerve numerous twigs arise which pierce the platysma and end in the skin of the front part of the neck.

The descending or supraclavicular branches.—These are derived from the third and fourth cervical nerves (figs. 782, 783), and arise under cover of the sternomastoid. At their commencements they are usually united with the muscular branches destined for the trapezius. They become superficial at the middle of the posterior border of the sternomastoid, and as they pass downward they pierce the deep cervical fascia (fig. 784). They include the following:

(1) The **anterior supraclavicular (suprasternal) branches** are small, and cross over the clavicular attachment of the sternomastoid to reach the integument over the upper part of the manubrium sterni. They also supply the sternoclavicular joint. (2) The **middle supraclavicular nerves** are of considerable size. They cross in front of the middle third of the clavicle under cover of the platysma, and are distributed to the skin covering the upper part of the pectoralis major as low as the third rib. (3) The **posterior supraclavicular (supra-acromial) branches** cross the clavicular insertion of the trapezius and the acromion process. They are distributed to the skin which covers the upper two-thirds of the deltoid muscle and they supply the acromioclavicular joint.

Deep Branches of the Cervical Plexus

The deep branches of the plexus (figs. 782, 783) pass lateralward and dorsalward, or ventralward and medialward; therefore they form two series, the lateral and the medial.

The **lateral branches** of the deep series include communicating branches from the second, third, and fourth cervical nerves to the spinal accessory nerve, and muscular branches to the sternomastoid and the scalenus medius, levator scapulæ, and trapezius.

The **communicating branches.**—The communicating branch from the second cervical nerve is ultimately distributed to the sternomastoid, and those from the third and fourth nerves end in the trapezius.

1. The **nerve to the sternomastoid** arises from the second cervical nerve. It pierces the deep surface of the sternomastoid, and communicates within the muscle with the spinal accessory nerve.

2. The **nerves to the scalenus medius** are derived from the third or fourth to the eighth cervical nerves close to their exit from the intervertebral foramina.

3. The **nerves to the levator scapulæ** are derived from the third and fourth cervical nerves, and occasionally from the second or fifth. They pierce the superficial surface of the levator scapulæ, and supply the upper three divisions of that muscle.

4. The **branches to the trapezius** are usually in the form of two stout twigs which are given off by the third and fourth cervical nerves. They emerge from under cover of the sternomastoid at its posterior border and cross the posterior superior triangle of the neck at a lower level than the spinal accessory nerve (fig. 784). They pass under cover of the trapezius in company with the last-named nerve, and communicate with it to form the **subtrapezial plexus**, from which the trapezius is supplied.

The **medial branches** of the deep series also comprise communicating and muscular branches.

The **communicating branches** (figs. 782, 783) include (1) branches which connect each of the first four cervical nerves with the superior cervical ganglion of the sympathetic; (2) a branch to the vagus; (3) a branch to the hypoglossus; and (4) branches which pass from the second and third cervical nerves to the *descendens cervicalis* (*hypoglossi*). The ultimate distribution of the twigs connected with the sympathetic and the vagus nerves is not known, but the fibers which pass to the hypoglossal nerve pass from it to the thyrohyoideus muscle and to the descendens cervicalis, and the latter joins with the branches from the second and third cervical nerves, forming with them the cervical or **hypoglossal loop [ansa hypoglossi]** which lies on the carotid sheath. From this loop the two bellies of the omohyoid muscle and the sternohyoid and sternothyroid muscles are supplied as described above.

The **muscular branches** supply the rectus capitis lateralis, the longus capitis (rectus capitis anterior major), the rectus capitis anterior (minor), the scalenus anterior, and the diaphragm. The nerve to the latter muscle is the **phrenic.**

1. The **branch to the rectus capitis lateralis** is furnished to that muscle by the first cervical nerve as it crosses the deep surface of the muscle.

2. The **nerve to the rectus capitis anterior** (minor) is given off by the first nerve at the upper part of the loop in front of the transverse process of the atlas.

3. The **longus capitis** (rectus capitis anterior major) receives twigs from the upper four cervical nerves.

4. The **longus colli** receives branches from the second, third, and fourth cervical nerves, and additional branches also from the fifth and sixth nerves.

5. The **phrenic nerve** (fig. 783) springs chiefly from the fourth cervical nerve, but it usually receives a twig from the third and another from the fifth cervical nerve, a small communicating branch from the sympathetic, and, rarely, a branch from the vagus. The twig from the fifth cervical nerve is frequently connected with the nerve to the subclavius. After the union of its roots the phrenic nerve passes downward and medialward on the scalenus anterior (figs. 501, 786). In this part of its course it is crossed by the tendon of the omohyoid and by the transverse cervical and transverse scapular (suprascapular) arteries. It is overlapped by the internal jugular vein, and it is covered by the sternomastoid muscle. At the root of the neck the left phrenic nerve lies behind the terminal portion of the thoracic duct, and each nerve passes off the anterior border of the scalenus anterior and descends in front of the first part of the subclavian artery and the pleura immediately below that artery; each nerve passes dorsal to the terminus of the subclavian vein, crosses either in front of or dorsal to the internal mammary artery and gains the medial surface of the pleural sac. From the root of the neck the relations of the phrenic nerves differ (fig. 501).

The right phrenic nerve descends along the medial surface of the right pleural sac and crosses in front of the root of the lung. It is accompanied by the pericardiacophrenic artery (comes nervi phrenici), and it is in relation medially, and from above downward, with the right innominate vein, the superior vena cava, and the pericardium, the latter membrane separating it from the wall of the right atrium. The **left phrenic nerve** descends along the medial surface of the left pleural sac accompanied by the pericardiacophrenic artery. In the superior mediastinum it lies between the left common carotid and the left subclavian arteries, and it crosses in front of the left vagus, the left superior intercostal vein, and the arch of the aorta. Below the arch of the aorta it crosses in front of the root of the left lung, and then lies along the left lateral surface of the pericardium, which separates it from the wall of the left ventricle.

Branches.—Both phrenic nerves distribute branches to the pericardium and to the pleura. The right nerve gives off a branch, **pericardiac**, which accompanies the superior vena cava and supplies the pericardium. Each phrenic nerve divides into numerous terminal **phrenicoabdominal** branches. As a rule, the *right phrenic* nerve divides into two main terminal branches, an anterior and a posterior. The *anterior* branch runs forward and one of its terminal filaments anastomoses with the phrenic of the opposite side in front of the pericardium; others descend between the sternal and costal attachments of the diaphragm into the abdomen, where some of them supply the diaphragm and others descend in the falciform ligament to the peritoneum on the upper surface of the liver. The *posterior* branch passes through the vena caval opening and ramifies upon the lower surface of the diaphragm, anastomosing with the diaphragmatic plexus of the sympathetic, and its terminal branches supply the muscular fibers of the right half of the diaphragm, the inferior vena cava, and the right suprarenal gland.

The *left phrenic* nerve divides into several branches. One of the most anterior branches anastomoses with the right phrenic nerve; the others pierce the diaphragm and ramify on its lower surface, where they anastomose with filaments of the left diaphragmatic plexus of the sympathetic and supply the left half of the diaphragm and the left suprarenal gland. The left phrenic nerve is considerably longer than the right nerve, partly on account of the lower level of the diaphragm on the left side, and partly on account of the greater convexity of the left side of the pericardium.

THE BRACHIAL PLEXUS

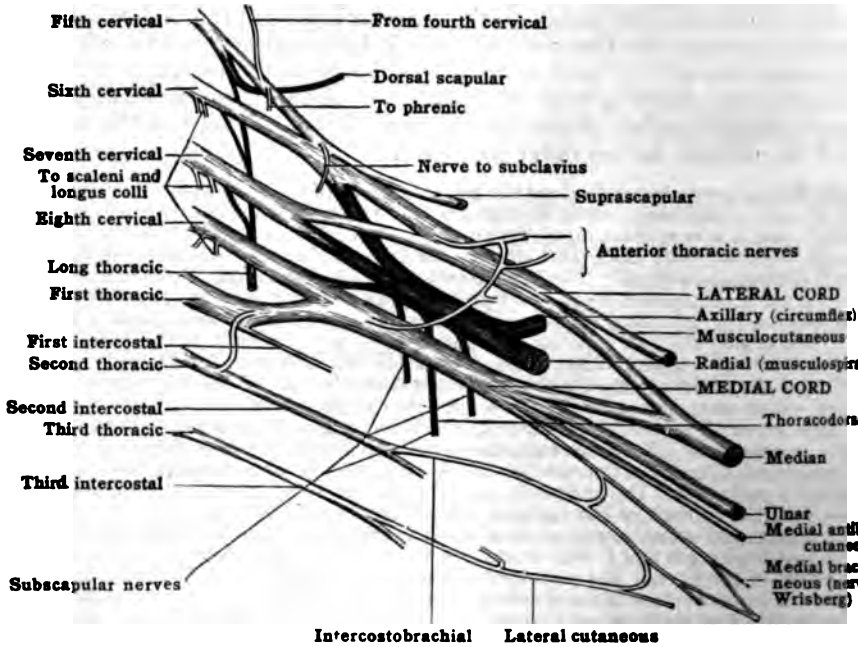
The **brachial plexus** (figs. 782, 785, 786) is formed by the anterior primary divisions of the **four lower cervical nerves** and the greater part of that of the **first thoracic nerve.** It is usually joined by small twigs from the **fourth cervical** and **second thoracic nerves.**

The anterior primary divisions of the lower four cervical nerves, after passing dorsal to the vertebral artery and between the anterior and posterior parts of the intertransverse muscles, pass into the posterior triangle in the interval between the adjacent borders of the anterior and middle scalene muscles, where those of the fifth and sixth nerves receive a gray ramus communicans each from the middle cervical sympathetic ganglion, and those of the seventh and eighth nerves each receives a gray ramus from the inferior cervical sympathetic ganglion. The anterior primary division of the first thoracic is connected by two rami communicantes with the first thoracic sympathetic ganglion, and it divides into a smaller and a larger branch. The smaller branch passes along the intercostal space as the

first intercostal nerve, and the larger branch, after being joined by a twig from the second thoracic nerve, passes upward and lateralward, in front of the neck of the first rib and behind the apex of the pleural sac, into the lower part of the posterior triangle of the neck, where it takes part in the formation of the plexus.

Trunks and branches.—The anterior primary divisions of those cervical nerves that form the brachial plexus show typically the following relations (fig. 785). The fifth and sixth cervical divisions unite to form the *upper trunk;* the seventh cervical forms the *middle trunk;* the eighth cervical and first thoracic form the *lower trunk* of the plexus. Each of these trunks divides into an *anterior* and a *posterior branch.* Variations in the mode of formation of the trunks and branches are so numerous that many different forms of the plexus have been described.

FIG. 785.—DIAGRAM OF A COMMON FORM OF BRACHIAL PLEXUS.
The posterior branches and cord of the plexus are darkly shaded.



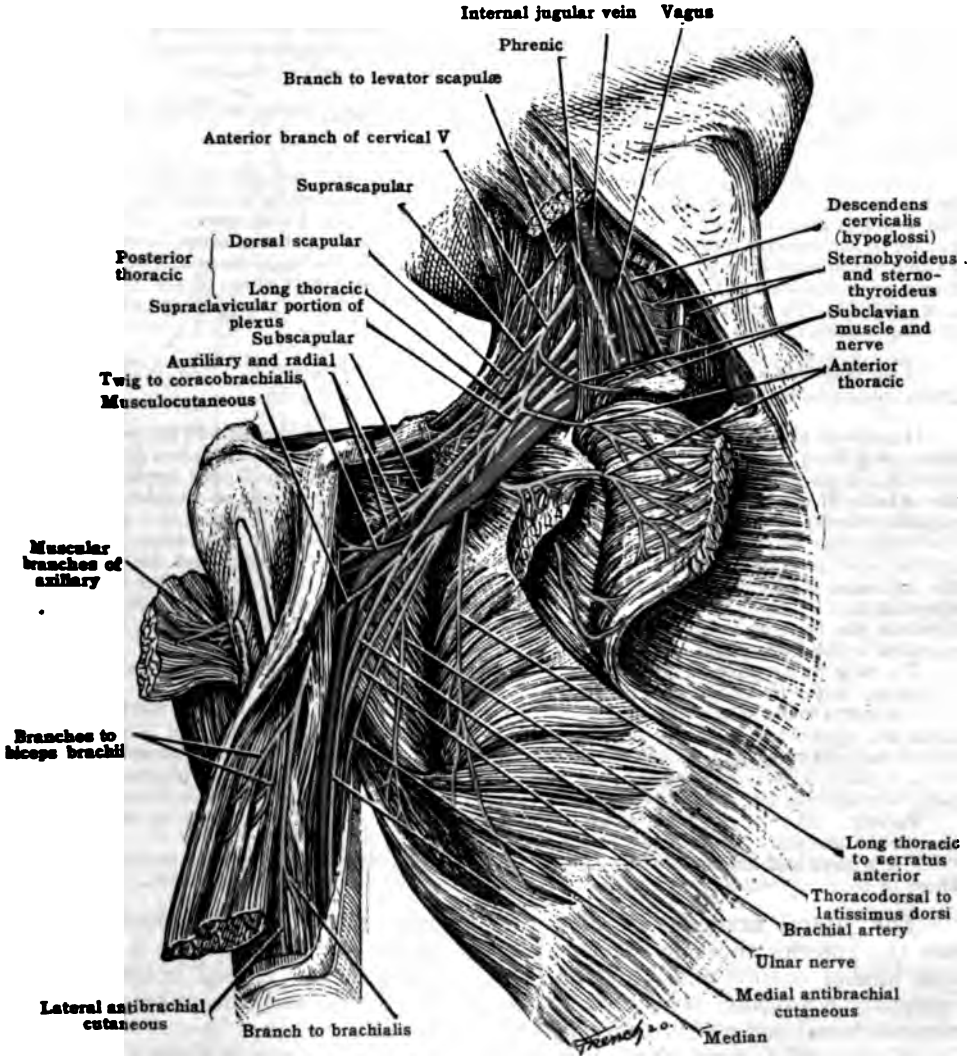
Three cords [fasciculi] are formed from these branches in the following manner:—(1) The **lateral** (outer) **cord** [fasciculus **lateralis**] is formed by the anterior branches of the upper and middle trunks (**anterior primary divisions** of the fifth, sixth, and seventh nerves); (2) the **medial (inner) cord** [fasciculus medialis], by the anterior branch of the lower trunk (**eighth cervical** and first thoracic nerves); and (3) the **posterior cord** [fasciculus **posterior**], by the posterior branches of all of these trunks and nerves.

In a study of 175 brachial plexuses, Kerr found that over 62 per cent. of them receive a communication from the anterior primary division of the fourth cervical nerve. Of those which receive no branch from this nerve, nearly 30 per cent. of the 175 plexuses studied receive the entire anterior primary division of the fifth cervical nerve. In most of the remaining 10 per cent., a part of the fifth nerve helps to form the cervical plexus. Brachial plexuses receiving the branch from the fourth cervical nerve are found more cephalic with reference to the vertebral column than these which do not receive it. Those which receive the largest part of the fifth cervical nerve are most caudal. He divides the plexuses studied into three groups and within these pictures eight types of forms.

Relations.—The plexus extends from the lateral border of the scalenus anterior, where the roots of its constituent nerves appear, to the lower border of the pectoralis minor, where each of its three cords divides into two terminal branches, and it lies in the posterior triangle, in the root of the neck, and in the axillary fossa. In the posterior triangle and in the root of the neck it is in relation behind with the scalenus medius (figs. 782, 786). In the posterior triangle it is covered superficially by the skin and superficial fascia, the platysma, the supraclavicular branches of the cervical plexus, and the deep fascia, and it is crossed by the lower part of the external jugular vein, by the nerve to the subclavius, the transverse cervical vein and the transverse scapular (suprascapular) vein, the posterior belly of the omohyoid muscle, and by

transverse cervical artery. At the root of the neck it lies behind the clavicle and the subclavius muscle, and the transverse scapular (suprascapular) artery crosses in front of it. In the axillary fossa the cords are arranged around the axillary artery, the lateral cord lying lateral to the artery, the medial cord medial to it, and the posterior cord dorsal to the artery. In this region the posterior relations of the plexus are the fat in the upper part of the fossa and the subscapularis muscle, and it is covered in front by the pectoral muscles and the coracoclavicular fascia. The lower border of the plexus is in relation in the posterior triangle and at the root of the neck with the pleura and the first rib, and it is overlapped in front by the third part of the subclavian artery. In the axillary fossa the medial cord, which forms the lower border of the plexus, is overlapped anteriorly by the axillary vein. The upper and lateral border of the plexus has no very important relations.

FIG. 786.—THE BRACHIAL PLEXUS AND ITS BRANCHES OF THE REGION OF THE NECK AND SHOULDER. (After Toldt, Atlas of Human Anatomy,' Rebman, London and New York.)



In summary the brachial plexus may be formulated as beginning with five nerves and terminating in five nerves, with its intermediate portions displayed in sets of threes. It begins with the fifth, sixth, seventh and eighth cervical and first thoracic nerves (anterior primary divisions); it terminates as a plexus with the formation of the musculocutaneous, radial, axillary, median, and ulnar nerves; in its intermediate portions, first, three main trunks are formed and these divide into two sets of threes which, by union, give rise to three cords. The **branches from the cords** are three main lateral branches from each and the terminal branches of the plexus. The *lateral branches*, according as they are given off

above, below, and dorsal to the clavicle, are grouped as the *supraclavicular*, the *infraclavicular* and the *subscapular portions* of the plexus (figs. 785, 786).

The branches of the supraclavicular portion.—After the roots of the plexus have received communications from the sympathetic, which have already been referred to, they give off a series of muscular branches, viz.—the posterior thoracic nerves (the dorsal scapular and the long thoracic nerve), the suprascapular nerve, a twig to the phrenic, the nerve to the subclavius, and small twigs to the scalene muscles and the longus colli muscle.

The **posterior thoracic nerves** are two in number:—(*a*) the **dorsal scapular** (nerve to the rhomboids) arises principally from the fifth cervical nerve, but it frequently receives a twig from the fourth nerve (fig. 782).

It passes downward and dorsalward, across the middle scalene, parallel with and below the spinal accessory nerve to the anterior border of the levator scapulæ, under which it disappears. It continues its descent under cover of the levator scapulæ and the rhomboids almost to the lower angle of the scapula, lying a little medial to the posterior border of the bone, and it supplies the lower fibers of the levator and the smaller and larger rhomboid muscles.

(*b*) The **long thoracic nerve** (external respiratory nerve of Bell) supplies the serratus anterior.

It usually arises, by three roots, from the fifth, sixth, and seventh cervical nerves. The last is sometimes absent (figs. 782 and 785). The upper two roots traverse the substance of the scalenus medius; the root from the seventh passes in front of that muscle. Twigs are furnished to the superior portion of the serratus anterior by the upper two roots; lower down they unite and are subsequently joined by the root from the seventh when present. The trunk of the nerve passes downward behind the brachial plexus and the first stage of the axillary artery and runs along the axillary surface of the serratus anterior (magnus), supplying twigs to each of the digitations of that muscle (fig. 786).

The **suprascapular nerve** (figs. 782, 785, 786) supplies the supraspinatus and infraspinatus muscles.

It receives fibers from the fifth and sixth cervical nerves, and in about 50 per cent. of cases also a twig from the fourth nerve. It is a nerve of considerable size, and it passes downward and dorsalward parallel with the dorsal scapular nerve, at first along the upper border of the posterior belly of the omohyoid muscle, then internal to the latter muscle and under cover of the anterior border of the trapezius to the suprascapular notch, where it comes into relation with the transverse scapular (suprascapular) artery. It is separated from the artery at the notch by the superior transverse ligament, the nerve passing through the notch and the artery above the ligament. After entering the supraspinous fossa the nerve supplies branches to the supraspinatus and a branch to the shoulder-joint; then it descends through the great scapular notch between the bone and the inferior transverse ligament to the infraspinous fossa, where it terminates in the infraspinatus muscle.

The **twig to the phrenic** (figs. 782, 785) arises from the fifth cervical nerve close to the point where the latter nerve receives its twig from the cervical plexus.

The **nerve to the subclavius** (figs. 785, 786) is a small twig which arises from the fifth nerve or from the upper trunk of the plexus, but occasionally it receives additional fibers from the fourth and sixth nerves. It runs downward in front of the lower part of the plexus and the third stage of the subclavian artery and, after giving off sometimes a branch to the phrenic, pierces the posterior layer of the coracoclavicular fascia, and enters the subclavius at its lower border.

Variety.—In rare cases the entire phrenic nerve may pass *via* the nerve to the subclavius in front of the third stage of the subclavian artery.

The *scaleni* and *longus colli* (figs. 782, 785) are supplied by twigs which arise from the lower three or four cervical nerves immediately after their exit from the intervertebral foramina.

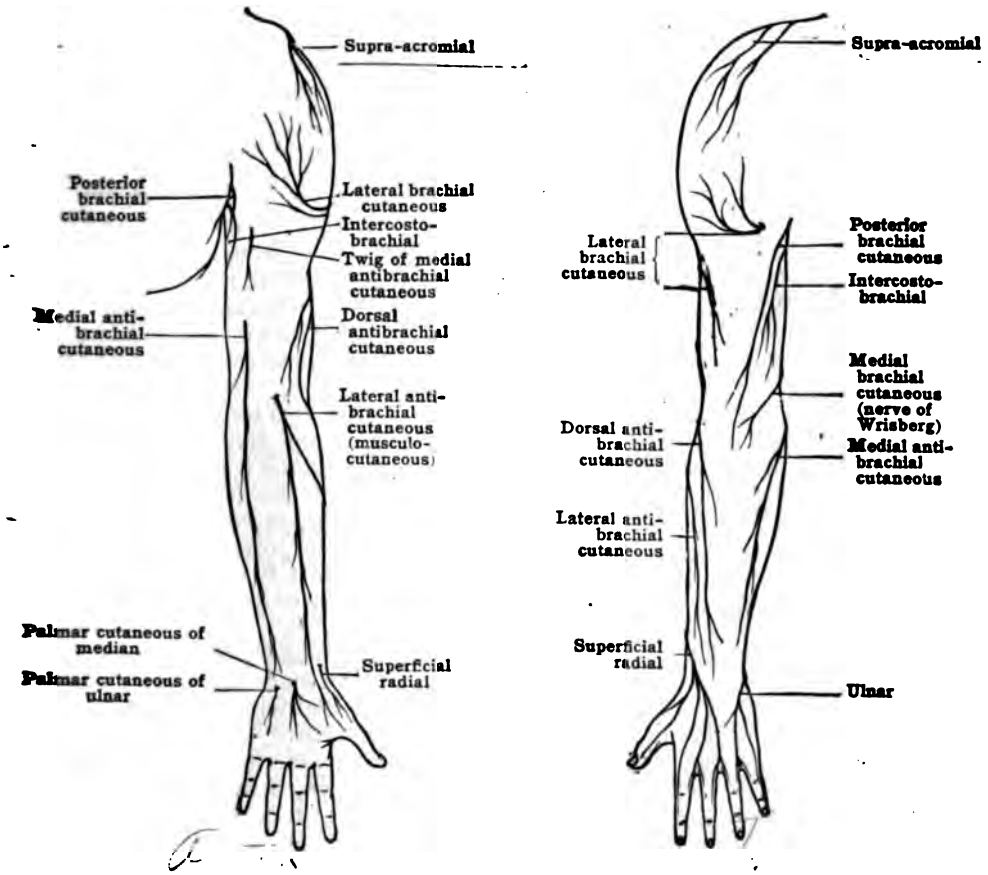
The lateral branches of the infraclavicular portion of the brachial plexus are the anterior thoracic nerves, from the lateral and medial cords respectively; the medial antibrachial (internal) cutaneous and the medial brachial (lesser internal) cutaneous nerves, from the medial cord, and the subscapular and thoracodorsal nerves from the posterior cord.

The **lateral anterior thoracic nerve** joins with the medial to form a loop which supplies the pectoralis major and minor.

It arises from the lateral cord of the plexus and contains fibers from the fifth, sixth, and seventh cervical nerves (figs. 782, 785, 786). After joining the medial anterior thoracic it pierces the coracoclavicular fascia and ends in branches that supply the pectoralis major muscle. The medial anterior thoracic nerve arises from the medial cord (figs. 782, 785, 786), contains fibers from the eighth cervical and first thoracic nerves, and passes forward between the first stage of the axillary artery and the axillary vein. It unites with a branch from the lateral anterior thoracic, to form a loop which is placed in front of the first stage of the axillary artery; it gives branches to the pectoralis minor, and branches which pass through the latter muscle and end in the pectoralis major. From the loop additional branches are furnished to the pectoralis major.

The medial brachial (lesser internal) **cutaneous nerve,** (or nerve of Wrisberg, 785, 787), arises from the medial cord of the brachial plexus and in 90 per . of the cases contains fibers from the eighth cervical and first thoracic nerves, sometimes fibers from the first thoracic nerve alone. It runs downward on medial side of the axillary vein, being separated by that vessel from the r nerve, and it continues downward with a slight inclination dorsalward er cover of the deep fascia on the inner side of the arm. At the middle of the it pierces the deep fascia, and near the bend of the elbow it turns somewhat ply dorsalward to supply the integument which covers the olecranon cess (fig. 787).

. 787.—Distribution of Cutaneous Nerves on the Anterior and Posterior Aspects of the Upper Extremity.



As it traverses the axilla the medial brachial cutaneous nerve communicates with the intercostobrachial nerve, forming one, or sometimes two loops (fig, 785). In its course down the arm it gives a few fine twigs to the integument, This nerve may be absent, its place being taken by the intercostobrachial or by part of the posterior brachial (internal) cutaneous branch of the radial (musculospiral) or, rarely, by a branch from the first intercostal nerve. It usually leaves the plexus as a single branch, but sometimes it leaves combined with the medial antibrachial cutaneous nerve.

The medial antibrachial (internal) **cutaneous nerve** (figs. 782, 785) arises from the medial cord in close relation with the ulnar nerve. It contains fibers from the eighth cervical and first thoracic nerves. At its origin it lies directly on the medial side of the axillary artery (fig. 786), but it soon becomes more superficial and then lies in the groove between the artery and the vein. In the upper two-thirds of the arm it lies in front and to the medial side of the brachial artery. It divides into two branches (volar and ulnar) which supply the medial aspect of the forearm.

At the junction of the middle and lower thirds of the arm this nerve pierces the de in company with the basilic vein, and divides into an anterior and a posterior branch. to its division it gives off twigs which pierce the deep fascia and supply the integume upper and medial part of the arm. The volar (anterior) branch is larger than the ul terior); it passes in front of or dorsal to the median basilic vein, and divides into seve which run down the forearm, supplying the integument covering its anterior and medi as far as the wrist, and anastomosing with the branches of the ulnar nerve. The ul terior) branch passes downward and dorsalward in front of the medial condyle of the h and divides into branches which supply the skin on the posteromedial aspect of the It anastomoses with the dorsal antibrachial (inferior external) cutaneous branch of t (musculospiral) nerve and the dorsal branch of the ulnar nerve.

The subscapular nerves are branches of the posterior cord (fig. 785). are usually three in number, distinguished as upper, thoracodorsal or mid lower, and are distributed to the subscapularis, latissimus dorsi, and tere muscles.

The upper or short subscapular nerve is derived from the fifth and sixth cervica It lies in the upper and posterior part of the axillary fossa, and it is distributed exclu the subscapularis muscle. It is occasionally double.

The thoracodorsal (middle, or long subscapular) nerve consists mainly of fiber seventh and eighth cervical nerves, but it may contain fibers from the fifth or the six It passes behind the axillary artery, accompanies the subscapular artery along th margin of the subscapularis muscle, and ends in the latissimus dorsi (fig. 786).

The lower subscapular nerve, carrying fibers from the fifth and sixth cervical nerv behind the subscapular artery, below the circumflex branch (dorsalis scapulæ), and is d to the teres major, and furnishes to the subscapularis one or two twigs which enter th near its axillary margin. In about 50 per cent. of the cases, the subscapular nerves, the upper and lower, may carry fibers from the fourth cervical nerves.

The terminal branches of the brachial plexus are two from each co posterior cord divides into the axillary (circumflex) and the radial (m spiral) nerves. The lateral cord divides into the musculocutaneous ne the lateral root of the median nerve. The medial cord divides into the uln and the medial root of the median nerve, the median nerve as a whole bei the five terminal branches of the plexus.

The axillary (circumflex) nerve is the smaller of the two terminal br the posterior cord, and contains fibers from the fifth and sixth cervica (figs. 782 and 785). At the lower border of the subscapularis it passes do and accompanies the posterior circumflex artery through the quadrilater which is bounded by the teres major, long head of triceps, and subscapul cles, and the surgical neck of the humerus, and it divides into a smaller and a larger inferior division. Previous to its division it furnishes an twig to the shoulder-joint. This twig pierces the inferior part of the capsule.

The superior division accompanies the posterior circumflex artery ar neck of the humerus, and gives off a number of stout twigs which enter toid muscle (fig. 786). A few fine filaments pierce the deltoid and en integument which covers the middle third of that muscle.

The inferior division divides into cutaneous and muscular branch cutaneous branch, the lateral brachial cutaneous nerve, turns around terior border of the deltoid, pierces the deep fascia, and supplies the skin the lower third of the deltoid and a small area of integument below the in the muscle (fig. 787). One muscular branch is distributed to the teres swells out into an ovoid or fusiform, reddish, gangliform enlargemen entering the muscle. Other branches supply the lower and posterior pa deltoid.

The radial (musculospiral) nerve [n. radialis] is the largest branc brachial plexus. It contains fibers from the sixth, seventh, and eighth and often from the fifth cervical or first thoracic nerve (figs. 782, 78 fourth cervical nerve also occasionally contributes fibers to it. It co at the lower border of the pectoralis minor, as the direct continuatio posterior cord of the brachial plexus, and passes downward and lateralwa axillary fossa behind the third part of the axillary artery (fig. 786) and i the subscapularis, latissimus dorsi, and teres major muscles. From t border of the axillary fossa it descends into the arm, where it lies, at fir medial side of the upper third of the humerus, behind the brachial arte front of the long head of the triceps; then it runs obliquely downward an

behind the middle third of the humerus, in the groove for the radial nerve (musculospiral groove), and between the lateral and medial heads of the triceps. It is accompanied, in this part of its course, by the profunda artery. At the junction of the middle and lower thirds of the humerus it reaches the lateral side of the arm, pierces the external intermuscular septum, and runs downward and forward between the brachioradialis and extensor carpi radialis longus externally, and the brachialis internally (fig. 789), and it terminates, a short distance above the epitrochlear, by dividing into deep and superficial terminal branches. In the last part of its course it is accompanied by the anterior terminal branch of the profunda artery.

Branches.—The branches of the radial (musculospiral) nerves are *cutaneous*, *muscular*, *articular*, and *terminal*, but for practical purposes it is best to consider them in association with the situations of their origins. While it is in the axillary fossa the radial nerve gives branches to the medial and long heads of the triceps (fig. 789), and a medial cutaneous branch. The branch to the long head of the triceps at once enters the substance of the muscle, that to the medial head breaks into branches which terminate in the muscle at different levels, and one of them, the *ulnar collateral nerve*, accompanies the ulnar nerve to the lower part of the arm. The **posterior brachial (internal) cutaneous branch** crosses the tendon of the latissimus dorsi, passes dorsal to the intercostobrachial (intercostohumeral) nerve, pierces the deep fascia, and is distributed to the skin of the middle of the back of the arm below the deltoid.

While it lies behind the middle third of the humerus, the radial nerve gives branches to the lateral and medial heads of the triceps and to the anconeus. The latter branch descends in the substance of the median head of the triceps, close to the bone, and it is accompanied by a small branch of the profunda artery. The **dorsal antibrachial (external) cutaneous branch,** passing down between the lateral and median heads of the triceps, divides near the elbow into its upper and lower branches (fig. 787), each of which perforates either the lateral head of the triceps muscle near its attachment to the humerus or the external intermuscular septum.

The upper branch, much the smaller, pierces the deep fascia in the line of the external intermuscular septum; it accompanies the lower part of the cephalic vein, and supplies the skin over the lower half of the lateral and anterior aspect of the arm. The **lower branch** is of considerable size. It pierces the deep fascia a little below the upper branch, runs behind the external condyle, and supplies the skin of the middle of the back of the forearm as far as the wrist, anastomosing with the medial antibrachial (internal) cutaneous and musculocutaneous nerves (fig. 790).

After the radial nerve has pierced the external intermuscular septum it gives branches to the brachioradialis, extensor carpi radialis longus, and to the lateral portion of the brachialis (fig. 790). From one of these branches an articular filament is distributed to the elbow-joint.

The **terminal branches** of the radial nerve are:—a motor branch, the *deep radial*, to the supinator and extensor muscles of the forearm, and a sensory branch, the *superficial radial*, which supplies the dorsal aspect of the radial half of the hand.

The deep radial nerve [ramus profundus] (posterior interosseous) runs downward in the interval between the brachialis and extensor carpi radialis longus. It passes in front of the lateral part of the elbow-joint, and after giving off branches to supply the extensor carpi radialis brevis and supinator, it is crossed in front by the radial recurrent artery (fig. 790). It then runs downward and dorsalward through the substance of the supinator, and enters the interval between the superficial and deep layers of muscles at the back of the forearm, where it comes into relation with the posterior interosseous artery, and accompanies it across the abductor pollicis longus. At the lower border of the latter muscle it gives off a branch to the extensor pollicis longus, and another which crosses this muscle to the extensor indicis proprius.

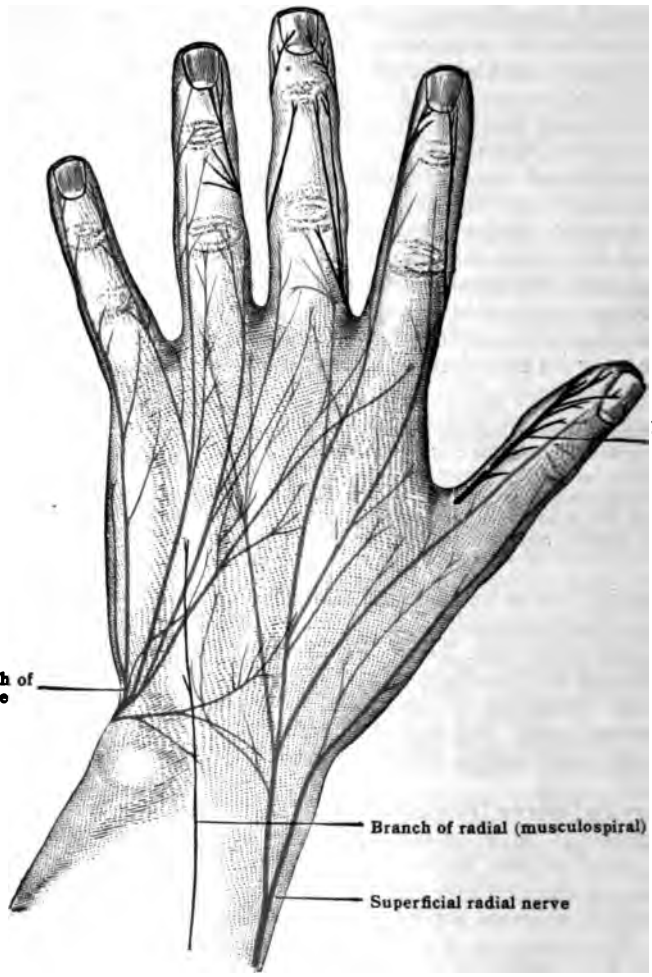
Continuing distalward as the *dorsal antibrachial interosseous* nerve the deep radial leaves the posterior interosseous artery, dips beneath the extensor pollicis longus, and joins the volar interosseous artery. It accompanies this artery upon the interosseous membrane and upon the back of the radius, passes through the groove for the extensor digitorum communis and extensor indicis proprius to the dorsum of the wrist, and terminates in a gangliform enlargement which gives branches to the carpal articulations. The muscles supplied by the deep radial nerve

are the extensor carpi radialis brevis, brachioradialis (supinator longus), extensor dig communis, extensor digiti quinti proprius, extensor carpi ulnaris, extensor indicis propri the extensor muscles of the thumb. The supinator (brevis) receives two twigs, one of is given off before the nerve pierces the muscle and the other while it is passing thro The characteristic 'wrist-drop' due to paralysis of the deep radial nerve is shown in fig. 112

The **superficial radial** (radial) **nerve** [ramus superficialis n. radialis] is what smaller than the deep radial (posterior interosseous), and is a purely neous nerve. It runs downward under cover of the brachioradialis, passi front of the elbow-joint, the radial recurrent artery, and the supinator (br At the lower border of the supinator it approaches the radial artery at an angle, and runs parallel to the lateral side of that vessel in the middle third

FIG. 788.—A DISSECTION OF THE CUTANEOUS NERVES ON THE DORSAL ASPECT OF THE AND FINGERS. (H. St. J. B.)

The branches of the median nerve are shown in black.



forearm, across the pronator teres. At the lower border of the pronator bends dorsalward on the deep surface of the tendon of the brachioradia appears on the back of the forearm. It pierces the deep fascia and is across the dorsal carpal (posterior annular) ligament toward the dorsum wrist, where it divides into its terminal branches (fig. 790).

The most lateral of these branches supplies the skin on the radial part of the ba nence; the most medial, designated the ulnar anastomotic branch, communicates with t branch of the ulnar nerve. The other terminal branches, the dorsal digital nerves, su

variable extent the skin on the dorsum of the first digit, both sides of the second and the radial side of the third digit. These branches usually extend to the base of the nail of the first digit, to the distal interphalangeal joint of the second, not quite to the proximal interphalangeal joint of the third, and to the metacarpophalangeal joint of the fourth digit.

The terminal branches of the lateral cord of the brachial plexus are the musculocutaneous and the *lateral component* of the median nerve. The latter nerve will be described with the medial cord.

The musculocutaneous nerve is composed of fibers derived chiefly from the anterior divisions of the fifth and sixth cervical nerves, together in about 50 per cent. of the cases with some fibers from the fourth and seventh (figs. 782. 785). The nerve to the coracobrachialis usually consists of two or three twigs given off from the nerve close to its origin before it enters the muscle (fig. 786). Sometimes, however the fibers from the seventh cervical nerve pass directly to this muscle without joining the main trunk. The musculocutaneous nerve is placed at first close to the lateral side of the axillary artery (fig. 786), but soon it leaves that vessel and, piercing the coracobrachialis muscle, it passes obliquely downward and lateralward between the biceps and brachialis muscles. Soon after piercing the coracobrachialis it gives off **muscular branches** to each head of the *biceps* and to the *brachialis* (fig. 789). It also gives twigs to the *humerus*, to the *nutrient artery*, and gives the chief supply to the *elbow-joint*. Below the branch to the brachialis the cutaneous portion of the nerve forms the **lateral antibrachial cutaneous nerve** (figs. 787, 789). This portion continues downward between the biceps and brachialis, pierces the deep fascia at the lateral border of the former muscle a little above the bend of the elbow, receives a communication from the upper branch of the dorsal antibrachial (upper external) cutaneous branch of the radial (musculospiral) nerve, passes dorsal to the median cephalic vein, and divides into an anterior and a posterior branch.

The **anterior branch** runs downward on the lateral and anterior part of the forearm, supplying the integument of that region, and it terminates in the skin covering the middle part of the thenar eminence (fig. 790). A short distance above the wrist, after it has received a communicating twig from the superficial radial nerve, it gives off an articular branch to the carpal joints. This branch pierces the deep fascia and accompanies the radial artery to the dorsum of the wrist. The **posterior terminal branch** is small, and is directed downward and backward in front of the external condyle of the humerus, to be distributed to the skin on the lateral and posterior aspect of the forearm as low as the wrist (fig. 787). In anastomoses with the superficial radial and with the lower branch of the dorsal antibrachial (lower external) cutaneous branch of the radial nerve.

The **terminal branches of the medial cord** of the brachial plexus are the ulnar nerve and the *medial component* of the median nerve. Neither of these gives any branches in the upper arm, and thus they differ from the other terminal branches of the plexus. They both supply the muscles and joints of the forearm, and the muscles, joints, and integument of the hand.

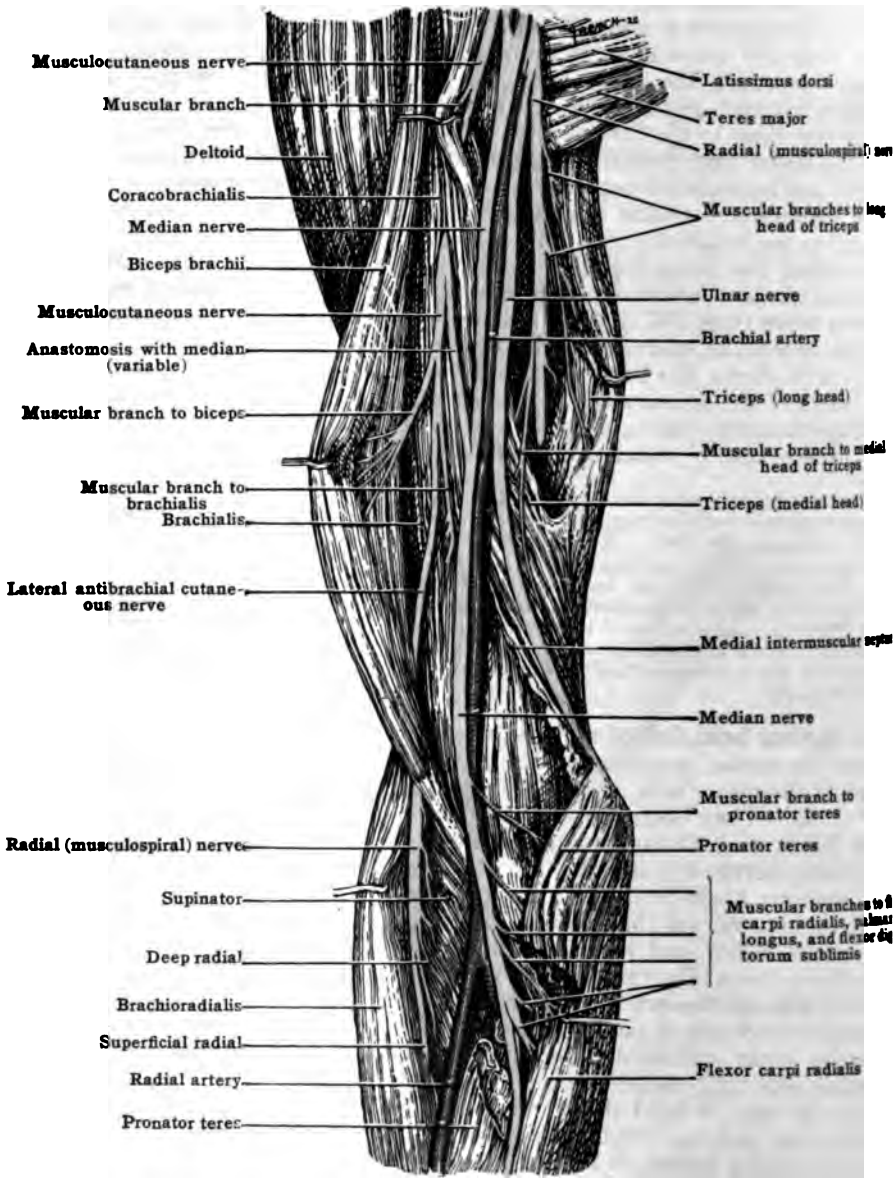
The ulnar nerve, which is the largest branch of the medial cord of the brachial plexus, contains fibers from the anterior primary divisions of the eighth cervical and first thoracic nerves (figs. 785 and 786). It commences at the lower border of the pectoralis minor and runs downward in the axillary fossa in the posterior angle between the axillary artery and vein. In the upper half of the arm it lies on the medial side of the brachial artery (fig. 786), but at the level of the insertion of the coracobrachialis it passes backward at an acute angle, and, accompanied by the superior ulnar collateral (inferior profunda) artery, it pierces the internal intermuscular septum. After passing through the septum it runs downward, in a groove in the medial head of the triceps (fig. 789), to the interval between the olecranon process and the medial condyle of the humerus, and in this part of its course it is closely bound to the muscle by the deep fascia. Immediately below the medial condyle it passes between the two heads of the flexor carpi ulnaris, along the medial side of the medial collateral ligament of the elbow, and it comes into relation with the dorsal ulnar recurrent artery.

In the upper forearm the ulnar nerve lies on the flexor digitorum profundus, covered by the flexor carpi ulnaris. Near the junction of the upper and middle thirds of the forearm it is joined by the ulnar artery, which accompanies it to its termination, lying throughout on its radial side (fig. 790). In the lower part of the forearm it still rests on the flexor digitorum profundus, but between the flexor carpi ulnaris and flexor digitorum sublimis, and is covered by skin and fascia. At a variable point in this part of the forearm, usually about 5 to 8 cm. from the carpus

the nerve divides into its two terminal branches, a dorsal branch to the dorsal aspect of hand and a volar branch to the volar aspect.

Branches.—The ulnar resembles the median nerve in not furnishing branches to the upper arm. As it passes between the olecranon process and medial condyle it gives off two or three fine filaments to the elbow-joint. the upper part of the forearm it supplies the flexor carpi ulnaris and the med

FIG. 789.—NERVES OF THE RIGHT UPPER ARM VIEWED FROM IN FRONT. (Spaltehol

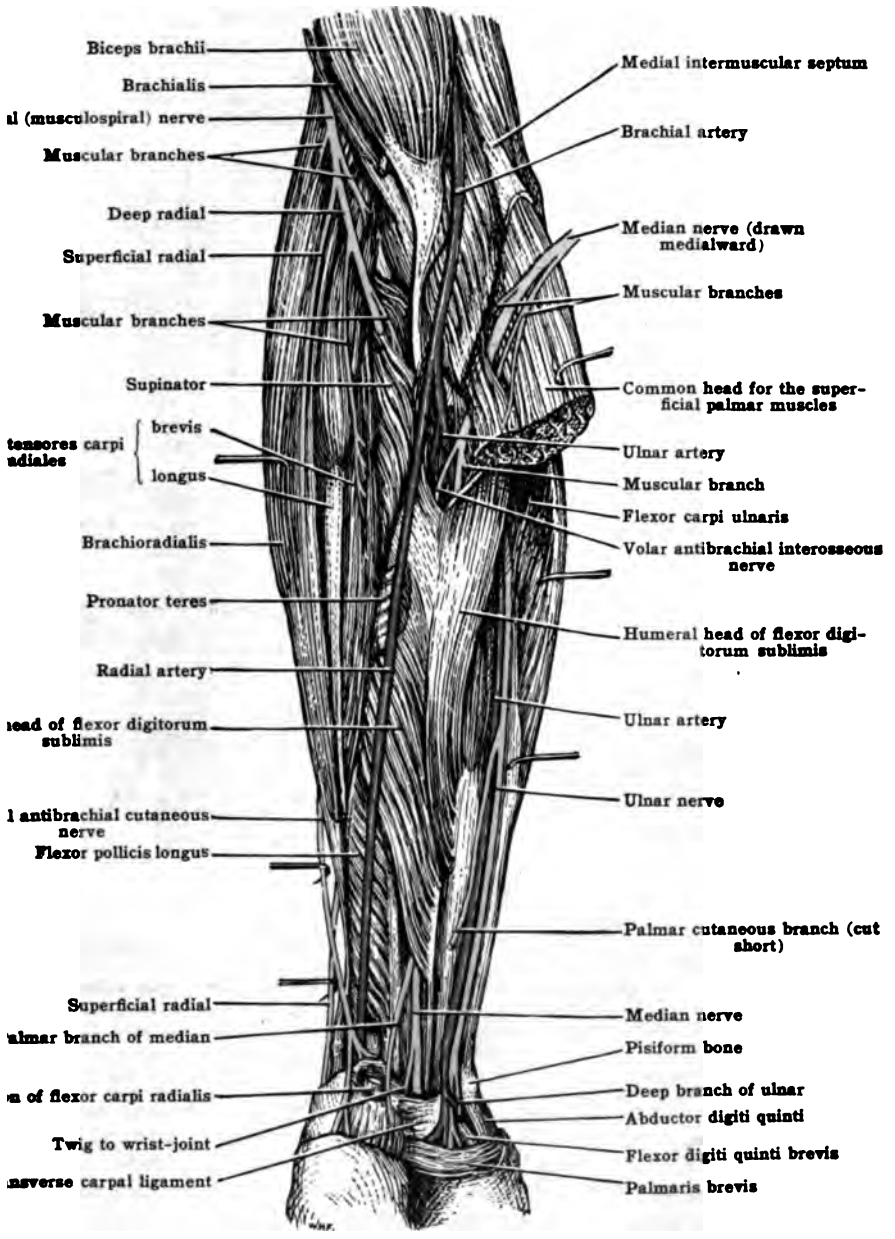


portion of the flexor digitorum profundus, and in the lower half it gives off three cutaneous branches. In the palm of the hand it supplies the integument of the hypothenar eminence, the fifth digit, and half of the fourth digit, and ulnar half of the skin of the dorsum. It also supplies the short intrinsic mu of the hand with the exception of the abductor pollicis, the opponens, the la head of the flexor pollicis brevis, and the two lateral lumbricales. The effec of paralysis of the ulnar nerve are shown in fig. 1130 B and C.

nerves to the flexor carpi ulnaris and to the medial two divisions of the **flexor digitorum us** arise from the ulnar nerve in the upper third of the forearm.

ıneous branches.—About the middle of the forearm the ulnar nerve gives off two **us** branches:—one pierces the fascia and anastomoses with the volar branch of the **antibrachial** (internal) cutaneous nerve, and the other, the **palmar cutaneous branch,** **wnward** in front of the ulnar artery (fig. 790) and is conducted by this vessel into the **g. 792).** It furnishes some filaments to the vessel, supplies a few twigs to the skin of the

0.—DEEP NERVES OF THE VOLAR SURFACE OF THE FOREARM. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



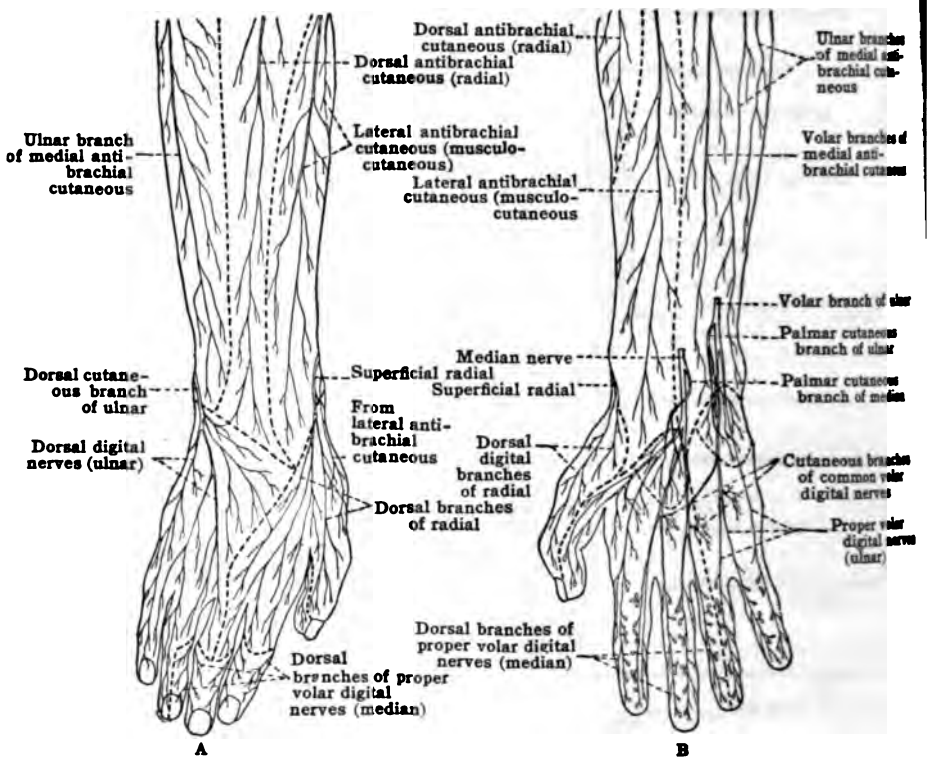
enar eminence, and ends in the integument covering the central depressed surface of the haring this surface with the palmar branches of the median nerve.

dorsal or **posterior cutaneous branch,** usually the smaller of the terminal branches, bout 5 cm. above the wrist-joint, and passes backward under cover of the flexor carpi to reach the dorsal aspect of the wrist (fig. 792), where it gives off delicate branches tomose with branches of the medial antibrachial (internal) cutaneous, the dorsal anti- l (external) cutaneous branch of the radial (musculospiral), the lateral antibrachial

cutaneous of the musculocutaneous nerve, and with branches of the superficial radial, and the ... divides into five branches, the **dorsal digitals** (fig. 788), which are distributed to the ... sides of the third, fourth, and fifth digits and the radial sides of the fourth and fifth ... These branches usually extend on the fifth digit only as far as the base of the terminal ... and on the fourth digit as far as the base of the second phalanx. The more distal parts ... these digits are supplied by palmar digital branches of the ulnar nerve.

The **volar branch,** the other terminal branch of the ulnar nerve, continues its course betw... the flexor carpi ulnaris and flexor digitorum sublimis, on the medial side of the ulnar artery, ... the wrist, where, on the lateral side of the pisiform bone, it divides into a **superficial** and a **deep branch** (figs. 790 and 792). The latter accompanies the deep branch of the ulnar ar... into the interval between the abductor digiti quinti and flexor digiti quinti brevis, and th... passes through the fibers of the opponens digiti quinti to reach the deep surface of the fl... tendons and their synovial sheaths. It supplies the abductor and opponens digiti quinti, th... flexor digiti quinti brevis, the third and fourth lumbricales, all the interossei, the adductor ...

FIG. 791.—DIAGRAM ILLUSTRATING A COMMON DISTRIBUTION OF CUTANEOUS NERVES OF THE FOREARM AND HAND; A, dorsum; B, volar aspect.


Dorsal antibrachial cutaneous (radial)
Dorsal antibrachial cutaneous (radial)
Ulnar branch of medial antibrachial cutaneous
Lateral antibrachial cutaneous (musculocutaneous)
Lateral antibrachial cutaneous (musculocutaneous)
Volar branches of medial antibrachial cutaneous
Volar branch of ulnar
Palmar cutaneous branch of ulnar
Median nerve
Superficial radial
Superficial radial
Palmar cutaneous branch of median
Dorsal cutaneous branch of ulnar
From lateral antibrachial cutaneous
Dorsal digital branches of radial
Cutaneous branches of common volar digital nerves
Dorsal digital nerves (ulnar)
Dorsal branches of radial
Proper volar digital nerves (ulnar)
Dorsal branches of proper volar digital nerves (median)
Dorsal branches of proper volar digital nerves (median)
A
B

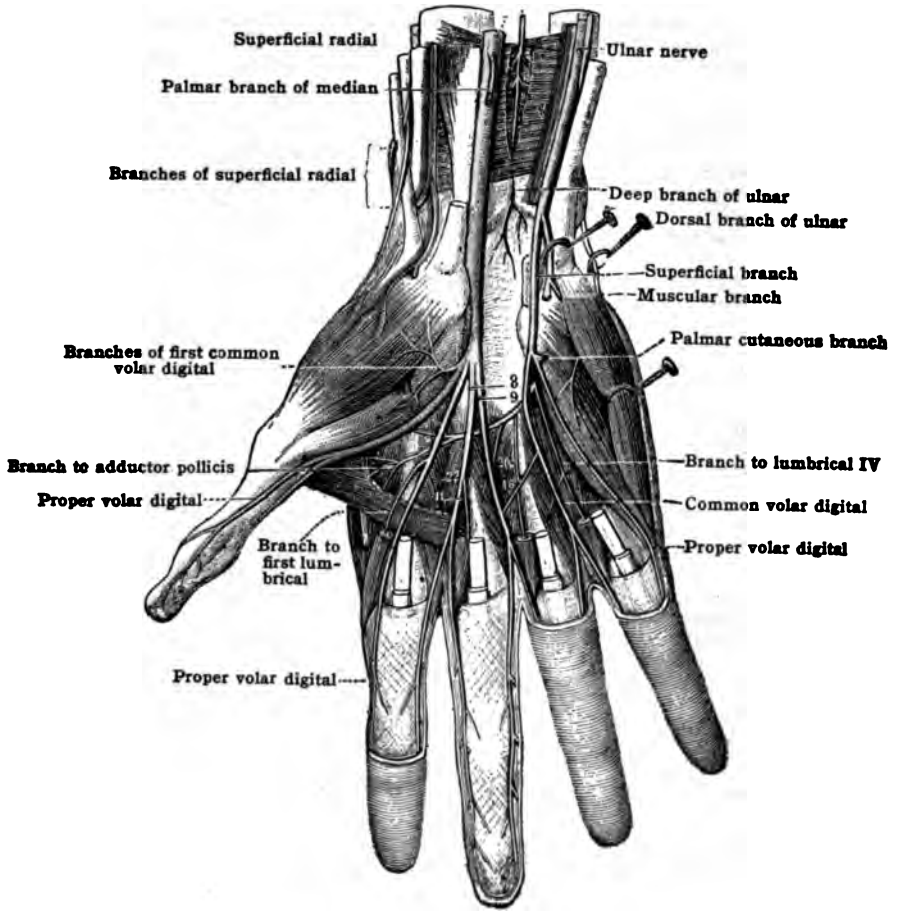
the thumb, and the medial head, and occasionally the lateral head, of the flexor pollicis brevis. The **superficial branch** gives off a branch to supply the palmaris brevis muscle, an anastomosing branch to the median nerve, and then divides into two branches, the **proper volar digital branch** which is distributed to the medial side of the fifth digit on its volar aspect, and the **common volar digital branch,** which passes underneath the palmar aponeurosis and divides into two branches, which supply the contiguous margins of the fourth and fifth digits. These branches usually supply also the dorsal surface of the second and third phalanges of the same digits.

The **median nerve** contains fibers of the sixth, seventh, and eighth cervical nerves and of the first thoracic, and sometimes of the fifth cervical nerve. The trunk is formed a little below the lower margin of the pectoralis minor, by the union of two components, one from the medial and one from the lateral cord of the brachial plexus. The medial component passes obliquely across the third part of the axillary artery (fig. 786), and in the upper part of the trunk the fibers of the two components are felted together. From its commencement the median nerve runs almost vertically through the lower part of the axillary fossa and through the arm and forearm to the hand.

In the fossa it lies lateral to the axillary artery and it is overlapped, on its lateral side by the coracobrachialis muscle. In the upper half of the arm it lies along the lateral side of the brachial artery, and it is overlapped by the medial border of the biceps. At the mid...

e arm it passes in front of the brachial artery, and it descends, on the medial side of the y, to the elbow. In the upper part of the antecubital fossa it is still at the medial side of the ial artery, but separated from it by a small interval, and in the lower part of the fossa it lies the medial side of the ulnar artery. In case of the high division of the brachial artery, the radial and the ulnar arteries lie together in the upper arm, the median nerve may pass een them and then one or the other of the arteries will be superficial to the nerve. As ves the antecubital fossa it passes between the two heads of the pronator teres, and it es in front of the ulnar artery (fig. 790), from which it is separated by the deep head of the ator. In the forearm it passes vertically downward, accompanied by the median (comes mediani) artery. In the upper two-thirds of this region it lies deeply, between the flexor orum sublimis and the flexor digitorum profundus, but in the lower third it becomes more rficial, and is placed beneath the deep fascia, between the flexor carpi radialis on the radial

FIG. 792.—NERVES OF THE PALMAR SURFACE OF THE HAND. (Testut.)
transverse carpal (anterior annular) ligament, superficial volar arch, the flexor tendons of the digits, and the proximal portions of the lumbrical muscles have been removed.



nd the palmaris longus and flexor digitorum sublimus tendons on the ulnar side. It crosses ith the transverse carpal (anterior annular) ligament, in front of the flexor tendons, and palm at the lower border of the ligament it enlarges and divides into three branches, the non volar digital nerves (fig. 791).

Branches.—The median nerve does not supply any part of the upper arm. rarely, it may receive a small branch from the musculocutaneous nerve. ront of the elbow-joint it furnishes one or two filaments to that articulation. he forearm it supplies all the superficial anterior muscles (with the exception e flexor carpi ulnaris) directly from its trunk, and it supplies the deep muscles h the exception of the ulnar half of the flexor digitorum profundus) by its r (anterior) interosseous branch. Thus in general it supplies the pronator flexor muscles of the forearm (radial side). In the hand it supplies the p of short muscles of the thumb, which are placed on the radial side of

the tendon of the flexor pollicis longus, the two lateral lumbricales, the integument covering the central part of the palm and ulnar aspect of the thenar eminence, and the dorsal and palmar aspects of the first, second, third, and radial half of the fourth digits. The effects of paralysis of the median nerve are shown in fig. 1130 A.

The **nerve to the pronator teres** usually arises a little above the bend of the elbow, and pierces the lateral border of the muscle (figs. 790 and 792). It may arise in a common trunk with the following nerves:—

The nerves to the **flexor carpi radialis, palmaris longus,** and **flexor digitorum sublimis** arise a little lower down, and pierce the pronator-flexor mass of muscles to end in the respective members of the group for which they are destined (fig. 789).

The **volar (anterior, antibrachial) interosseous nerve** arises from the median at the level of the bicipital tubercle of the radius (fig. 790), and runs downward, on the interosseous membrane, accompanied by the volar (anterior) interosseous artery. It passes under cover of the pronator quadratus, and pierces the deep surface of that muscle, which it supplies. The volar interosseous nerve also furnishes a twig to the front of the wrist-joint, and supplies the flexor digitorum profundus and the flexor pollicis longus. The nerve to the former muscle arises from the volar interosseous near its commencement; it supplies the lateral two divisions of the muscle, and it communicates within the substance of the muscle with twigs derived from the ulnar nerve.

It also supplies a branch to the interosseous membrane which runs downward upon, or in, the membrane, supplying it and giving branches to the volar (anterior) interosseous and nutrient arteries and to the periosteum of the radius, the ulna, and the carpus.

The **palmar cutaneous branch** [ramus palmaris] arises immediately above the transverse carpal (anterior annular) ligament and passes between the tendons of the flexor carpi radialis and the palmaris longus (fig. 790). It then crosses the superficial surface of the transverse carpal ligament, and is distributed to the integument and fascia on the central, depressed surface of the palm. It also supplies a few twigs to the medial border of the thenar eminence; these twigs communicate with the musculocutaneous and superficial radial nerves.

The three **common volar digital nerves** pass in the palm of the hand dorsal to the superficial volar arch and its digital branches, while the **proper volar digitals,** branches of these nerves, lie on the volar side of the digital arteries.

The **first** of the common volar digital nerves gives off a branch to supply the abductor pollicis, the opponens, and the superficial head of the flexor pollicis brevis, and joins by a delicate branch with the deep branch of the ulnar nerve. It then divides into three **proper volar digitals** (fig. 792). The lateral of these passes obliquely across the long flexor tendon of the thumb and runs along the radial border of the thumb to its extremity. It gives numerous branches to the pulp of the thumb, and a strong twig which passes to the dorsum to supply the matrix of the nail. The second of these proper volar digitals supplies the medial side of the volar aspect of the thumb and gives off a twig to the matrix of the thumb nail. The third supplies the radial side of the second digit and gives a twig to the first lumbrical muscle.

The **second** common volar digital sends a twig to the second lumbrical muscle, and divides a little above the metacarpophalangeal articulation into two **proper volar digitals,** which respectively supply the adjacent sides of the second and third digits (fig. 791).

The **third** common volar digital communicates with the ulnar nerve, often gives a branch to the third lumbrical muscle, and divides into two **proper volar digitals** which supply the adjacent sides of the third and fourth digits.

As the proper volar digitals pass along the margins of the fingers they give off twigs for the innervation of the skin on the dorsum of the second and third phalanges and the matrix of their nails. Each of the nerves terminates in filaments to the pulp of the finger.

TABLE SHOWING RELATION OF CERVICAL AND THORACIC NERVES TO BRANCHES OF BRACHIAL PLEXUS

NERVES CONTRIBUTING	NERVES, BRANCHES OF PLEXUS
5 C.	Dorsal scapular (nerve to rhomboids)
	Nerve to subclavius
5 and 6 C.	Suprascapular
	Nerve to subclavius
	Upper subscapular
	Lower subscapular
	Axillary (circumflex)
5, 6, and 7 C.	Long (posterior) thoracic
	Lateral anterior thoracic.
5, 6 (and 7) C.	Musculocutaneous
(5), 6, 7, 8 C.	Radial (musculospiral)
(5), 6, 7, 8 C and 1 T.	Median
7 and 8 C.	Thoracodorsal (middle or long subscapular)
8 C. and 1 T.	Medial anterior thoracic
	Ulnar
	Medial antibrachial (internal) cutaneous
1 T.	Medial brachial (lesser internal) cutaneous

TABLE SHOWING THE RELATIONS OF THE CERVICAL NERVES TO THE MUSCLES OF THE UPPER EXTREMITY

NERVES CONTRIBUTING	MUSCLES	NERVES TO MUSCLES
Accessory, 2 C.....	Sternomastoid	Spinal accessory
Accessory, 3, 4 C...	Trapezius	Spinal accessory, 3 and 4 C.
3 and 4 C.....	Levator scapulæ	3 and 4 C.
5 and 6 C.....	Subclavius	Nerve to subclavius
	Supraspinatus	Suprascapular
	Infraspinatus	Suprascapular
	Subscapularis	Upper and lower subscapular
	Teres major	Lower subscapular
	Teres minor	Axillary (circumflex)
	Deltoid	Axillary (circumflex)
	Brachialis	Musculocutaneous
	Biceps	Musculocutaneous
6 C..	Brachioradialis	Radial (musculospiral)
	Supinator	Deep radial (posterior interosseous)
	Pronator teres	Median
	Flexor carpi radialis	Median
	Palmaris longus	Median
6 and 7 C.....	Ext. carpi radialis longus	Radial (musculospiral)
	Ext. carpi radialis brevis	Deep radial (posterior interosseous)
	Abductor pollicis brevis	Median
	Opponens pollicis	Median
	Flexor pollicis brevis (superf. head)	Median
5, 6 and 7 C.....	Serratus anterior	Long (posterior) thoracic
7 C	Coracobrachialis	Musculocutaneous
	Ext. digitorum comm.	Deep radial (posterior interosseous)
	Ext. digiti quinti proprius	Deep radial (posterior interosseous)
	Ext. carpi ulnaris	Deep radial (posterior interosseous)
	Abductor pollicis longus	Deep radial (posterior interosseous)
	Extensor pollicis brevis	Deep radial (posterior interosseous)
	Extensor pollicis longus	Deep radial (posterior interosseous)
	Ext. indicus proprius	Deep radial (posterior interosseous)
7 and 8 C.....	Latissimus dorsi	Thoracodorsal (long subscapular)
	Triceps	Radial (musculospiral)
	Anconeus	Radial (musculospiral)
5, 6, 7 and 8 C.....	Pectoralis major	Lat. and med. ant. thoracic
8 C.	Dorsal interosseus	Ulnar
	Volar interosseus	Ulnar
	Add. pollicis	Ulnar
	Add. pollicis trans.	Ulnar
	Flex. pollicis brev. (deep)	Ulnar
7, 8 C and 1 T.....	Pectoralis minor	Med. ant. thoracic
	Flex. digit. subl.	Median
	Lumbricalis	Median and ulnar
8 C. and 1 T.....	Flex. carpi ulnaris	Ulnar
	Flex. digit. prof.	Ulnar and median
	Flex. pollicis long.	Median
	Pronator quadratus	Median

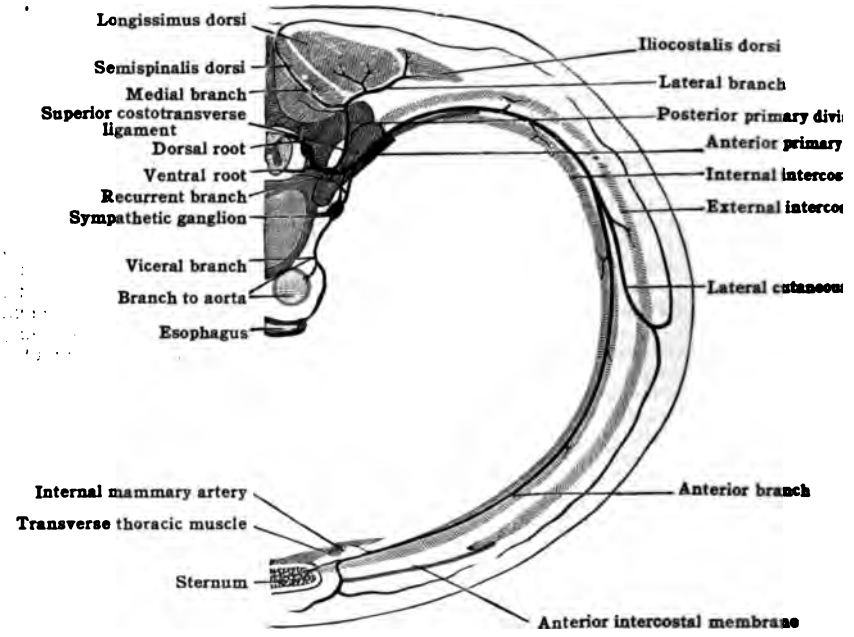
2. THE THORACIC NERVES

The **anterior primary divisions of the thoracic nerves,** with the exception of the first and usually the twelfth, retain, in the simplest form, the characters of anterior primary divisions of the typical spinal nerve. They do not form plexuses, but remain distinct from each other. Each divides into an easily recognizable lateral or dorsal and anterior or ventral branch (figs. 793 and 794), and they are not distributed to the limbs. The first, second, and last thoracic nerves, on account of their peculiarities, require separate description. The remainder are separable into two groups, an upper and a lower. The **upper group** consists of four nerves, the third to the sixth inclusive, which are distributed entirely to the thoracic wall. The **lower group** contains five nerves, the seventh to the eleventh inclusive, which are distributed partly to the thoracic and partly to the abdominal wall. The upper group is therefore purely thoracic in distribution, and the lower thoracoabdominal. All the thoracic nerves are connected with the smpathetic trunk by means of both white and gray rami communicantes.

The first thoracic nerve is connected with the first thoracic sympathetic ganglion, and it frequently is joined by a small branch with the second nerve (fig. 785). Its anterior primary division is distributed chiefly to the upper limb. Opposite

The **second thoracic nerve,** as it lies between the pleura and the costotransverse ligament of the third rib, gives a branch to the first ne it pierces the posterior intercostal membrane and passes between the ext

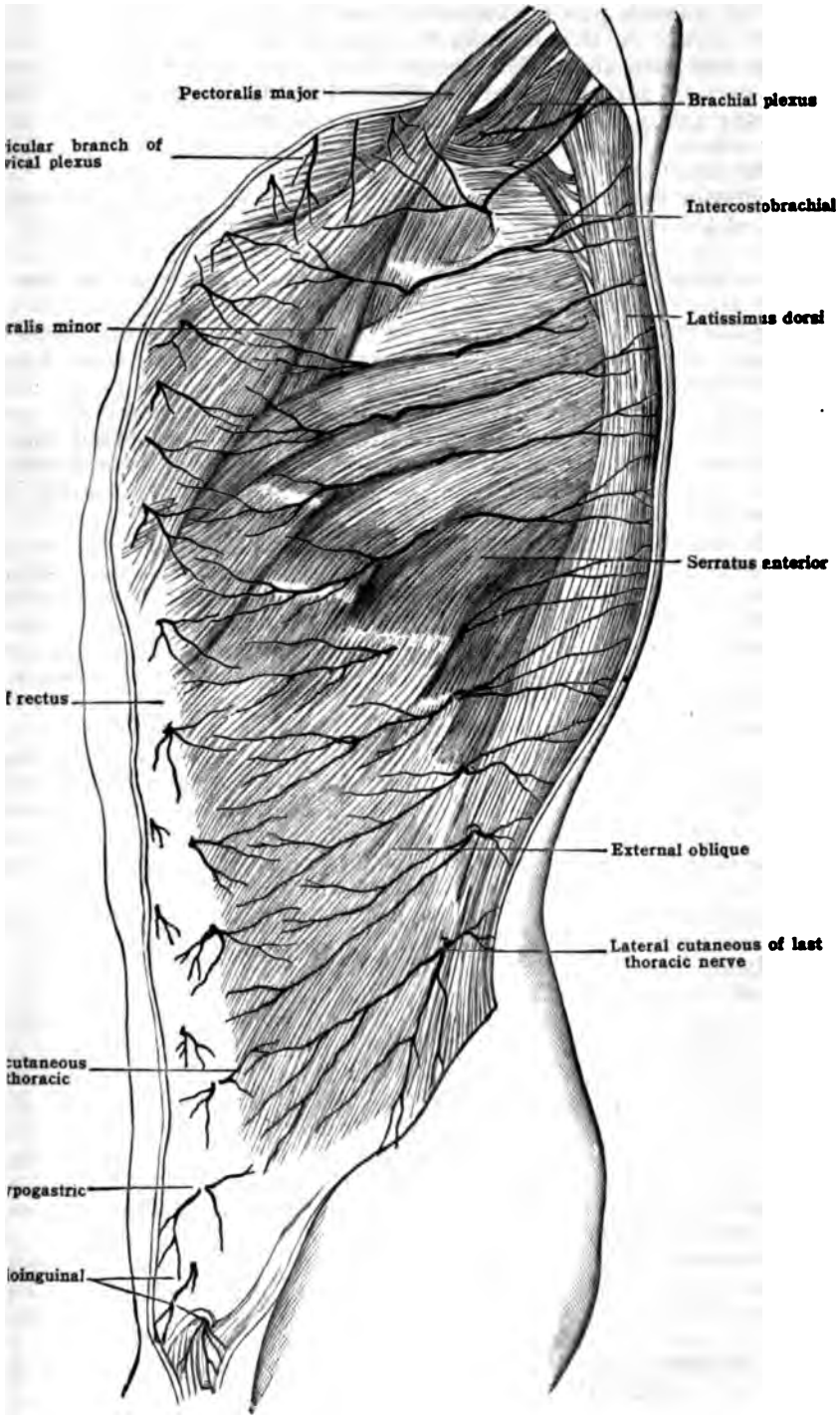
FIG. 793.—DIAGRAM OF THE DISTRIBUTION OF A TYPICAL THORACIC NER



internal intercostal muscles in the second intercostal space. In the do of the space it sends branches backward, through the external intercosta to supply the second levator costæ and the serratus posterior superior, it divides into a *lateral* and an *anterior* branch (fig. 793). The two bra forward together to the midaxillary line, where the lateral branch pi external intercostal muscle and passes between two digitations of the

thoracic intercostal nerves (upper group).—The anterior primary divi- the third, fourth, fifth, and sixth thoracic nerves, in the posterior parts

.—CUTANEOUS NERVES OF THE THORAX AND ABDOMEN, VIEWED FROM THE SIDE. (After Henle.)



ıtercostal spaces, give **muscular branches** to the levatores costarum, the he fourth also giving branches to the serratus posterior superior. They ward a short distance between the external and internal intercostals,

giving twigs to these muscles, and divide into two branches, lateral and anterior (figs. 793, 794).

The **lateral cutaneous branches** continue forward between the intercostal muscles, and, near the midaxillary line, pierce the external intercostals and serratus anterior and divide each into two branches, posterior and anterior. The *posterior branches* pass backward over the latissimus dorsi to supply the skin in the lower part of the scapular region. The *anterior branches*, in the four nerves, increase in size from above downward. They pass around the lateral border of the great pectoral muscle and are distributed to the integument over the front of the thorax and mamma, sending filaments, the *lateral mammary branches*, into the latter organ. The lowest two nerves also supply twigs to the upper digitations of the external oblique muscle.

The **anterior branches** run obliquely forward and medialward through the substance of the internal intercostal muscles, reaching the deep surface of these muscles at the extremity of the costal cartilages (fig. 793). They continue forward between these muscles and the pleura, pass in front of the internal mammary artery, turn abruptly ventralward a short distance from the sternum, pierce the internal intercostals, the anterior intercostal membrane, and the pectoralis major, and give off three sets of terminal branches. One set supplies the transverse thoracic muscle and the back of the sternum. A second set, cutaneous, runs mesially. The third set passes laterally over the pectoralis major, supplying the skin in that region, and, in the female, the mammary gland through the **medial mammary branches.** The anterior branches in their course supply the intercostal and subcostal muscles and give filaments that supply the ribs, the periosteum, and the pleura.

The thoracoabdominal nerves (lower group).—The relations of the posterior portions of the anterior primary divisions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves to the thoracic wall are similar to those of the upper thoracic intercostal nerves. Each divides in a similar manner into a *lateral* and an *anterior* branch, but these branches are distributed partly to the abdominal and partly to the thoracic wall, and the smaller muscular branches have also different distributions (fig. 794).

The **lateral cutaneous branches,** *lateral cutaneous nerves of the abdomen,* pierce the external intercostal muscles and pass through or between the digitations of the external oblique into the subcutaneous tissue, where they divide in the typical way into anterior and posterior branches. The *posterior branches* pass backward over the latissimus dorsi. The *anterior branches* give filaments to the digitations of the external oblique and extend forward, medialward and downward to the lateral border of the sheath of the rectus.

The **anterior cutaneous branches** pass forward between the external and internal intercostal muscles, to the ends of the intercostal spaces; there they insinuate themselves between the interdigitating slips of the diaphragm and the transversus abdominis and enter the abdominal wall. Those of the seventh, eighth, and ninth nerves, in their transit from the thoracic to the abdominal wall, pass behind the upturned ends of the eighth, ninth, and tenth costal cartilages respectively. Having entered the abdominal wall the nerves run forward between the transversus abdominis and the internal oblique muscles to the lateral border of the rectus abdominis, where they pierce the posterior lamella of the internal oblique aponeurosis and enter the sheath of the rectus. In the sheath they pass through the substance of the rectus. Finally they turn directly forward, pierce the anterior part of the sheath, and become **anterior cutaneous nerves of the abdomen.**

The muscular branches.—Muscular branches from all the thoracoabdominal nerves are distributed to the levatores costarum, the intercostal muscles, the transversus abdominis, the internal oblique, and to the rectus abdominis, and the ninth, tenth, and eleventh nerves gives branches also to the serratus posterior inferior. Branches are also distributed from a variable number of the lower nerves to the costal portions of the diaphragm.

The last thoracic nerve. - The anterior primary division of the last thoracic nerve is distributed to the wall of the abdomen and to the skin of the upper and front part of the buttock (fig. 794). It appears in the thoracic wall immediately below the last rib, where a ramus joins it with the sympathetic trunk, and gives off

a communicating branch to the first lumbar nerve. It passes from the thorax into the abdomen beneath the lateral lumbocostal arch (external arcuate ligament), accompanied by the subcostal artery, and it runs across the upper part of the quadratus lumborum, dorsal to the kidney and to the ascending or the descending colon according to the side considered. At the lateral border of the quadratus lumborum it pierces the aponeurosis of attachment of the transversus abdominis muscle and divides, between the transversus and the internal oblique muscle, into a *lateral* and an *anterior* branch. It gives branches to the transversus abdominis, the quadratus lumborum, and the internal oblique muscles.

The **anterior branch** passes forward, between the internal oblique and the transversus abdominis, to which it supplies twigs. It enters the sheath of the rectus, turns forward through that muscle, and terminates in branches which become cutaneous midway between the umbilicus and the symphysis. Before it becomes cutaneous it supplies twigs to the transversus abdominis, the internal oblique, the rectus abdominis, and the pyramidalis muscles.

The **lateral branch** pierces the internal oblique; it supplies the lowest digitation of the external oblique, and then pierces the latter muscle from 2.5 to 8 cm. (1 to 3 in.) above the iliac crest, and descends in the superficial fascia of the anterior part of the gluteal region, crossing the iliac crest about 2.5 cm. (1 in.) behind its anterior extremity, reaching as far down as the level of the great trochanter. Occasionally this branch is absent and its place is taken by the iliac branch of the iliohypogastric. In such cases, however, the branch from the last thoracic to the first lumbar nerve is larger than usual.

THE LUMBOSACRAL PLEXUS

The lumbosacral plexus (fig. 795) is formed by the union of the *anterior primary divisions* of the lumbar, sacral, and coccygeal nerves. In about 50 per cent. of cases it receives a branch from the twelfth thoracic nerve. Its components are distributed to the lower extremity in a manner homologous and similar to the distribution of the parts of the brachial plexus to the upper extremity; the lumbar nerves are distributed similarly to the nerves formed from the anterior (medial and lateral) cords of the brachial plexus, and the sacral nerves are distributed in a manner similar to the distribution of the nerves from the posterior cord of the brachial plexus.

Partly for convenience of description and partly on account of the differences in position and course of some of the nerves arising from it, this plexus is subdivided into four parts—the lumbar, sacral, pudendal, and coccygeal plexuses. These plexuses overlap so that there is no definite line of demarcation between them in origin and distribution. However, they will be considered separately.

3. THE LUMBAR NERVES

The anterior primary divisions of the five lumbar nerves increase in size from the first to the last. Each lumbar nerve is connected by one or two long, slender rami with a lumbar sympathetic ganglion. The first three nerves and the greater part of the fourth enter into the formation of the lumbar plexus, and the smaller part of the fourth and the fifth nerve commonly unite to form the lumbosacral trunk which takes part in the formation of the sacral plexus (figs. 795, 796). When the fourth nerve enters into the formation of both lumbar and sacral plexuses, it may be called the *furcal nerve*, but this name is also applied to any of the nerves that enter into the formation of both plexuses, so there may be one or more furcal nerves.

THE LUMBAR PLEXUS

Although the **lumbar plexus** is ordinarily formed by the anterior primary divisions of the first three lumbar nerves and a part of the fourth, yet it is subject to considerable variation in the manner of its formation.

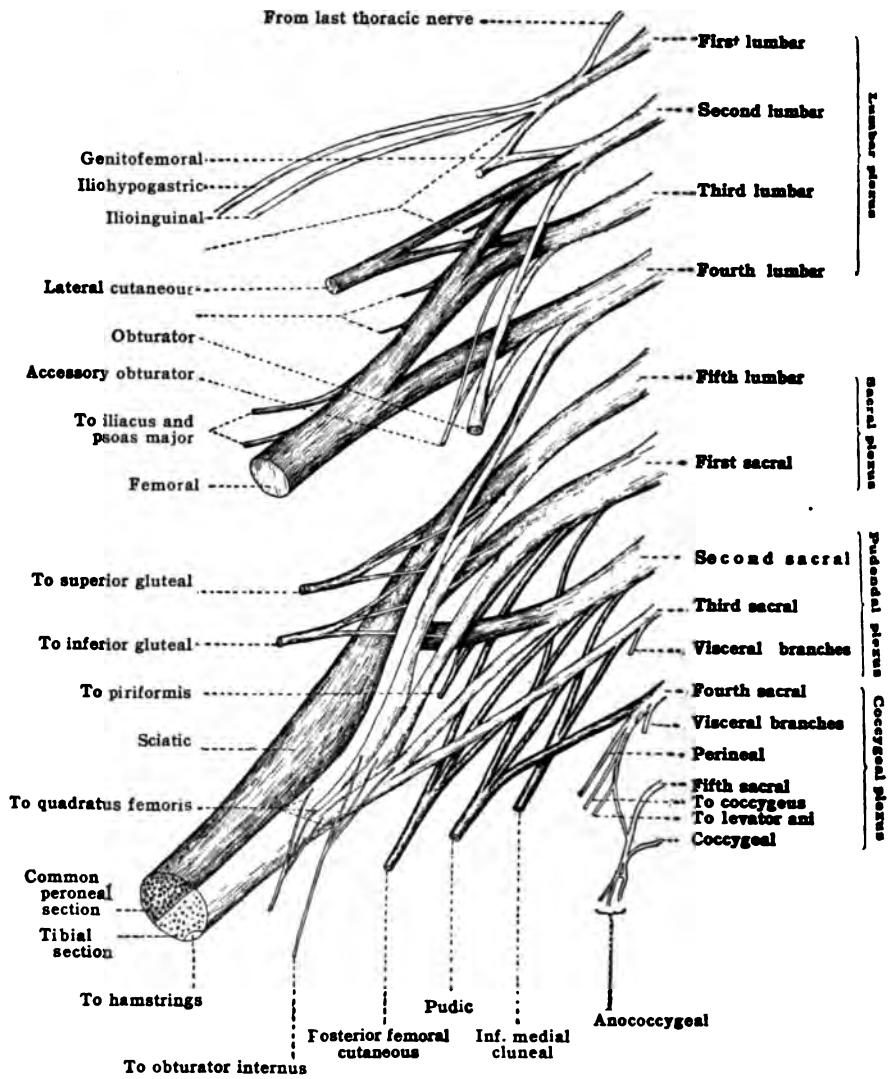
Owing to this variation three general classes of plexuses may be found, **prefixed** (proximal), **ordinary**, and **postfixed** (distal). The basis of classification is the relation of the nerves of the limb to the spinal nerves which enter into their formation. The intermediate or slighter degrees of variation may consist only of changes in the size of the portions contributed by the different spinal nerves to a given peripheral nerve, for a given nerve may receive a larger share of its fibers from a spinal nerve more anterior (cephalad) in position, and a smaller share from a more posterior nerve, or *vice versa*. However, in the more marked degrees of variation the origin of a given peripheral nerve may vary in either direction to the extent of one spinal nerve. The

more extreme types of the plexuses are sometimes associated with abnormal conditions of the vertebral column. It has been suggested that when the prefixed condition occurs, it indicates that the lower limb is placed a segment more cephalad than in the ordinary cases, and when the postfixed condition is present, that the limb is arranged a segment more caudad. Three types each of the prefixed classes and one type of the ordinary class have been described by Bardeen. His statistics are made use of in the compilation of the following tables, in which are shown the common composition and the range of variation of each class of plexus:—

COMMON COMPOSITION (RANGE IN PARENTHESIS)

NERVE	PREFIXED	ORDINARY	POSTFIXED
Lateral (external) cutaneous	1, 2 L (12T–3L)	1, 2, 3 L (1–4L)	2, 3 L (1–4L)
Femoral (anteror crural)....	1, 2, 3, 4 L (12T–4L)	2, 3, 4 L (1–4L)	2, 3, 4, 5 L (1–5L)
Obturator.....	1, 2, 3, 4 L	2, 3, 4 L (1–4L)	2, 3, 4 L (2–5L)
Furcal.....	4 L (3–4L)	4 L	4 L (4–5L)

FIG. 795.—DIAGRAM OF A COMMON FORM OF LUMBOSACRAL PLEXUS. (Modified from Paterson.)



The lumbar plexus lies in the posterior part of the psoas muscle (figs. 7[illegible] 796, 800), in front of the transverse processes of the lumbar vertebræ and t medial border of the quadratus lumborum, and its terminal branches are d tributed to the lower part of the abdominal wall, the front and medial part of t thigh, the external genital organs, the front of the knee, the medial side of the l and the medial side of the foot.

The first and second of the lumbar nerves give collateral *muscular branches* to the quadratus lumborum muscle, and the second the third nerves give similar branches to the psoas. The remaining branches of the plexus are *terminal branches*. The first lumbar nerve, after it has been joined by the branch from the last thoracic nerve, divides into three terminal branches, the iliohypogastric nerve, the ilioinguinal nerve, and a branch which joins the second nerve. The fibers of this latter branch pass mainly into the genitofemoral (genitocrural) nerve, but occasionally some of them enter the femoral (anterior crural) and obturator nerves. The remaining nerves divide into anterior or ventral and posterior or dorsal divisions. The **anterior divisions** form a portion of the genitofemoral (genitocrural) nerve and the obturator nerve, and the **posterior divisions** enter the lateral (external) cutaneous and femoral (anterior crural) nerves.

All the terminal branches of the plexus are formed in the substance of the psoas muscle; four of them, the iliohypogastric, the ilioinguinal, the lateral (external) cutaneous, and the femoral (anterior crural), leave the muscle at its lateral border. The genitofemoral (genitocrural) passes through its anterior surface, and the obturator through its medial border.

Terminal branches.—The **iliohypogastric nerve** springs from the first lumbar nerve, after the latter has been joined by the communicating branch from the last thoracic nerve, as it is in about 50 per cent. of the cases, and it thus contains fibers of both the last thoracic and the first lumbar nerves. It pierces the lateral border of the psoas and crosses in front of the quadratus lumborum (fig. 796), and behind the kidney and the colon. At the lateral border of the quadratus it pierces the aponeurosis of origin of the transversus abdominis and enters the areolar tissue between the transversus and the internal oblique, where it frequently communicates with the last thoracic and with the ilioinguinal nerve, and it divides into an iliac and a hypogastric branch, which correspond, respectively, with the lateral and anterior branches of a typical spinal nerve.

The **anterior cutaneous (hypogastric) branch** passes forward and downward, between the transversus abdominis and the internal oblique muscles, giving branches to both; it communicates with the ilioinguinal nerve, and, near the anterior superior spine of the ilium, it pierces the internal oblique muscle and continues forward beneath the external oblique aponeurosis toward the middle line. About 2.5 cm. above the subcutaneous inguinal ring it pierces the aponeurosis of the external oblique, becomes subcutaneous, and supplies the skin above the symphysis.

The **lateral cutaneous (iliac) branch** pierces the internal and external oblique muscles, emerging through the latter above the iliac crest at the junction of its anterior and middle thirds (fig. 800). It is distributed to the integument of the upper and lateral part of the thigh, in the neighborhood of the gluteus medius and tensor fasciæ latæ muscles (fig. 799).

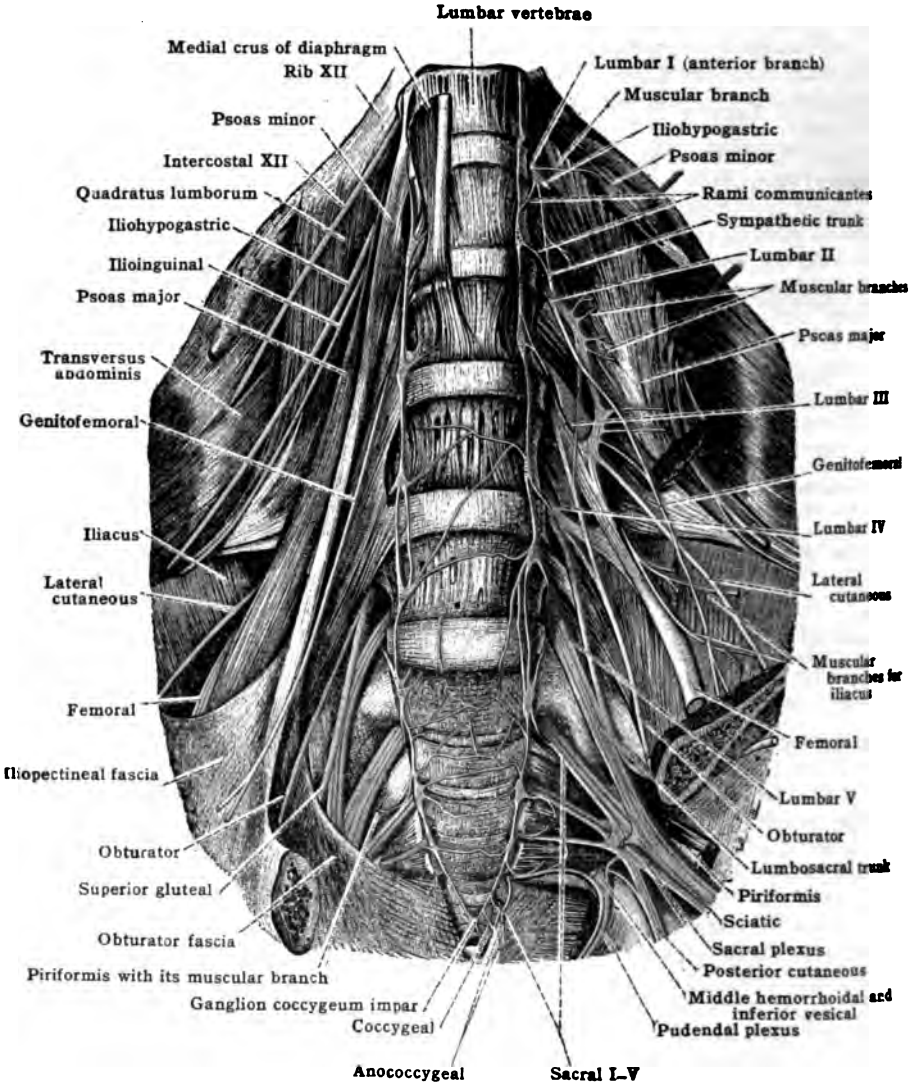
The **ilioinguinal nerve** arises principally from the first lumbar nerve, but it frequently contains fibers of the last thoracic nerve. It emerges from the lateral border of the psoas, at a lower level than the iliohypogastric nerve, and passes across the quadratus lumborum (figs. 796, 797). As a rule, it is below the level of the inferior end of the kidney, but it passes dorsal to the ascending or the descending colon according to the side considered, and crosses the posterior part of the inner lip of the iliac crest; it then runs forward on the upper part of the iliacus, pierces the transversus abdominis near the anterior part of the crest, and communicates with the anterior cutaneous (hypogastric) branch of the iliohypogastric nerve. A short distance below the anterior superior spine it passes through the internal oblique muscle, and then descends in the inguinal canal to the subcutaneous inguinal (external abdominal) ring, through which it emerges into the thigh on the lateral side of the spermatic cord (fig. 794). It is distributed to the skin of the upper and medial part of the thigh, in the male to the root of the penis and to the skin of the root of the scrotum through the **anterior scrotal nerves** (fig. 799), and in the female to the mons veneris and labium majus through the **anterior labial nerves.**

Not uncommonly the ilioinguinal nerve is blended with the iliohypogastric nerve and separates from the latter between the transversus abdominis and the internal oblique muscles. It may be replaced by branches of the genitofemoral (genitocrural) nerve, or it may replace that nerve or the lateral femoral cutaneous nerve.

The **genitofemoral (genitocrural) nerve** is connected with the first and second lumbar nerves, but the majority of its fibers are derived from the second nerve. It passes obliquely forward and downward through the psoas and emerges from

the anterior surface of that muscle, close to its medial border, at the level of the lower border of the third lumbar vertebra. After emerging from the substance of the psoas it runs downward on the anterior surface of the muscle (fig. 796), to the lateral side of the aorta and the common iliac artery, passes behind the ureter and divides into two branches, an external spermatic and a lumboinguinal (fig. 797). Occasionally it divides in the substance of the psoas, and then the two branches issue separately through the anterior surface of the muscle.

FIG. 796.—LUMBOSACRAL PLEXUS. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

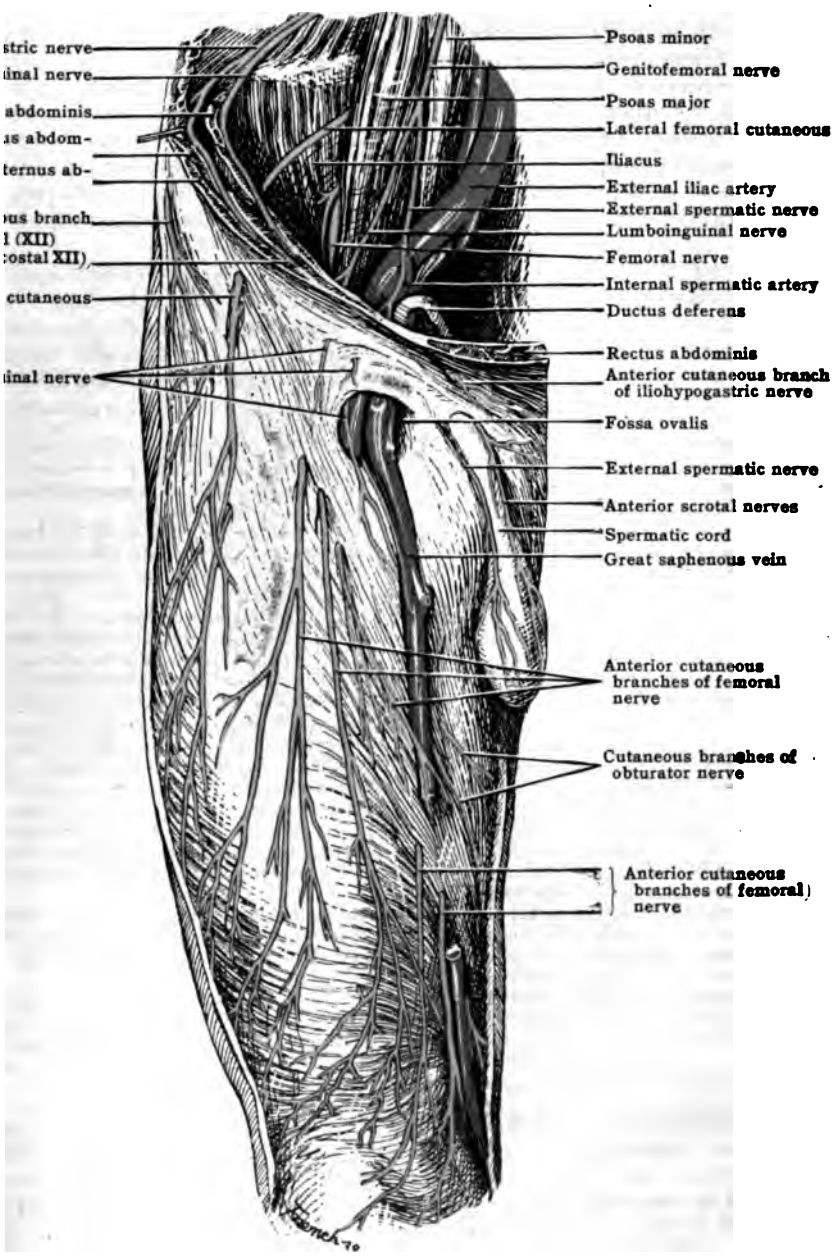


The **external spermatic** (genital) branch runs downward on the psoas muscle, external t the external iliac artery; it gives a branch to the psoas, and at Poupart's ligament it turn around the inferior epigastric artery and enters the inguinal canal, accompanying the spermat cord in the male or the round ligament in the female. It supplies the cremaster muscle, an gives twigs to the integument of the scrotum (fig. 797) or the labium majus.

The **lumboinguinal** (crural) branch passes downward along the external iliac artery an beneath Poupart's ligament into the thigh, which it enters to the lateral side of the femor artery. A short distance below Poupart's ligament it pierces the fascia lata or passes throu the fossa ovalis (saphenous opening) and supplies the skin in the middle of the upper part of t thigh. A short distance below Poupart's ligament it sometimes sends branches to the anteri branch of the lateral cutaneous nerve, and about the middle of the thigh it often joins with t cutaneous branches of the femoral (anterior crural) nerve.

ral femoral cutaneous nerve receives fibers from the dorsal branches of r primary divisions of the second and third lumbar nerves, and fre- ne fibers from the first lumbar (fig. 800). It emerges from the lateral e psoas and passes obliquely across the iliacus, dorsal to the iliac fascia o the cecum on the right side and the sigmoid colon on the left side, to

797.—Cutaneous Nerves of the Right Thigh. (After Spalteholz.)
(The iliac fascia has been removed, the fascia lata retained.)



ediately below the anterior superior spine of the ilium, where it passes art's ligament into the lateral angle of the femoral trigone (Scarpa's eaving the trigone at once it passes through, behind, or in front of s and divides into two branches, anterior and posterior, which enter cia (figs. 797, 799).

rior branch of the lateral cutaneous nerve breaks up into several secondary h become subcutaneous, and they supply the integument of the lateral part of the

thigh, from the great trochanter to the level of the middle of the femur. The anterior branch runs downward in a canal in the deep fascia, for three or four inches, before it becomes subcutaneous. It usually divides into two branches, a lateral and a medial. The *lateral branch* supplies the skin of the lower half of the lateral side of the thigh, and the *medial branch* is distributed to the skin of the lateral side of the front of the thigh as far as the knee (fig. 797). Its lower filaments frequently unite with the cutaneous branches of the femoral and with the patellar branch of the saphenous nerve in front of the patella, forming with them the **patellar plexus.**

The **femoral** (anterior crural) **nerve** is the largest terminal branch of the lumbar plexus. It is formed chiefly by fibers of the dorsal branches of the anterior primary divisions of the second, third, and fourth lumbar nerves, but it sometimes receives fibers from the first nerve also (figs. 796 and 800). It emerges from the lateral border of the psoas a short distance above Poupart's ligament, and descends in the groove between the psoas and the iliacus, behind Poupart's ligament, into the femoral trigone (Scarpa's triangle), where it lies to the lateral side of the femoral artery (figs. 798, 1142), from which it is separated by some of the fibers of the psoas. In this situation it is flattened out and it divides into two series of terminal branches, the superficial and the deep. In general, they supply the muscles and skin on the anterior aspect of the thigh.

Branches.—The branches of the femoral nerve are collateral and terminal.

The **collateral branches** are twigs of supply to the iliacus, and a branch to the femoral artery; they are given off before the nerve enters the femoral trigone.

The **terminal branches** form two groups, the superficial and the deep.

The **superficial terminal branches** are two muscular branches, the nerve to the pectineus, and the nerve to the sartorius, and two anterior cutaneous branches.

The **nerve to the pectineus** passes medially and downward behind the femoral sheath and in front of the psoas to the anterior surface of the pectineus, in which it terminates.

The **nerve to the sartorius** accompanies the middle cutaneous nerve; it leaves the latter nerve above the sartorius and ends in the upper part of the muscle.

The **anterior (middle and internal) cutaneous nerves** (branches of the femoral) are best described separately. The **middle cutaneous nerve** soon divides into two branches, medial and lateral. The lateral branch pierces the sartorius and both branches become cutaneous about the junction of the upper and middle thirds of the thigh (figs. 797, 799). They descend along the medial part of the front of the thigh to the knee, supplying the skin in the lower two-thirds of the medial part of the front of the thigh, and their terminal filaments take part in the formation of the patellar plexus. About the middle of the thigh the middle cutaneous is often joined by a twig with the lumboinguinal nerve (crural branch of the genitocrural nerve). The **medial (or internal) cutaneous nerve** runs downward and medialward along the lateral side of the femoral artery, to the apex of the femoral trigone (Scarpa's triangle), where it crosses in front of the artery and divides into an anterior and a posterior terminal branch. Before this division takes place, however, two or three collateral branches are given off from the trunk. The highest of these passes through the fossa ovalis (saphenous opening), or it pierces the deep fascia immediately below the opening, and supplies the skin as low as the middle of the thigh. The lowest pierces the deep fascia at the middle of the thigh and it descends in the subcutaneous tissue, supplying the skin on the medial side of the thigh from the middle of the thigh to the knee (figs. 799, 800). This nerve frequently varies in size inversely with the cutaneous branches of the obturator and saphenous nerves.

The **anterior branch** of the medial cutaneous nerve passes vertically downward to the junction of the middle and lower thirds of the thigh, where it pierces the deep fascia. It still continues downward for a short distance, then it turns lateralward and passes to the front of the knee, where it enters into the patellar plexus.

The **posterior branch** descends along the dorsal border of the sartorius, and it gives off a branch which passes beneath that muscle to unite with twigs from the saphenous and from the superficial division of the obturator nerve, forming with them the **subsartorial plexus** which lies on the roof of the adductor (Hunter's) canal. At the medial side of the knee the nerve pierces the deep fascia and it descends to the middle of the calf (figs. 797, 799).

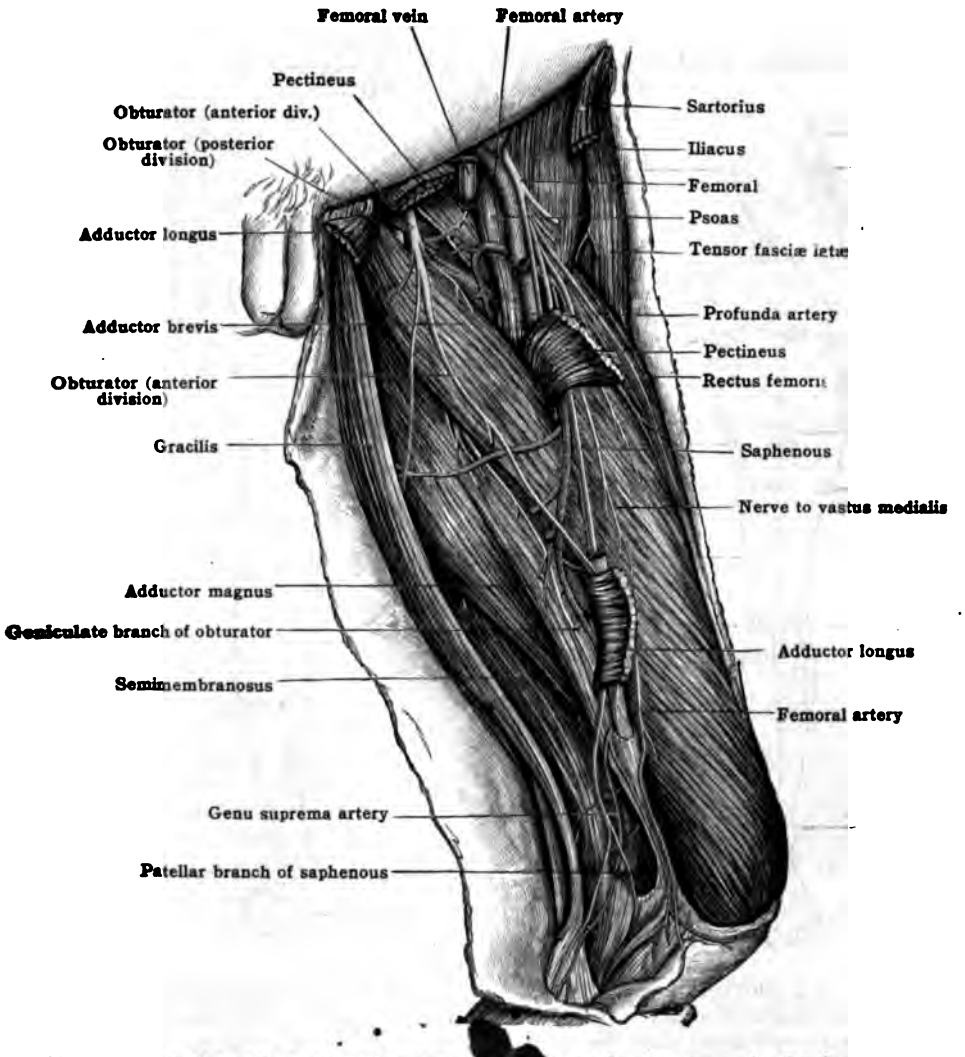
The **deep terminal branches** of the femoral nerve are six in number, one cutaneous branch, the *saphenous*, and five *muscular branches*. The branches radiate from the termination of the trunk of the femoral nerve, and they are arranged in the following order from medial to lateral:—the saphenous nerve, the nerve to the vastus medialis, the nerve to the articularis genu (subcrureus), the nerve to the vastus intermedius (crureus), the nerve to the vastus lateralis, and the nerve to the rectus femoris.

The **saphenous nerve** passes down through Scarpa's triangle along the lateral side of the femoral artery. At the apex of the triangle it enters the adductor (Hunter's) canal and descends through it, lying first to the lateral side, then in front, and finally to the medial side of the artery (fig. 798). After emerging from the lower end of the canal, accompanied by the superficial branch of the genu suprema (anastomotic) artery, it passes between the dorsal border of the sartorius and the anterior border of the tendon of the gracilis, and, becoming superficial, it

[redacted]rs into relationship with the great saphenous vein and descends with it along the inner bor-[redacted] of the upper two-thirds of the tibia (fig. 799). It crosses the medial surface of the lower [redacted]d of the tibia, passes in front of the internal malleolus, and runs forward along the medial [redacted]der of the foot to the ball of the great toe.

While it is in the adductor (Hunter's) canal it gives off a twig to the subsartorial plexus. [redacted]fore it passes from under cover of the sartorius it gives off an infrapatellar branch, which [redacted]rces the sartorius just above the knee and passes outward to the patellar plexus. After it [redacted]comes superficial it supplies the integument on the medial side of the leg and foot, and it [redacted]stomoses, in the foot, with the medial dorsal cutaneous branch of the superficial peroneal [redacted]usculocutaneous) nerve.

FIG. 798.—FEMORAL AND OBTURATOR NERVES. (Ellis.)



The **nerve to the vastus medialis** accompanies the saphenous nerve in the femoral trigone (**Scarpa's triangle**), lying to its outer side. At the upper end of the adductor canal it passes beneath the sartorius, external to the roof of the canal, and enters the medial surface of the vastus medialis. It sends a twig down to the knee-joint.

The **nerve to the articularis genu** (subcrureus), usually a terminal branch of the femoral, frequently arises from the nerve to the vastus intermedius. It passes between the vastus medialis and the vastus intermedius to the lower third of the thigh, where it supplies the articularis genu and sends a branch to the knee-joint.

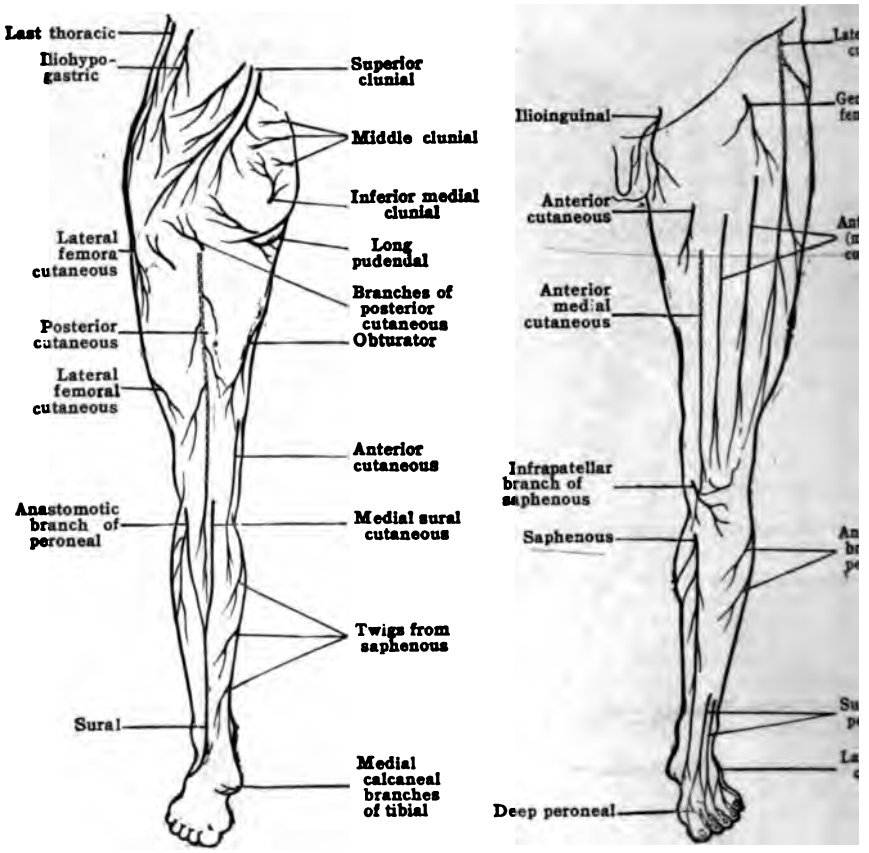
The **nerve to the vastus intermedius** (crureus) is represented by two or three branches which enter the upper part of the muscle. One of them frequently sends a twig to the knee-joint.

The **nerve to the vastus lateralis** passes downward behind the rectus and along the anterior border of the vastus lateralis accompanied by the descending branch of the lateral circumflex artery. It also sends a branch to the knee-joint.

The **nerve to the rectus femoris** (fig. 798) enters the deep surface of that muscle, having previously given off a twig to the hip-joint which accompanies the ascending branch of the external circumflex artery.

The **obturator nerve** contains fibers from the anterior primary division second, third, and fourth lumbar nerves, but its largest root is derived fr third nerve (figs. 796, 800). It sometimes receives fibers from the first nerve. It emerges from the medial border of the psoas at the dorsal part brim of the pelvis, where it lies in close relation with the lumbosacral trunk plexus, from which it is separated by the iliolumbar artery. Immediatel its exit from the psoas it pierces the pelvic fascia, crosses the lateral side internal iliac vessels and the ureter, and runs forward in the extraperiton below the obliterated hypogastric artery and along the upper part of the surface of the obturator internus to the upper part of the obturator fo where it passes through the obturator canal below the so-called horizonta

FIG. 799.—DISTRIBUTION OF CUTANEOUS NERVES ON THE POSTERIOR AND ANTERIOR OF THE INFERIOR EXTREMITY.



of the pubis and above the obturator membrane, into the upper part of t It is accompanied in the pelvis and the obturator canal by the obturato which lies at a lower level than the nerve and it divides in the obturator c two branches, an anterior and a posterior, which supply the adductor muscles, the hip and knee-joints, and the skin on the medial aspect of

The **anterior branch** of the obturator has a twig joining it with the a obturator nerve, if that nerve is present, and then descends behind the p and adductor longus and in front of the obturator externus and adducto muscles (fig. 798). Its branches are:-

1. A **twig** to the accessory obturator nerve if the latter is present.
2. An **articular branch** to the hip-joint.
3. **Muscular branches** to the gracilis, adductor longus, and, usually, to the addue
4. Two **terminal branches**, of which one is distributed to the femoral artery and communicates with the subsartorial plexus. The *subsartorial branch* is occasions than usual, and it then descends, along the dorsal border of the sartorius, to the me the knee, where it enters the subcutaneous tissue, and supplies the skin on the medial leg as far as the middle of the calf. Twigs join it with the saphenous nerve.

The **posterior branch** of the obturator (fig. 798) pierces the upper part of the obturator externus and passes downward between the adductor brevis and adductor magnus. Its branches are:—

1. **Muscular branches** to the obturator externus, to the oblique fibers of the adductor magnus and to the adductor brevis when the latter is not entirely supplied by the anterior branch. The branch to the obturator externus is given off in the obturator canal.

2. An **articular branch** to the knee-joint which appears in some cases to be the continuation of the trunk of the posterior branch (fig. 798). It either pierces the lower part of the adductor magnus, or it passes through the opening for the femoral artery. In the popliteal space it descends on the popliteal artery to the back of the joint, where it pierces the posterior ligament, and its terminal filaments are distributed to the crucial ligaments and the structures in their immediate neighborhood. This branch is not uncommonly absent. Occasionally the posterior branch of the obturator nerve also supplies a twig to the hip-joint.

The **accessory obturator nerve** arises from the third or fourth or from the third and fourth lumbar nerves, in the angles between the roots of the femoral (anterior crural) and obturator nerves. It is present in about 29 per cent. of all cases (Eisler). It is often closely associated with the obturator nerve to the level of the brim of the pelvis, but instead of passing through the obturator foramen, it descends along the medial border of the psoas, crosses the anterior part of the brim of the pelvis, passes beneath the pectineus, and terminates in three main branches. One of these branches joins the anterior division of the obturator nerve, another supplies the pectineus, and the third is distributed to the hip-joint.

The Lumbosacral Trunk

The trunk of the plexus usually formed by the union of the smaller part of the fourth and the entire fifth lumbar nerves is called the **lumbosacral trunk** (figs. 796, 800). Sometimes the larger part of the fourth nerve may help to form the trunk. It may receive fibers from the third lumbar nerve or be formed entirely from the fifth. At its formation it is situated on the ala of the sacrum under cover of the psoas. It descends into the pelvis, and, as it crosses the anterior border of the ala of the sacrum, it emerges from beneath the psoas at the medial side of the obturator nerve, from which it is separated by the iliolumbar artery. It passes behind the common iliac vessels and unites with the first and second sacral nerves, forming with them the upper trunk of the sacral plexus.

4. SACRAL NERVES

The anterior primary divisions of the upper four sacral nerves enter the pelvis through the anterior sacral foramina and they diminish in size progressively from above downward. The first sacral is the largest of the spinal nerves, the second is slightly smaller than the first, while the third and fourth are relatively small. The fifth sacral nerve is still smaller than the fourth; it enters the pelvis between the sacrum and the coccyx. The anterior divisions of these nerves enter into the formation of three parts of the lumbosacral plexus, the sacral, pudendal, and coccygeal parts (figs. 795, 796).

Sacral Plexus

The **sacral plexus** shows in its formation variations similar to those of the lumbar plexus; hence there are also seven types of this plexus, three of them belonging to the prefixed (proximal) class, three to the postfixed (distal) class, and one to the ordinary class. The following tables show the range of variation and the common arrangement in these classes:—

Composition of the Nerves of the Sacral Plexus

Common Composition

Nerve	Prefixed	Ordinary	Postfixed
Lumbosacral trunk	4L.	4L.	4L.
Common peroneal	4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.
Tibial (internal popliteal)	3,4, 5 L. 1, 2 S.	4, 5 L. 1, 2, S.	4, 5 L. 1, 2, 3, 4 S.
Posterior femoral cutaneous (small sciatic)	1, 2, 3 S.	1, 2, 3 S.	2, 3 S.

RANGE OF VARIATION

NERVE	PREFIXED	ORDINARY	POSTFIXED
Lumbosacral trunk.....	3 or 3, 4 L.	4 L.	4, 5 or 5 L.
Common peroneal.....	3, 4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.
Tibial (internal popliteal)	3, 4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.	4, 5 L. 1, 2, 3, 4 S.
Posterior femoral cutaneous (small sciatic).....	5 L. 1, 2, 3 S.	5 L. 1, 2, 3, 4 S.	5 L. 1, 2, 3, 4 S.

The ordinary type of sacral plexus is commonly formed by the smaller part of the anterior division of the fourth lumbar nerve and the entire anterior division of the fifth lumbar nerve, together with the first and parts of the second and third sacral nerves.

The plexus lies in the pelvis on the anterior surface of the piriformis (fig. 796) and behind the pelvic fascia and the branches of the hypogastric (internal iliac) artery. It is also dorsal to the coils of intestine, the sigmoid colon lying in front of the left plexus, and the lower part of the ileum in front of the right plexus.

The branches given off by this plexus are:—visceral, cutaneous, and muscular.

Visceral branches are given off from the second, third, and fourth sacral nerves to the pelvic viscera.

The visceral branches correspond to white rami communicantes, though not joining the sympathetic trunk. The branches from the second and fourth sacral nerves are inconstant.

Cutaneous branches.—The **posterior femoral cutaneous** (small sciatic) nerve arises partly from the anterior and partly from the posterior branches of the anterior primary divisions of the first, second, and third sacral nerves. It lies on the back of the plexus (figs. 796, 800), leaves the pelvis at the lower border of the piriformis, and descends in the buttock between the gluteus maximus and the posterior surface of the sciatic nerve (fig. 801). At the lower border of the gluteus maximus it passes behind the long head of the biceps femoris, and descends, immediately beneath the deep fascia, through the thigh and the upper part of the popliteal space. At the lower part of the popliteal region it perforates the deep fascia, and it terminates in branches which are distributed to the skin of the calf.

Branches of the posterior femoral cutaneous.—1. **Perineal branches** go in part to the skin of the upper and medial sides of the thigh on its dorsal aspect. One of the branches, known as the **long pudendal nerve** (fig. 801), runs forward and medialward in front of the tuberosity of the ischium to the lateral margin of the anterior part of the perineum, where it perforates the fascia lata and Colles' fascia and enters the anterior compartment of the perineum. In the perineum twigs join it with the superficial perineal nerves, and its terminal filaments are distributed to the skin of the scrotum in the male, and to the labium majus in the female.

2. **Inferior clunial** (gluteal) **branches,** two or three in number, are given off beneath the gluteus maximus; they turn around the lower border of this muscle and are distributed to the skin of the lower and lateral part of the gluteal region.

3. **Femoral cutaneous branches** are given off as the nerve descends through the thigh. They perforate the deep fascia and are distributed to the skin of the back of the thigh, especially toward the medial side.

In case of the separate origin of the tibial (internal popliteal) and common peroneal (external popliteal) nerves, the posterior femoral cutaneous (small sciatic) also arises from the sacral plexus in two parts. The *ventral portion* descends with the tibial nerve below the piriformis and gives off the perineal branches and medial femoral branches, while the *dorsal portion* passes through that muscle with the common peroneal nerve, and furnishes the gluteal and lateral femoral branches.

The **inferior medial clunial (perforating cutaneous) nerve** arises from the posterior portion of the second and third sacral nerves (figs. 795, 799, 800). It perforates the lower part of the sacrotuberous (great sciatic) ligament, turns around the inferior border of the gluteus maximus, and is distributed to the skin over the lower and medial part of that muscle. It is sometimes associated at its origin with the pudic nerve. It is not always present. Its place is sometimes taken by a small nerve (the *greater coccygeal perforating nerve* of Eisler), arising from the third and fourth or fourth and fifth sacral nerves, and sometimes it is represented by a branch of the posterior femoral cutaneous.

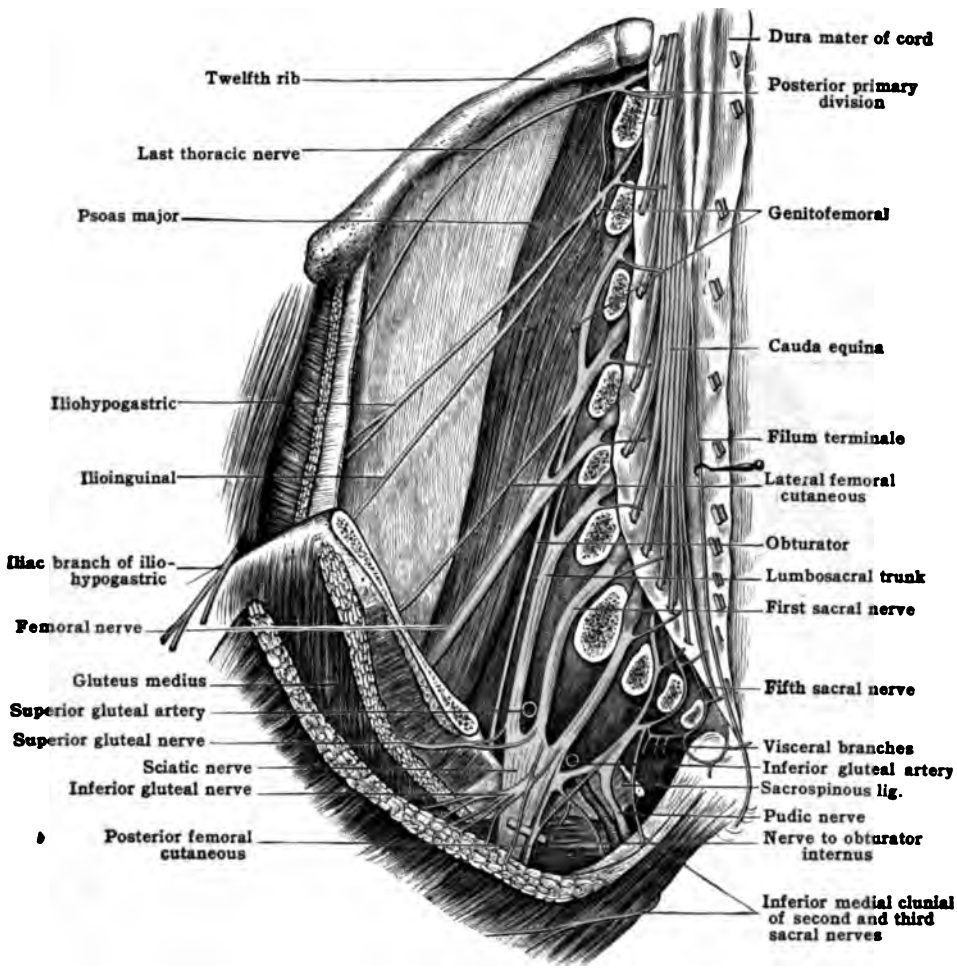
Muscular branches of the sacral plexus.—(*a*) One or two small **nerves to the piriformis** pass from the posterior branches of the first and second sacral nerves.

(*b*) The **superior gluteal nerve** receives fibers from the posterior branches of the fourth and fifth lumbar, and the first sacral nerves. It passes out of the pelvis through the great sciatic foramen, above the upper border of the piriformis, and it is accompanied by the superior gluteal artery. As soon as it enters the buttock it divides into two branches, an upper and a lower.

1. The **upper branch** is the smaller. It accompanies the upper branch of the deep division the superior gluteal artery below the middle curved line of the ilium, and it ends entirely the gluteus medius (fig. 801).
2. The **lower branch,** larger than the upper, passes forward across the middle of the gluteus minimus, with the lower branch of the gluteal artery; it supplies the gluteus medius and the gluteus minimus, and it ends in the medial and posterior part of the tensor fasciæ latæ.

(*c*) The **inferior gluteal nerve** is formed by fibers from the posterior branches of the fifth lumbar, and the first and second sacral nerves. It passes through the great sciatic foramen, below the piriformis, and divides into a number of branches which end in the gluteus maximus (figs. 796, 800).

FIG. 800.—A DISSECTION OF THE LUMBAR AND SACRAL PLEXUSES, FROM BEHIND.



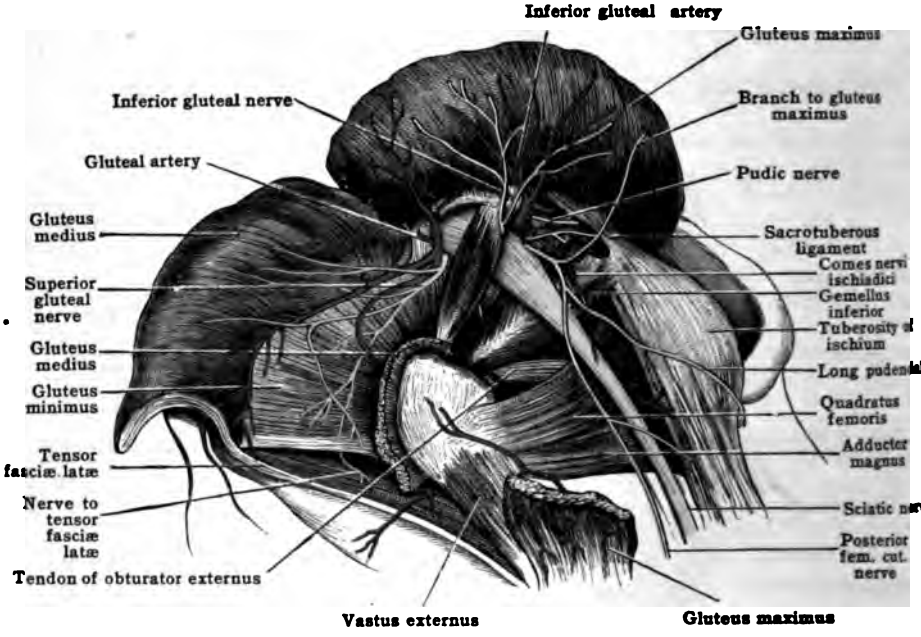
(*d*) The **nerve of the quadratus femoris** is formed by the anterior branches of the fourth and fifth lumbar and the first and second sacral nerves. It lies on the front of the plexus and issues from the pelvis below the piriformis. In the buttock it lies at first between the sciatic nerve and the back of the ischium, and, at a lower level, between the obturator internus with the gemelli and the ischium. It terminates in the anterior surface of the quadratus femoris, having previously given off a branch to the hip-joint and another to the inferior gemellus.

(*e*) The **nerve of the obturator internus** is formed by the anterior branches of the fifth lumbar, and the first and second sacral nerves (figs. 795, 800). It leaves the pelvis below the piriformis, and crosses the spine of the ischium on the lateral side of the internal pudic artery and on the medial side of the sciatic nerve. It gives a branch to the gemellus superior, and turns forward through the small

sciatic foramen into the perineum, where it terminates in the inner surface of the obturator internus.

The **sciatic nerve** [n. ischiadicus].—The sciatic is not only the largest nerve of the sacral plexus, but it is also the largest nerve in the body. Its terminal branches are chiefly muscular, though some of its fibers are cutaneous. Although it is referred to as one trunk, it consists in reality of peroneal (lateral) and tibial (medial popliteal) portions (fig. 795), which are bound together by a sheath of fibrous tissue as far as the upper end of the popliteal space. In about 10 per cent. of the cases the two parts remain separate, and in such cases the peroneal (lateral popliteal) part usually pierces the piriformis. The peroneal portion of the nerve consists of fibers derived from the dorsal branches of the anterior primary divisions of the fourth and fifth lumbar and the first and second sacral nerves, while the tibial part is formed by the fibers from the anterior branches of

FIG. 801.—A DISSECTION OF THE NERVES IN THE GLUTEAL REGION.
(The gluteus maximus and gluteus medius have been divided near their insertions, and thrown upward.)



the fourth and fifth lumbar, and the first, second, and third sacral nerves (figs. 796, 800). The common trunk leaves the pelvis by passing through the great sciatic foramen, usually below the piriformis, and descends through the buttock, running midway between the tuber ischii and the great trochanter (fig. 801). Passing down the thigh, the trunk terminates at the upper angle of the popliteal space by dividing into the common peroneal (external popliteal) and the tibial (internal popliteal) nerves (fig. 802).

The relation of the trunk to the piriformis muscle is more or less unique. It may pass either above or below the muscle, it may split and pass around the muscle, or the muscle may be split and surround the nerve. Again, there may be a splitting of both the muscle and the nerve, in which case any possible combination of the four parts may occur; a portion of the nerve may be above and a portion between the parts of the muscle, or a portion may be below and a portion between. The trunk of the nerve lies deeply in the thigh, and it is covered posteriorly by the skin and fascia, the gluteus maximus and the long head of the biceps femoris. Anteriorly it is in relation, from above downward, with the following structures:—the posterior surface of the ischium and the nerve to the quadratus femoris, the gemellus superior, obturator internus, gemellus inferior, quadratus femoris, and adductor magnus muscles.

Muscular branches of the sciatic are given off at the upper part of the thigh to the semitendinosus, to the long head of the biceps femoris, to the semimembranosus, and to the adductor magnus, and, about the middle of the thigh, a branch is furnished to the short head of the biceps.

The branch to the **short head of the biceps femoris** is derived from the peroneal (lateral popliteal) portion of the nerve, while all the other muscular branches are given off by the tibial (medial popliteal) part. The **semitendinosus** receives two branches, one which enters it above and another which passes into it below its tendinous intersection. The nerve to the **long head of the biceps** descends along the sciatic trunk and enters the middle of the deep surface of the muscle. The nerves to the **semimembranosus** and **adductor magnus** arise by a common trunk which divides into three or four branches. One branch ends in the adductor, and the others are distributed to the semimembranosus. The branch to the adductor magnus supplies only those fibers of the muscle which begin from the tuberosity of the ischium and descend vertically to the medial condyle of the femur.

At the popliteal space the two component parts of the common trunk of the sciatic are always distinct, forming (*A*) the tibial and (*B*) the common peroneal nerve.

(*A*) The **tibial nerve** (internal popliteal), formed by fibers from the anterior branches of the fourth and fifth lumbar and first, second, and third sacral nerves, passes vertically through the popliteal space, descends through the leg to a point midway between the medial malleolus and the most prominent part of the medial tubercle of the calcaneus, where it divides into its terminal branches, the *lateral plantar* and the *medial plantar* nerves.

The part of the nerve from the point of bifurcation to the lower border of the popliteus muscle was formerly called the *internal popliteal;* the part of the nerve in the dorsum of the leg being then designated the *posterior tibial nerve.*

In the upper part of the popliteal space the tibial nerve lies relatively superficially, being covered dorsally by the skin and fascia, while in the lower part of the space it is overlapped by the heads of the gastrocnemius and is crossed by the plantaris. In the upper part of the space it lies in front of the posterior femoral cutaneous (small sciatic) nerve and to the lateral side of the vein and artery; at the middle of the space it is dorsal, and in the lower part of the space it is medial to both of them.

The **branches** given off by the tibial nerve *in the popliteal space* are articular, cutaneous, and muscular.

The **articular branches** are usually three in number, a superior and an inferior internal articular and an azygos articular. They accompany the corresponding arteries, and, after piercing the ligaments, are distributed in the interior of the joint. The superior branch is often wanting.

The **medial sural cutaneous** (tibial communicating) nerve, descends between the heads of the gastrocnemius, beneath the deep fascia, to the middle of the calf, where it pierces the fascia and unites with the peroneal anastomotic branch of the lateral sural cutaneous nerve to form the **sural** (external saphenous) nerve, through which its fibers are distributed to the skin of the lower and dorsal part of the leg and the lateral side of the foot (fig. 802).

The **muscular branches** are distributed to both heads of the gastrocnemius, to the plantaris, soleus, and popliteus.

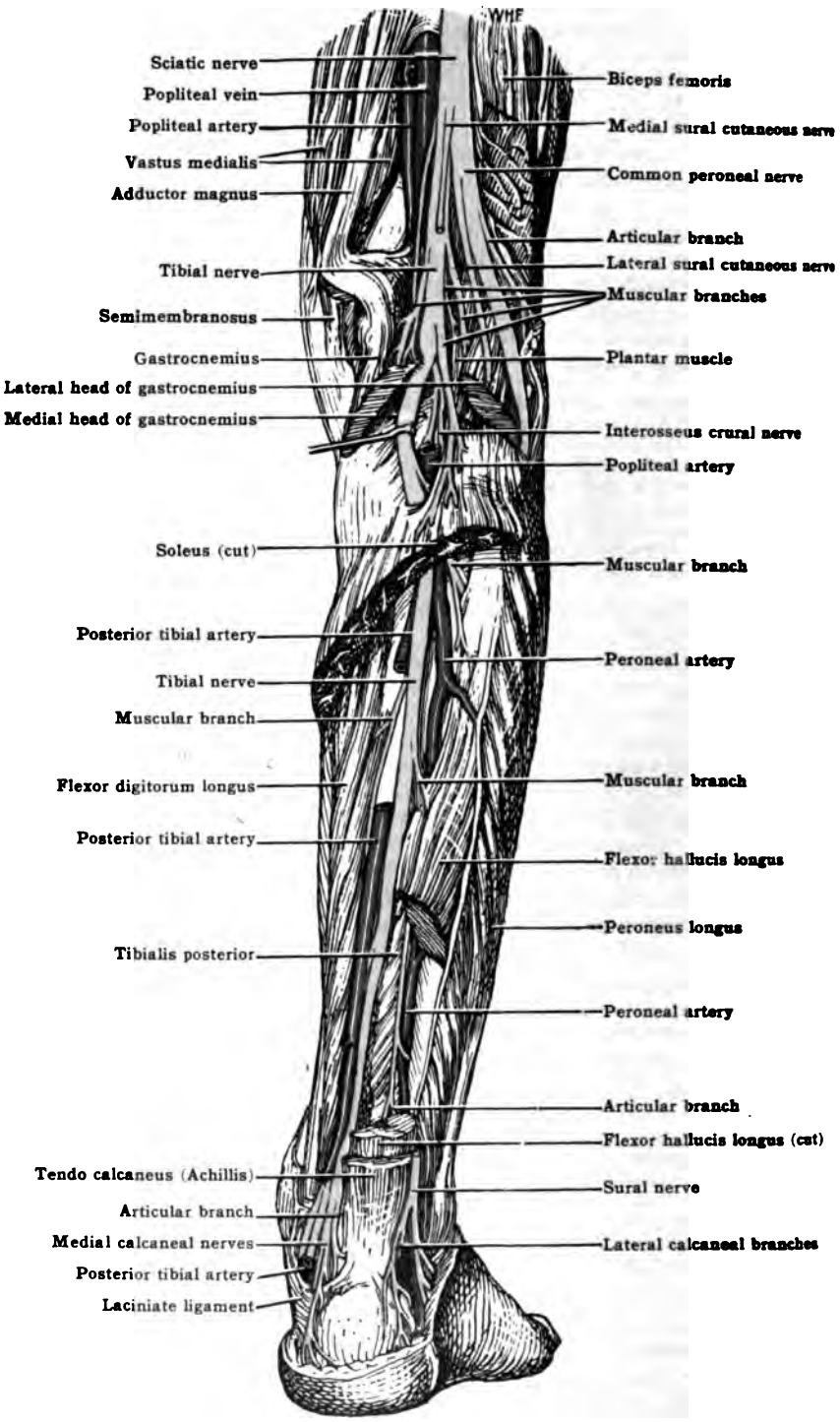
The *nerve to the soleus* is relatively large, and passes between the lateral head of the gastrocnemius and the plantaris before it reaches its termination (fig. 802). The *nerve to the popliteus* descends on the posterior surface of the muscle, turns around its lower border, and is distributed on its anterior aspect. In addition to supplying the popliteus, it gives articular branches to the knee and superior tibiofibular joints, a branch to the tibia which accompanies the medullary artery, and a long, slender twig which gives filaments to the anterior and posterior tibial arteries, and it descends as the **interosseous crural** nerve on the interosseous membrane to the inferior tibiofibular joint. It also gives branches to the interosseous membrane and to the periosteum of the lower part of the tibia.

Relations.—In the upper part of the leg the tibial nerve is placed deeply, under the gastrocnemius and soleus, but in the lower half it is merely covered by the deep fascia, which is thickened between the medial malleolus and the calcaneus to form the lacinate (internal annular) ligament, and the termination of the nerve lies either under cover of this ligament, or under the attachment of the abductor hallucis. The anterior relations of the nerve are, from above downward, the tibialis posterior, the flexor digitorum longus, the lower part of the tibia, and the posterior ligament of the ankle-joint. For a short distance after its commencement the nerve lies to the medial side of the posterior tibial artery; then it crosses behind the artery and runs downward along its lateral aspect.

The **branches of the lower part** of the tibial nerve (below the popliteal space) are likewise muscular, cutaneous, and articular. They are supplied to the deep muscles of the dorsum of the leg, to the fibula, to the skin of the heel and foot, and to the ankle-joint. Several of the terminal branches are important enough to receive special names and special treatment.

The **muscular branches** pass from the upper part of the nerve to the tibialis posterior, flexor digitorum longus, soleus, and flexor hallucis longus. The **fibular branch** arises with the

FIG. 802.—MUSCLE-NERVES OF THE RIGHT LEG, VIEWED FROM BEHIND. (After Spalteholz.) The semitendinosus, semimembranosus, biceps femoris, gastrocnemius, plantaris, soleus, and flexor hallucis longus have been wholly or in part removed.



nerve to the flexor hallucis longus, and accompanies the peroneal artery. It supplies periosteum and gives filaments which accompany the medullary artery.

The articular branches arise from the lower part of the nerve, immediately above its minal branches, and they pass into the ankle-joint through the deltoid ligament.

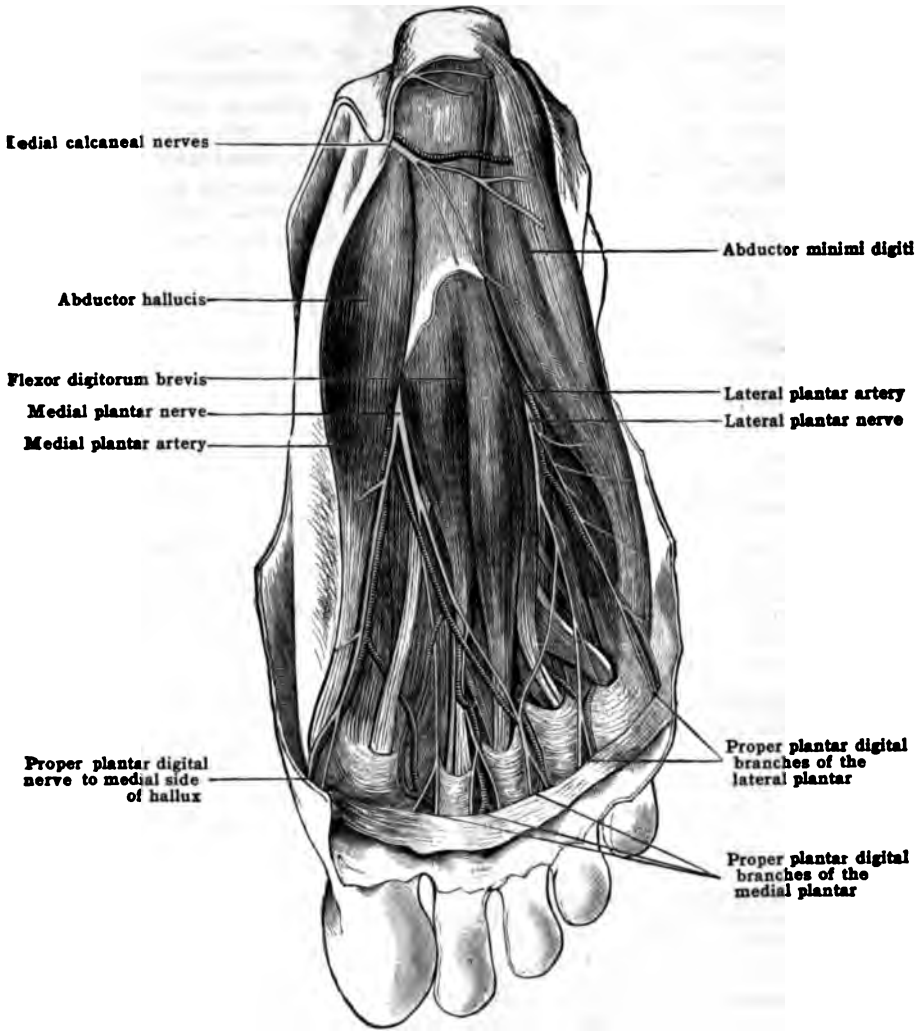
The medial calcaneal (calcaneoplantar cutaneous) nerves arise from the trunk of tibial nerve in the lower part of the leg. They pierce the laciniate (internal annular) ligan

l are distributed to the integument of the medial side and plantar surface of the heel and adjoining part of the sole of the foot (figs. 802, 803).

Terminal branches of tibial nerve.—Between the medial malleolus and the lcaneus the tibial nerve divides into (1) the medial plantar and (2) the lateral antar nerve.

1. The **medial plantar nerve** is the larger of the two terminal branches of the ıial nerve. It commences under cover of the lower border of the laciniate ıternal annular) ligament, or under the posterior border of the abductor hallucis, ıd passes forward, accompanied by the small medial plantar artery, in the

FIG. 803.—SUPERFICIAL NERVES IN THE SOLE OF THE FOOT. (Ellis.)


Medial calcaneal nerves
Abductor minimi digiti
Abductor hallucis
Flexor digitorum brevis
Medial plantar nerve
Medial plantar artery
Lateral plantar artery
Lateral plantar nerve
Proper plantar digital nerve to medial side of hallux
Proper plantar digital branches of the lateral plantar
Proper plantar digital branches of the medial plantar

ıtermuscular septum between the abductor hallucis and the flexor digitorum revis. At the middle of the length of the foot it becomes superficial, in the ıterval between the two muscles, and divides into four sets of terminal branches ig. 803):—

(*a*) **Muscular branches** pass from the trunk of the nerve to the abductor allucis and the flexor digitorum brevis.

(*b*) **Articular branches** are distributed to the talonavicular and the navicular-ıneiform joints.

(*c*) **Plantar cutaneous branches** are supplied to the skin of the medial part of ıe sole.

(*d*) The **digital branches** are four in number, the first, a **proper plantar digital**, the second, third, and fourth, the **common plantar digitals.** Near the bases of the metatarsal bones, the second, third and fourth common plantar digitals divide into **proper plantar digital nerves.**

The first proper plantar digital nerve becomes subcutaneous farther back than the others, and, after sending a branch to the flexor hallucis brevis, passes to the medial side of the great toe. The second (common digital) nerve gives a twig to the first lumbrical and bifurcates to supply the adjacent sides of the first and second toes. The third supplies the adjacent sides of the second and third toes, and the fourth, after connecting with the superficial branch of the lateral plantar nerve, divides to supply the adjacent sides of the third and fourth toes. All the proper digital nerves run along the sides of the toes and lie below the corresponding arteries: they supply the joints of the toes, and each give off a dorsal branch to the skin over the second and terminal phalanges and to the bed of the nail. All of them give fibers terminating in numerous Pacinian corpuscles in the subcutaneous connective tissue.

2. The **lateral plantar nerve** is the smaller of the two terminal branches of the tibial nerve. It commences at the lower border of the laciniate (internal annular) ligament, or under cover of the origin of the abductor hallucis, and passes forward and lateralward to the base of the fifth metatarsal bone, where it divides into a superficial and a deep branch (fig. 803). As it runs forward and lateralward it is superficial to the tendon of the flexor hallucis longus and to the quadratus plantæ (flexor accessorius), and deep to the flexor digitorum brevis. At its termination it lies in the interval between the flexor digitorum brevis and abductor digiti quinti.

Branches.—From the trunk of the lateral plantar nerve muscular, superficial and deep, and articular branches are given off.

The **muscular branches** arise from the commencement of the nerve and are distributed to the abductor digiti quinti and quadratus plantæ.

The **articular branches** supply the calcaneocuboid joint.

The **superficial branch** supplies muscular filaments to the flexor digiti quinti brevis, the opponens, the third plantar and fourth dorsal interosseous muscles, and divides into two **common plantar digital nerves,** each of which subdivides to form **proper plantar digital nerves.**

The lateral of the two common branches supplies the lateral side of the fifth digit; the medial connects with the lateral digital branch of the medial plantar nerve (fig. 803) and divides into proper plantar digital nerves for the adjacent sides of the fourth and fifth digits. The digital branches of the superficial division of the lateral plantar, like those of the medial plantar, supply the skin of the toes and the beds of the nails, and their fibers terminate in numerous Pacinian corpuscles.

The **deep branch** passes forward and medialward into the deep part of the sole with the plantar arterial arch. It runs deep to the quadratus plantæ, the long flexor tendons and the lumbricals, and the oblique adductor of the great toe. It lies, therefore, immediately beneath the bases of the metatarsal bones and it supplies the following muscular and articular branches:—

Muscular branches to the lateral three lumbricals, the interossei of the medial three intermetatarsal spaces, and the transverse and oblique adductor muscles of the great toe.

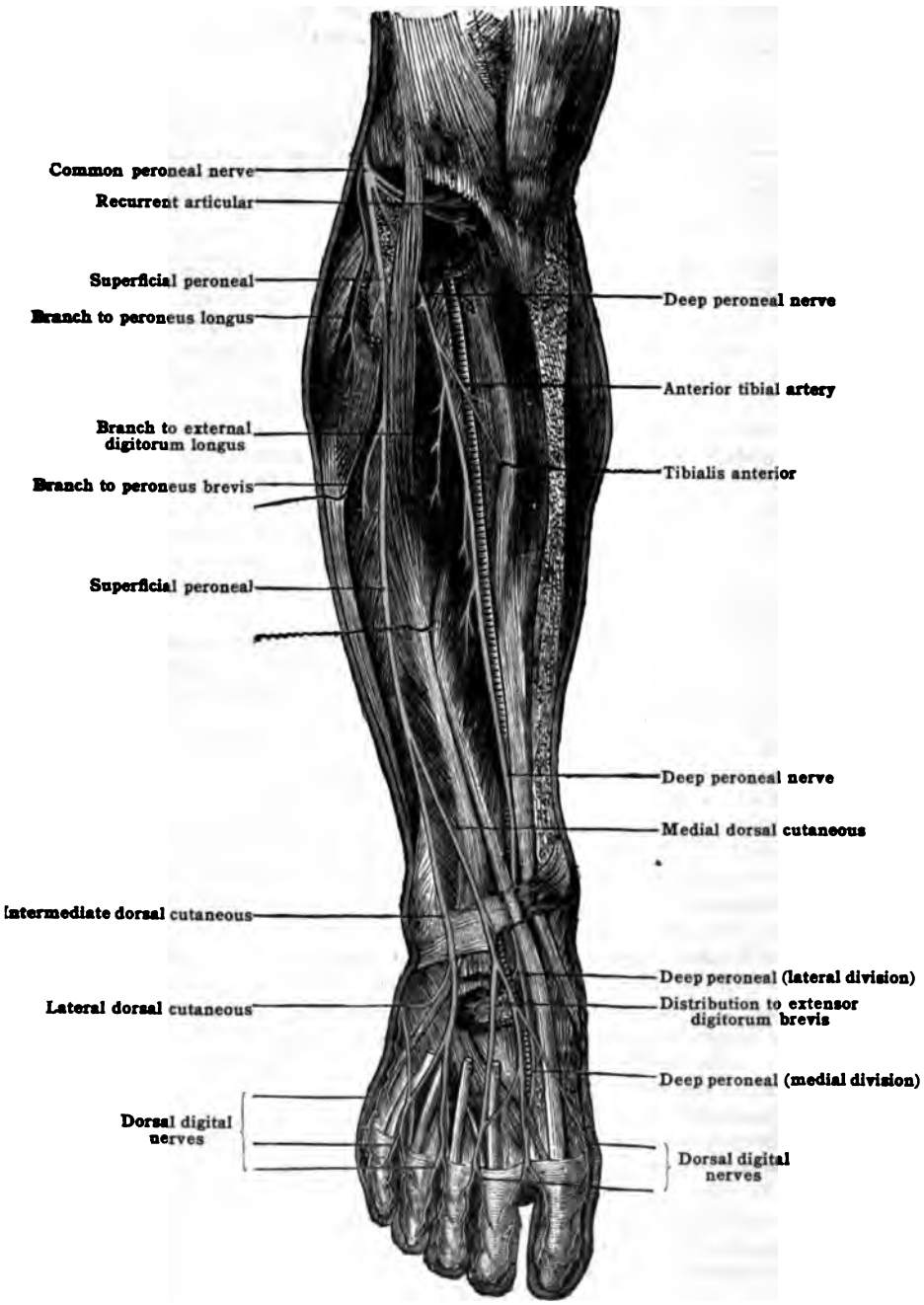
Articular branches to the intertarsal and to the tarsometatarsal joints and not uncommonly to the metatarsophalangeal joints also. Filaments from the deep branch frequently pass through the interosseous spaces and join with the interosseous branches of the deep peroneal (anterior tibial) nerve.

(B) The **common peroneal** (external popliteal) **nerve.**—At the apex of the popliteal space, where the two component parts of the sciatic trunk usually become distinct, the lateral portion receives the name *common peroneal nerve.* It descends along the posterior border of the biceps femoris, which forms the upper part of the lateral boundary of the space (fig. 802). It leaves the space at the lateral angle, crosses the plantaris, the lateral head of the gastrocnemius, the popliteus, and the inferior external artery, and descends behind the upper part of the soleus, to the neck of the fibula, where it turns forward between the peroneus longus and the bone, and breaks up into its three terminal branches, the recurrent articular, the superficial peroneal (musculocutaneous), and the deep peroneal (anterior tibial) nerves (fig. 804).

Upper branches.—While it is in the popliteal space the common peroneal nerve gives off two articular branches and a cutaneous branch.

The superior articular branch accompanies the superior external articular artery. The **inferior articular branch** passes down with the trunk of the nerve, across the plantaris and the lateral head of the gastrocnemius, and it joins the inferior-lateral articular artery behind the tendon of the biceps femoris. Both the upper and lower articular branches pierce the ligaments and are distributed in the interior of the knee joint.

FIG. 804.—DISTRIBUTION AND DEEP PERONEAL NERVES ON THE ANTERIOR ASPECT OF THE LEG AND ON THE DORSUM OF THE FOOT. (Hirschfeld and Leveillé.)



The **cutaneous branch** (*communicans fibularis*), the **lateral sural cutaneous,** is extremely variable both as to the number of its branches and as to the place of its anastomosis with the medial sural cutaneous. Leaving the common peroneal (external popliteal) in the popliteal space, it descends between the deep fascia and the lateral head of the gastrocnemius to the middle of the calf, where it pierces the fascia and unites with the medial sural cutaneous to form the **sural** (external saphenous) nerve. In its course it may give off no branches; or it may give

off several, some of which supply the skin of the dorsum of the leg, while one of them the peroneal anastomotic branch, unites with the medial sural cutaneous to form the sural (short saphenous) nerve. The junction of the peroneal anastomotic branch with the medial sural cutaneous may take place at any point between the popliteal space and the lower third of the leg.

The **sural** (external or short saphenous) **nerve** is formed by the union of the lateral sural cutaneous nerve either directly, or through a connecting branch, the peroneal anastomotic, with the medial sural cutaneous. It descends along the lateral border of the tendo Achillis, (figs. 799, 802), giving branches to the lower and lateral part of the leg, and **lateral calcaneal** branches to the lateral side of the heel.

It passes dorsal to the lateral malleolus, turns forward across the lateral surface of the cruciate (external annular) ligament, and becomes the **lateral dorsal cutaneous nerve.** Continuing along the lateral side of the foot it divides into two branches, the **dorsal digitals,** one of which supplies the lateral side of the fifth digit, while the other anastomoses with or takes the place of a branch of the superficial peroneal (musculocutaneous) nerve, which is distributed to the adjacent sides of the fourth and fifth digits (fig. 804).

The terminal branches of the common peroneal.—(1) The **recurrent articular nerve** (fig. 804) passes medialward, around the neck of the fibula, and through the upper part of the attachment of the extensor digitorum longus. At the medial border of the fibula it becomes associated with the anterior tibial recurrent artery, with which it ascends through the upper part of the tibialis anterior to the head of the tibia and the knee-joint. It supplies the tibialis anterior, the superior tibiofibular joint, and the knee-joint.

(2) The **superficial peroneal** (musculocutaneous) **nerve** (fig. 804) arises from the common peroneal between the peroneus longus and the neck of the fibula and descends in the intermuscular septum between the long and short peronei on the *lateral* side, and the extensor digitorum longus on the medial side. It gives off muscular and cutaneous branches in its descent, and at the junction of the middle and lower thirds of the leg it pierces the deep fascia and divides into a *medial dorsal* and a *lateral branch* (fig. 804).

Muscular branches are given off from the superficial peroneal to the peroneus longus and peroneus brevis before the nerve pierces the deep fascia.

Cutaneous branches pass from the trunk of the superficial peroneal to the skin of the lower part of the front of the leg.

The **medial dorsal cutaneous nerve** passes downward and medialward across the transverse and the cruciate (anterior annular) ligament of the ankle and subdivides into two branches. The *medial branch* passes to the medial side of the great toe; it also supplies twigs to the skin of the medial side of the foot, and it anastomoses with the deep saphenous nerve and with the medial terminal branch of the deep peroneal (anterior tibial) nerve. The *lateral branch* passes to the base of the cleft between the second and third toes and divides into two dorsal digital branches which supply the adjacent sides of the cleft.

The **lateral branch** (**intermediate dorsal cutaneous**) of the superficial peroneal, in separating from the medial, crosses in front of the cruciate ligament and divides into two dorsal digital branches, which pass beneath the dorsal venous arch. The medial of these branches supplies the adjacent sides of the third and fourth toes (fig. 804). The lateral branch communicates with the sural (external saphenous) nerve and is distributed to the adjacent sides of the fourth and fifth toes. This latter branch is frequently replaced by the sural nerve.

(3) The **deep peroneal** (**anterior tibial**) **nerve** springs from the end of the common peroneal (external popliteal) nerve between the peroneus longus muscle and the neck of the fibula. It passes forward and medialward through the upper part of the origin of the extensor digitorum longus, to the interval between that muscle and the tibialis anterior; then it descends, in the anterior compartment of the leg, to the ankle, where it divides into a medial and a lateral terminal branch (fig. 804).

In the upper part of the leg the deep peroneal nerve lies between the extensor digitorum longus and tibialis anterior and lateral to the anterior tibial artery. In the middle of the leg it is in front of the artery and between the extensor hallucis longus and tibialis anterior; then it crosses beneath the extensor hallucis, and in the lower third of the leg it is again to the lateral side of the artery, but between the extensor hallucis longus and the extensor digitorum longus.

Branches furnished from the trunk of the deep peroneal are muscular, articular, and terminal.

The **muscular branches** supply the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius.

Articular filaments are given to the ankle-joint and the inferior tibiofibular articulation.

Terminal branches.—The **medial terminal branch** passes downward along the side of the dorsalis pedis artery and divides into two dorsal digital branches which supply the adjacent sides of the first and second toes. It also gives filaments to the periosteum of the adjacent bones, to the metatarsophalangeal and interphalangeal articulations, a twig to the dorsal interosseous muscle of the first space, and a perforating twig which connects with the lateral plantar nerve. The **lateral terminal branch** passes lateralward, beneath the extensor digitorum brevis, and it ends in a gangliform enlargement from which branches are distributed to the extensor digitorum brevis, the tarsal joints, and to the three lateral intermetatarsal spaces. The latter branches supply the neighboring bones, periosteum, and joints. They give off perforating twigs, which pass through the spaces and anastomose with branches of the lateral plantar nerve, and the most medial also gives a twig to the second dorsal interosseous muscle.

TABLE SHOWING ORDINARY RELATIONS OF LUMBAR AND SACRAL NERVES TO BRANCHES OF THE LUMBAR AND SACRAL PLEXUSES AND TO THE PUDIC NERVE

NERVES CONTRIBUTING	NERVES
1 L	Iliohypogastric
	Ilioinguinal
1 and 2 L	Genitofemoral
1, 2, and 3 L	Lateral cutaneous
2, 3, and 4 L	Femoral
	Obturator
4, 5 L., and 1 S	Superior gluteal
	Nerve to quadratus femoris
4, 5 L., 1 and 2 S	Sciatic (peroneal part)
4, 5 L., 1, 2, and 3 S	Sciatic (tibial part)
5 L., 1 and 2 S	Inferior gluteal
	Nerve to obturator internus
1 and 2 S	Nerve to piriformis
2 and 3 S	Medial inferior clunial
1, 2, and 3 S	Posterior femoral cutaneous
2, 3, and 4 S	Pudendal (Pudic)

TABLE SHOWING RELATIONS OF MUSCLES OF LOWER EXTREMITY TO NERVES OF LUMBAR AND SACRAL PLEXUSES

NERVES CONTRIBUTING	MUSCLES	NERVES
2 and 3 L	Iliopsoas	Femoral
	Sartorius	Femoral
	Pectineus	Femoral
	Adductor longus	Obturator
2, 3, and 4 L	Gracilis	Obturator
	Adductor brevis	Obturator
3 and 4 L	Quadriceps femoris	Femoral
	Obturator externus	Obturator
3, 4, and 5 L	Adductor magnus	Obturator and sciatic
4, 5 L., and 1 S	Gluteus medius	Superior gluteal
	Gluteus minimus	Superior gluteal
	Tensor fasc. latæ	Superior gluteal
	Semimembranosus	Sciatic
	Plantaris	Tibial
	Popliteus	Tibial
	Quadratus femoris	Nerve to quad. fem.
	Inferior gemellus	Nerve to quad. fem.
5 L., and 1 S	Flex. digit. long.	Tibial
	Tibialis posterior	Posterior medial
	Flexor digit. brev.	Plantar
	Flexor hallucis brev.	Plantar
	Abductor hallucis	Plantar
	First lumbrical	Plantar

Nerves Contributing	Muscles	Nerves
5 L., 1 and 2 S.	Superior gemellus	Nerve to obt. int.
	Obturator internus	Nerve to obt. int.
	Gluteus maximus	Inferior gluteal
	Semitendinosus	Sciatic
	Soleus	Tibial
	Flex. hallucis long.	Tibial
1 and 2 S.	Piriformis	
	Gastrocnemius	Tibial
	Flexor quadratus plantæ	Lateral plantar
	Abd. quinti digiti	Lateral plantar
	Plantar interossei	Lateral plantar
	Dorsal interossei	Lateral plantar
	Add. hallucis trans.	Lateral plantar
	Add. hallucis obliq.	Lateral plantar
1, 2, and 3 S.	Long head of biceps femoris	Sciatic
4, 5 L., and 1 S.	Ext. hall. long.	Deep peroneal
	Ext. digit. long.	Deep peroneal
	Ext. digit. brev.	Deep peroneal
	Tibiæis anterior	Deep peroneal
	Peroneus tertius	Deep peroneal
	Peroneus longus	Superficial perone
	Peroneus brevis	Superficial perone

THE PUDENDAL PLEXUS

The **pudendal plexus,** like the parts of the lumbosacral plexus alread scribed, varies in its formation. The following table shows the extreme ra variation and the common method of formation of the largest nerve (puden pudic) of this plexus in each of the three classes previously referred to.

Common Composition

Nerve	Prefixed	Ordinary	Post
Pudic nerve	2, 3 S.	2, 3, 4 S.	3, 4

Range of Variation

Nerve	Prefixed	Ordinary	Post
Pudic nerve	1, 2, 3, 4, 5 S.	1, 2, 3, 4 S.	2, 3, 4

The pudendal plexus is commonly formed by parts of the anterior divisi the second, third, and fourth sacral nerves (fig. 795). It lies in the lower p the back of the pelvis, and gives off visceral, muscular, and terminal bran

Visceral branches (pelvic splanchnics) arise from the third and fourth nerves especially, and enter branches of the sympathetic plexus. Th distributed both directly by their afferent or sensory fibers terminating pelvic viscera and indirectly by their visceral efferent fibers terminating ganglia of the sympathetic plexus or upon ganglion cells in the walls of the viscera (figs. 795, 818). The **middle hemorrhoidal nerves** pass to the rectu **inferior vesical nerves** to the bladder, and, in the female, the **vaginal nerves** vagina (see Sympathetic System).

Muscular branches are given by the fourth sacral nerve to the cocc levator ani, and sphincter ani externus (fig. 795).

The nerves to the two former muscles pass into the pelvic surfaces of the muscles, t to the last-named muscle, called the **perineal branch,** passes backward between the ani and the coccygeus, or through the posterior fibers of the latter muscle, into the p part of the ischiorectal fossa, and, in addition to supplying the sphincter ani, it gives cu filaments to the skin between the anus and the coccyx.

Terminal branches.—The **pudendal (pudic) nerve** [n. pudendus] rises i from the anterior primary divisions of the second, third, and fourth sacral (figs. 795, 796). It emerges from the pelvis below the piriformis, crosses th of the ischium, lying to the medial side of the internal pudic artery (figs. 80(and accompanies the artery, through the small sciatic foramen, into Alcock' in the obturator fascia on the lateral wall of the ischiorectal fossa, where it nates by dividing into three branches, the inferior hemorrhoidal, the perine the dorsal nerve of the penis.

The inferior hemorrhoidal nerves frequently arise independently from the third and fourth sacral nerves, pierce the medial wall of Alcock's canal, and pass forward and medialward through the ischiorectal fat to supply the sphincter ani externus and adjacent skin. They anastomose with branches of the perineal nerve.

The perineal nerve (fig. 1100) runs forward for a short distance in Alcock's canal and divides into a deep and a superficial branch. The *deep branch* breaks up into filaments, one or two of which pierce the medial wall of the canal and pass medialward to the anterior fibers of the sphincter and levator ani. The remaining part of the nerve pierces the base of the urogenital diaphragm, and enters the superficial pouch of the urethral triangle, where it is distributed to the bulb of the urethra, and to the transversus perinei, bulbocavernosus, and ischiocavernosus. It also sends some sensory filaments to the mucous membrane of the urethra. The *superficial branch* almost at once divides into medial and lateral branches, the *posterior scrotal* (*labial*) nerves.

Both branches pass through the wall of Alcock's canal into the anterior part of the ischiorectal fossa, then they pierce the base of the urogenital diaphragm, and enter the superficial pouch of the urethral triangle. The lateral branch usually passes below the transversus perinei, and the medial branch above the muscle or through its fibers. The lateral branch connects with the long pudendal nerve, and with the inferior hemorrhoidal nerve, and both branches end in terminal filaments which anastomose and which are distributed to the skin of the scrotum and the anterior part of the perineum in the male, and to the labium majus in the female.

The dorsal nerve of the penis runs forward in Alcock's canal above the internal pudic artery. It pierces the base of the urogenital diaphragm, continues forward between its layers, embedded in the fibers of the constrictor urethræ, and it gradually passes to the lateral side of the internal pudic artery. A short distance below the pudic arch it pierces the anterior layer of the urogenital diaphragm, gives a branch to the corpus cavernosum penis, passes forward between that structure and the bone, and turns downward on the dorsum of the penis, passing between the layers of the suspensory ligament and along the outer side of the dorsal artery of the penis. It supplies the skin of the dorsum of the penis, and, having given branches to the prepuce, it breaks up into terminal filaments which are distributed to the glans penis.

The dorsal nerve of the clitoris is much smaller than the dorsal nerve of the penis to which it corresponds. It is distributed to the clitories.

THE COCCYGEAL PLEXUS

This plexus is frequently, and with reason, considered as a subdivision of the pudendal plexus, and sometimes it is described with the coccygeal nerves. It is formed chiefly by the anterior division of the fifth sacral nerve and the coccygeal nerve, but it receives a small filament from the anterior division of the fourth sacral nerve (figs. 795, 796, 800). These constituents unite to form plexiform cords lying on either side of the coccyx. From these cords arise the **anococcygeal nerves,** which pierce the sacrotuberous (great sacro-sciatic) ligament and supply the skin in the neighborhood of the coccyx.

III. THE DISTRIBUTION OF THE CUTANEOUS BRANCHES OF THE SENSORY AND MIXED CRANIAL AND SPINAL NERVES.

The cutaneous filaments of the sensory and mixed nerves are distributed to definite regions of the surface of the body which are known as 'cutaneous areas.' Each cutaneous area has one special nerve of supply and the central part of the area receives that nerve alone, but wherever the borders of two areas meet they reciprocally overlap, therefore each margin of every cutaneous area has two nerves of supply, its own nerve and that of an adjacent area, and of these, sometimes one and sometimes the other preponderates.

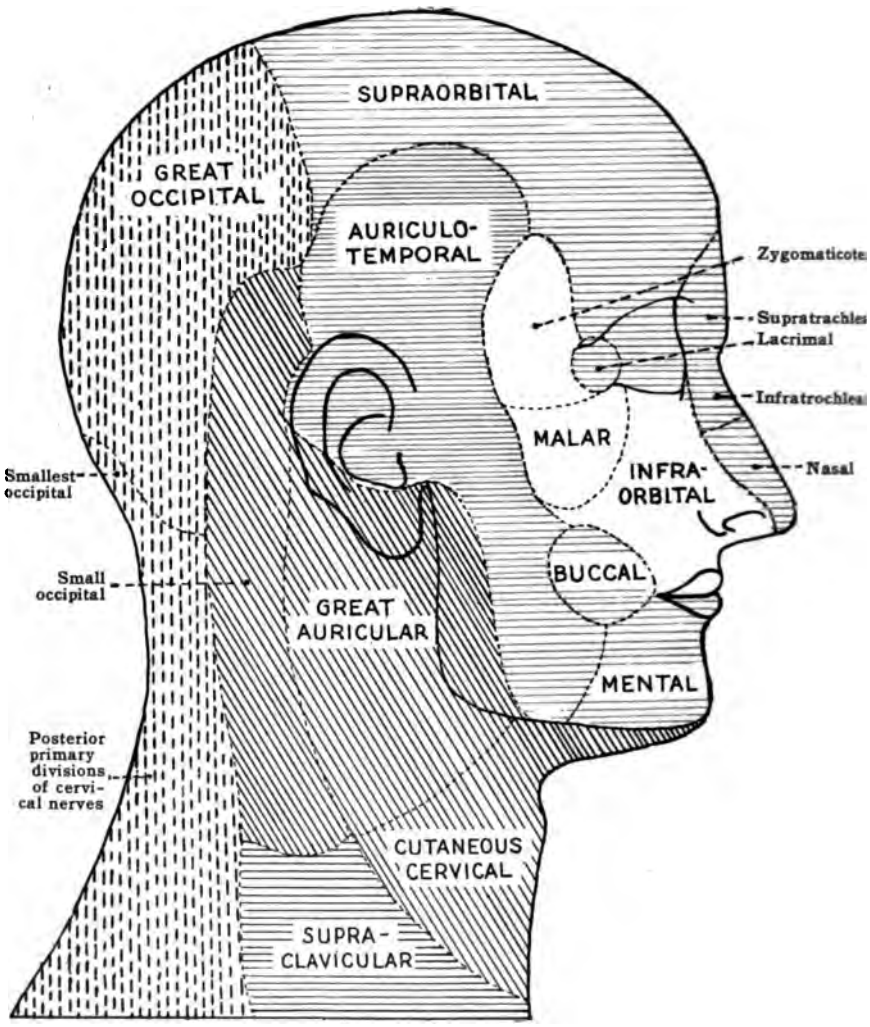
The Cutaneous Areas of the Scalp

The limits of the cutaneous areas in the scalp region are indicated in figs. 805, 807, but in general terms it may be said that the skin of the scalp in front of the auricle is supplied by

four cutaneous nerves, viz., the medial part by the supratrochlear and the supraorbital bra of the ophthalmic division of the trigeminus, and the lateral part by the temporal branch maxillary division, and the auriculotemporal branch of the mandibular division of the nerve.

The portion of the scalp behind the auricle also receives four cutaneous nerves; later is supplied by the great auricular and small occipital branches of the cervical plexus contain filaments from the second and third cervical nerves, and medially it receives the and smallest occipital nerves which are derived from the medial branches of the pos primary divisions of the second and third cervical nerves respectively.

FIG. 805.—DIAGRAM OF THE CUTANEOUS NERVE-AREAS OF THE HEAD AND NECK
Red—ophthalmic division of trigeminus. White—maxillary division of trige
Blue—mandibular division of trigeminus.
Vertical broken line shading—Posterior primary divisions of cervical nerves.
Oblique shading—Ascending and transverse superficial branches of cervical plexus.
Transverse shading—Descending superficial branches of cervical plexus.
It must be remembered that the boundaries of each area are not distinct; wherev areas meet they overlap.



THE CUTANEOUS AREAS OF THE FACE

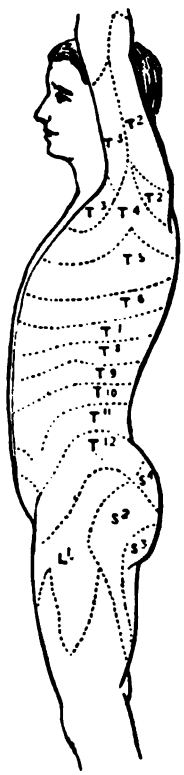
With the exception of the skin over the posterior part of the masseter muscle, th of the skin of the face is supplied by the branches of the trigeminus (figs. 805, 807). Th supplied medially by the supratrochlear, the infratrochlear, and the nasal branches ophthalmic division, and laterally by the infraorbital branch of the maxillary division upper eyelid is supplied by the supratrochlear, the supraorbital, and the lacrimal b of the ophthalmic division; the lower eyelid by the infratrochlear branch of the o mic division andby the infraorbital and the zygomaticofacial (malar) branches of the m division. The skin over the upper jaw and the zygomaticofacial (malar) bone is supp

infraorbital and zygomaticofacial branches of the maxillary division, that over the buccinator by the buccal branch of the mandibular division, and that over the lower jaw, from in front backward, by the mental, buccal, and auriculotemporal branches of the mandibular division, except a small part near the posterior border which receives its supply from the great auricular nerve.

The Cutaneous Areas of the Auricle

The upper two-thirds of the outer surface of the auricle (pinna) are supplied by the auriculotemporal branch of the mandibular division of the trigeminus, and the lower third by twigs of the great auricular nerve (fig. 805). The lower three-fourths of the cranial surface of the auricle are supplied by the great auricular nerve, and the upper fourth by the small occipital nerve. The posterior surface of the external auditory meatus receives filaments from the auricular branch of the vagus.

Fig. 806.—Diagram of the Cutaneous Areas of the Side of the Body and Part of the Limb. (After Head.)



The Cutaneous Areas of the Neck

The skin over the anterior part of the neck (figs. 805, 807) is supplied by the superficial cervical branch of the cervical plexus, which contains fibers from the second and third cervical nerves, and in the lower part of its extent, by the anterior supraclavicular nerves (suprasternal branches), which convey twigs of the third and fourth cervical nerves. The lateral part of the neck receives filaments from the second, third, and fourth cervical nerves by way of the great auricular, small occipital, and middle supraclavicular (supraclavicular) branches of the cervical plexus, and posteriorly the skin of the neck is supplied by the smallest occipital nerve and by the medial branches of the posterior primary divisions of the cervical nerves from the second to the sixth inclusive.

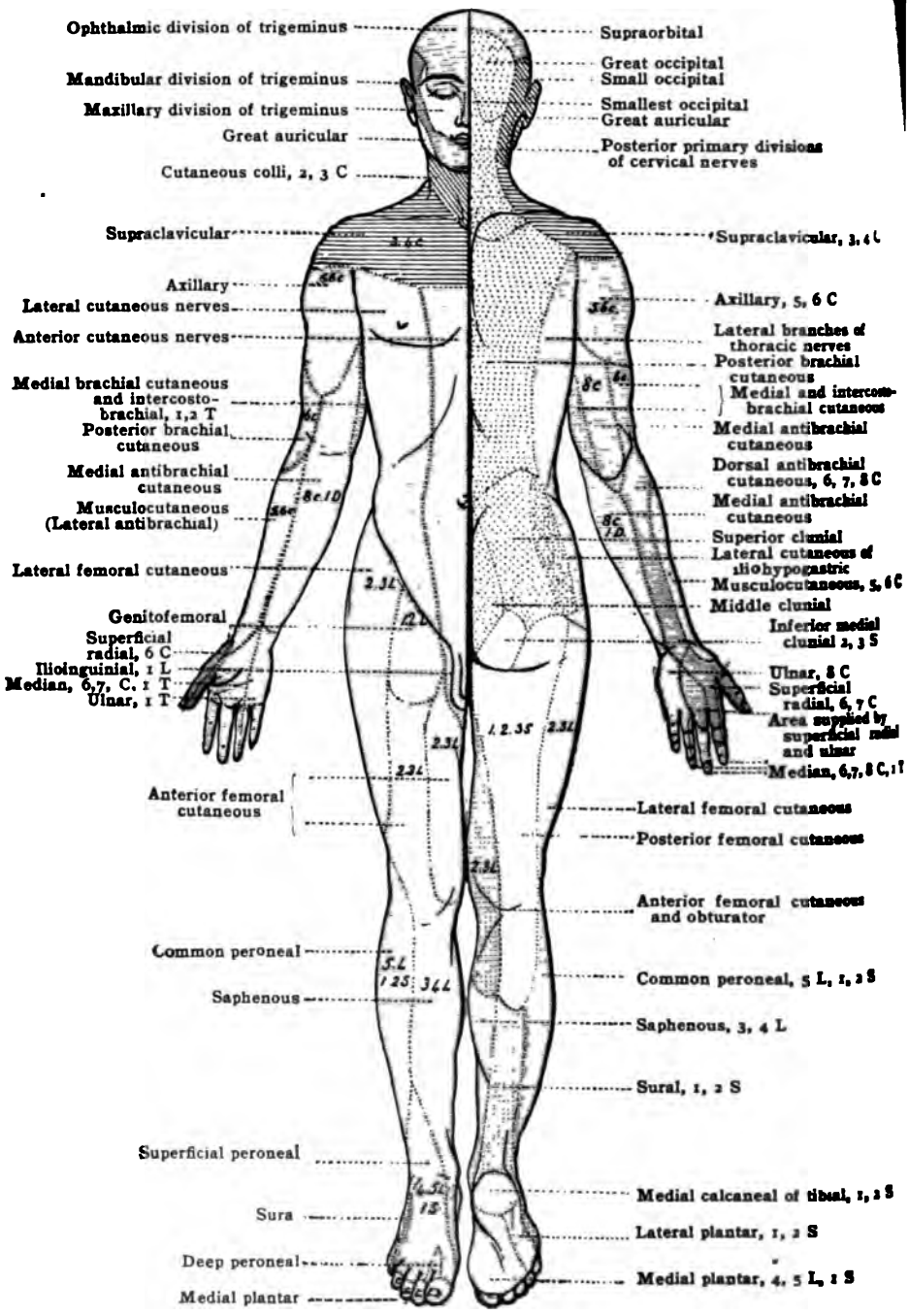
The Cutaneous Areas of the Trunk

The skin over the ventral aspect of the trunk as far down as the third rib is supplied by the anterior supraclavicular (suprasternal) and middle supraclavicular (supraclavicular) branches of the cervical plexus, which contain filaments from the third and fourth cervical nerves (fig. 807). From the third rib to the lower part of the abdominal wall the skin receives the anterior cutaneous branches, and the anterior divisions of the lateral cutaneous branches of the thoracic nerves except the first, second, and twelfth. The skin over the lower and anterior part of the abdominal wall is supplied by the ilio-hypogastric branch of the first lumbar nerve.

FIG. 807.—DIAGRAM SHOWING AREAS OF DISTRIBUTION OF CUTANEOUS NERVES.

HEAD:—RED—Ophthalmic division of trigeminus. White—maxillary division of trigeminus. Blue—mandibular division of trigeminus. Dotted area—Posterior primary divisions of cervical nerves. Oblique and transverse shading—Branches of cervical plexus.

BODY AND LIMBS:—RED—Anterior branches of anterior primary divisions. Blue—Posterior branches of anterior primary divisions. Two colors in one area indicate that the area is supplied by two sets of nerves, and it should be remembered that wherever two nerve areas approach each other they overlap. The dotted blue area of the posterior femoral cutaneous (small sciatic) indicates that the nerve comes from the posterior as well as from the anterior parts of the anterior primary divisions of the sacral nerves, but it supplies a flexor area. The area of the inferior medial cluneal nerve is left uncolored, because its true nature is uncertain. Dotted shading—posterior primary divisions. The numbers and initial letters refer to the respective spinal nerves from which the nerve-supplies are derived.



The cutaneous supply of the lateral aspects of the body (fig. 806) is derived from the lateral branches of the anterior primary divisions of the thoracic nerves from the second to the eleventh, and the skin over the dorsal aspect of the body is supplied laterally by the posterior divisions of the lateral branches of the thoracic nerves from the third to the eleventh, and medially by the posterior primary divisions of the thoracic nerves, in the upper half by their medial branches and in the lower half principally by their lateral branches.

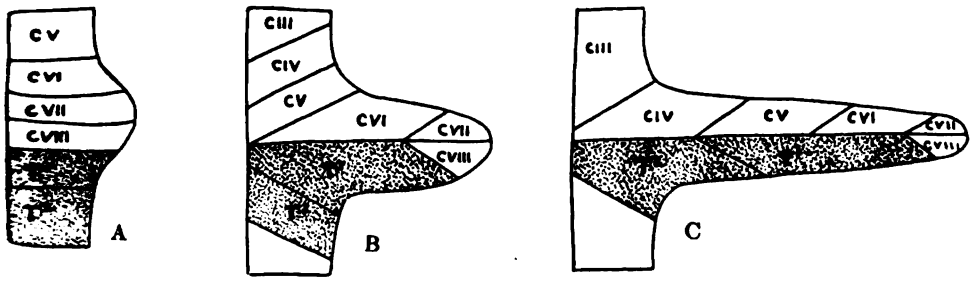
THE CUTANEOUS AREAS OF THE LIMBS

The areas of skin of the upper and lower limbs which are supplied by the branches of the brachial, lumbar, and sacral plexuses are indicated in fig. 807, and the spinal nerves which contribute to each nerve area are noted. The question of the skin areas supplied by any given spinal nerve is one of great clinical importance, in connection with the diagnosis of injuries of nerves and of pathological conditions affecting them. Therefore, considerable attention has been directed to the matter and it has been found that the areas which become hypersensitive when certain spinal nerve-roots are irritated, or anesthetic when the roots are destroyed, do not correspond exactly with the regions to which the fibers of the roots can apparently be traced by dissection.

Moreover, it has been discovered, partly by clinical observations on the human subject and partly by experiment on monkeys, that the nerves of the limbs have a more or less definite *segmental distribution*. To understand clearly this segmental arrangement the reader must remember that in the embryonic stage when no limbs are present the body is formed of a series of similar segments, each of which is provided with its own nerve. At a later stage when the limbs grow outward, each limb is formed by portions of a definite number of segments which fuse

FIG. 808.—DIAGRAMS A, B, AND C, ILLUSTRATING STAGES IN THE PROJECTION OF THE LIMB-BUDS FOR THE UPPER EXTREMITY, AND THE DRAWING OUT OF THE NERVES OF THE CORRESPONDING BODY SEGMENTS FOR THE CUTANEOUS AREAS OF THE PREAXIAL AND POSTAXIAL BORDER OF THE LIMB.

Postaxial border shaded.

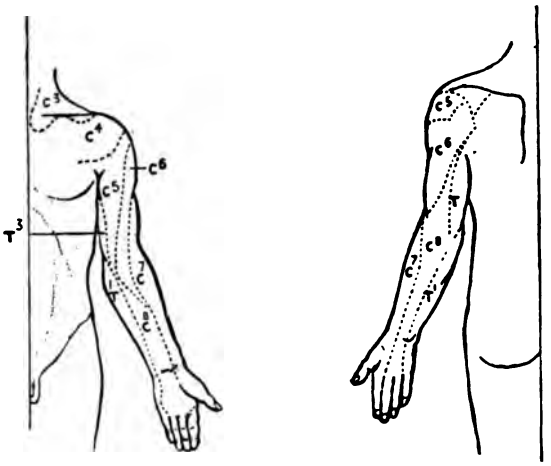


together into a common mass of somewhat wedge-like outline. Each rudimentary limb possesses a dorsal and a ventral surface. The dorsal surfaces of both the upper and the lower limbs are originally the extensor surfaces, and the ventral surfaces the flexor surfaces, but, as the upper limb rotates lateralward and the lower limb rotates medianward as development proceeds, in the adult, the extensor surface of the upper limb becomes the posterior surface, and the extensor surface of the lower limb, the anterior surface. The preaxial border of the upper limb is the radial or thumb border, and the postaxial border, the ulnar or little finger border. The preaxial border of the lower limb is the tibial or great toe border, and the postaxial border, the fibular or little toe border. As projections of the segments of the body grow out to form the limb-buds and limbs each projection carries with it the whole or part of the nerve of the segment to which it belongs, and therefore the number of body segments which take part in a limb is indicated by the number of spinal nerves which pass into it. If these facts are remembered it will naturally be expected (1) that the highest spinal nerves passing into a limb will be associated with its preaxial portion and the lowest with its post-axial portion; (2) that only the nerves of those segments forming middle or central portions of the limbs will extend to the tips of the limbs; (3) that the highest and lowest segments in each limb area will take a smaller part in the formation of the limb that the middle segments; and (4) that, consequently, the highest and lowest nerves will pass outward into the limb for a shorter distance than the middle nerves. Observers are not yet in perfect agreement as to the exact distribution of each nerve, but the diagrams in figs. 806 to 812 show the embryonic derivation of the cutaneous areas and the adult dorsoventral segmental arrangement in the projected portions of both the upper and lower limbs as assumed from clinical observations. In the upper parts of the lower limbs, the original segmental distribution appears to be masked. This may be due (1) partly to the fact that the areas recognizable by clinical phenomena do not correspond exactly with the areas to which definite dorsal root-fibers are distributed, but rather to definite segments of the gray substance of the spinal cord with which the root-fibers are connected; (2) partly to the overlapping of segments and the acquired preponderance of one nerve over another in the overlapping areas, and (3) partly to the fact that in the lower limb there has been a greater amount of shifting of parts to result in the fixed flat position of the sole of the foot; (4) and partly to the incompleteness of the data which are at our disposal in the case of the human subject. Sherrington has proved that in the monkey the sensory areas of the limbs are arranged in serial correspondence

with the spinal nerves, the middle nerves of each limb series passing to the distal par extremity while the higher and lower nerves are limited to the proximal regions. Th observations, which differ from Head's, are, especially as regards the upper limb, conformity with the results obtained by Sherrington's experiments on monkeys.

Each limb may be divided into its preaxial and postaxial borders by a line dra tudinally along the middle of both its anterior and posterior surfaces (compare figs. 808

FIG. 809.—DIAGRAM OF THE CUTANEOUS AREAS OF THE UPPER EXTREMIT (Modified from Head.)

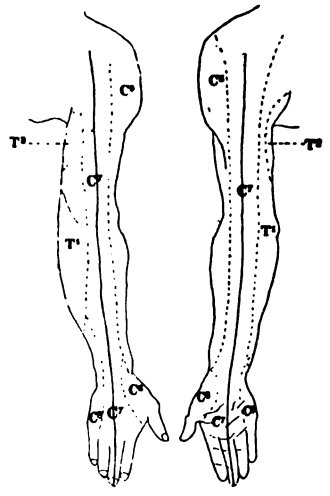


The cutaneous nerves to the preaxial border are from the cephalic portion of the li and those to the postaxial are from the caudal components of the plexus. Thus t and index finger are cephalad.

THE CUTANEOUS AREAS OF THE UPPER LIMB

A line passing along the middle of both the anterior and posterior surfaces of the tremity to the tip of the middle finger (fig. 810) separates the preaxial from the border and passes longitudinally along the area of the cutaneous fibers derived from t cervical nerve.

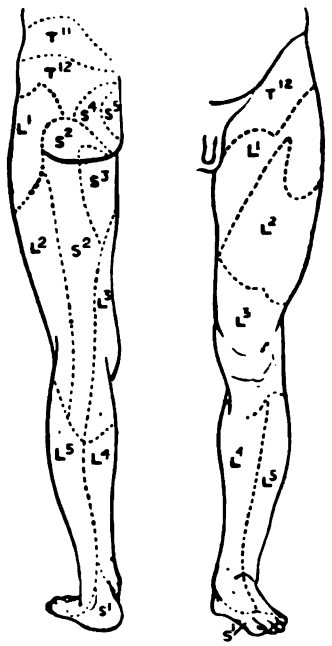
FIG. 810.—DIAGRAM OF THE CUTANEOUS AREAS OF THE UPPER EXTREMI The solid middle lines are drawn to separate preaxial (radial) borders from postaxi (After Thorburn, modified.)



The skin over the upper third of the deltoid muscle is supplied by the poste clavicular (supra-acromial) and middle supraclavicular (supraclavicular) nerves, branches of the cervical plexus containing fibers of the third and fourth cervical that over the lower two-thirds by the axillary (circumflex) nerve which conveys f fifth and sixth cervical nerves (fig. 807).

The skin over the lateral surface of the upper arm is supplied externally by the axillary (circumflex) nerve above, and below by the superior branch of the dorsal antibrachial cutaneous, the external cutaneous branch of the radial (musculospiral) nerve. The former contains filaments of both the fifth and sixth cervical nerves, and the latter filaments of the sixth alone. The skin of the medial side of the upper arm is supplied by the medial antibrachial cutaneous (internal cutaneous) nerve with fibers of the eighth cervical and first thoracic nerves, and by the medial brachial cutaneous (lesser internal cutaneous) and intercostobrachial (intercostohumeral) nerves which are derived from the first and second thoracic nerves. The dorsal side of the upper arm is supplied, laterally, by the fifth and sixth cervical nerves through the axillary (circumflex) nerve and by the dorsal antibrachial cutaneous; the middle portion, by the seventh cervical nerve through the posterior brachial cutaneous, the internal cutaneous branch of the radial (musculospiral) nerve; and the medial portion by the first and second thoracic nerves through the medial brachial cutaneous (lesser internal cutaneous) nerve, and the intercostobrachial (intercostohumeral) nerve (fig. 807).

FIG. 811.—DIAGRAM OF THE CUTANEOUS AREAS OF THE LOWER EXTREMITY. (After Head.)



The front of the forearm is divided into three areas, a lateral which is supplied by the fifth, sixth, and possibly the seventh cervical nerves, through the musculocutaneous branch of the brachial plexus; a middle which is supplied by the seventh cervical nerve as above, and a medial area supplied by the eighth cervical and first thoracic nerve through the medial antibrachial cutaneous (internal cutaneous) nerve. On the dorsal side of the forearm there are three areas: —(1) a lateral supplied by fibers of the fifth and sixth cervical nerves through the musculocutaneous nerve; (2) a middle, which receives fibers of the seventh, and probably some from the sixth and eighth cervical nerves through the lower branch of the dorsal antibrachial cutaneous branch of the radial (inferior external cutaneous branch of the musculospiral nerve), and (3) a medial which receives fibers from the eighth cervical and first thoracic nerves through the medial antibrachial cutaneous (figs. 807, 810).

The palm of the hand is supplied by the sixth, seventh, and eighth cervical nerves through the superficial radial (radial) nerve, and through the median and ulnar nerves. The superficial radial supplies the radial side of the thumb by its palmar cutaneous branch. The remainder of the palm and the palmar aspects of the fingers are supplied by the median and ulnar nerves through their palmar cutaneous and digital branches, the median supplying three and a half digits and the ulnar the remaining one and a half (figs. 791, 807 and 810).

The dorsal aspect of the hand is supplied by the sixth, seventh, and eighth cervical nerves, which reach it through the superficial radial (radial) and through the median and ulnar nerves. The superficial radial supplies the lateral part of the dorsum and the lateral three and a half digits, except the lower portions of the second, third, and half of the fourth digits, which receive twigs from the median nerve; the ulnar nerve supplies the ulnar half of the dorsum of the hand, including the medial one and a half digits. The areas supplied by definite spinal nerves according to the observations of Head and Thorburn, are shown in figures 809 and 810 respectively.

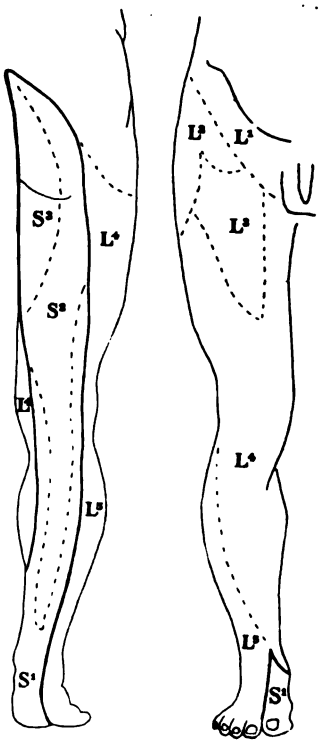
THE CUTANEOUS AREAS OF THE LOWER EXTREMITY

The segmental arrangement of the cutaneous areas of the lower extremity is not so well retained as in the upper, due largely to a greater amount of developmental shifting of the parts.

Both of the lines separating the areas of the lumbar (cephalic) and the sacral (caud of the lumbosacral plexus lie on the dorsal aspect of the limb. The nerves from the part of the plexus are distributed to the entire anterior and the medial and lateral su the limb and to the muscles of the anterior and medial portions of the thigh and the portion of the leg, whereas the cutaneous nerves from the sacral part of the plexus fined to a narrow strip along the dorsal aspect of the limb (fig. 812). However, the n distribution of the sacral part is as much expanded as its cutaneous area is contracted; it the muscles in the dorsal portions of the hip, thigh and knee, the whole of the dorsa the leg and ankle and the plantar muscles of the foot.

There are six cutaneous areas in the region of the buttock, three upper and thr Of the upper areas the lateral is supplied by the anterior primary divisions of the last and first lumbar nerves through the iliac branches of the last thoracic and the iliohy nerves; the middle upper area receives the lateral divisions of the posterior primary of the upper three lumbar nerves, and the medial upper area is supplied by twigs from th branches of the posterior primary divisions of the upper two or three sacral nerves (811).

FIG. 812.—DIAGRAM OF THE CUTANEOUS AREAS OF THE LOWER EXTREMIT (After Thorburn, modified.)



Of the lower three areas, the lateral receives filaments from the second and thi nerves through the lateral femoral cutaneous (external cutaneous) branch of the lumb the middle area is supplied by the first, second, and third sacral nerves through th femoral cutaneous (small sciatic) nerve; and the medial area by the second and th nerves through the medial inferior clunial (perforating cutaneous) branch of the sa (fig. 807).

On the back of the thigh there are three areas. According to Head, the medial a areas are supplied by the second and third lumbar nerves, the former through t femoral cutaneous (external cutaneous) branch of the lumbar plexus, and the latte the anterior cutaneous branches of the femoral (internal cutaneous branch of th crural) nerve. The middle area receives twigs from the first, second, and third sac through the posterior femoral cutaneous (small sciatic), a branch of the sacral plexu

The front of the thigh is supplied by the first, second, and third lumbar nerves, and, to Head, there are five cutaneous areas. The lateral area receives twigs of the second lumbar nerves through the lateral (external) cutaneous nerves. There are two me an upper and a lower. The former is supplied by the lumboinguinal (crural) branch of t femoral (genitocrural), which conveys twigs of the first and second lumbar nerves; receives fibers of the second and third lumbar nerves through one of the anterio cutaneous branches of the femoral (anterior crural) nerve. The small upper and mec supplied by the first lumbar nerve through the ilioinguinal, and the lower medial ar twigs of the second and third lumbar nerves through one of the anterior cutaneou (internal cutaneous) of the femoral (anterior crural) nerve (fig. 807).

The front of the knee is supplied by the second, third, and fourth lumbar nerves through the anterior (middle and internal) cutaneous and saphenous (long saphenous) branches of the femoral (fig. 807).

Of the skin over the region of the popliteal space, the medial portion receives fibers from the second, third, and fourth lumbar nerves through the anterior (internal) cutaneous branch of the femoral (anterior crural) nerve and through the superficial division of the obturator nerve; the middle and lateral portion receives twigs of the first three sacral nerves through the posterior cutaneous (small sciatic) nerve (fig. 807).

The skin over the front and medial side of the leg is supplied by the fourth lumbar nerve through the saphenous nerve, and the skin of the front and lateral side receives nerve-fibers from the fifth lumbar nerve through the sural cutaneous (fibular communicating) branch of the common peroneal (external popliteal) nerve.

In the skin of the back of the leg four areas can be distinguished, a medial, two middle, upper and lower, and a lateral area. The medial area is supplied by the fourth and fifth lumbar nerves through an anterior cutaneous branch (internal cutaneous) of the femoral (anterior crural) nerve and the superficial branch of the obturator nerve. The upper middle area is supplied by the second and third sacral nerves through the posterior femoral cutaneous (small sciatic) nerve, and the lower middle area by the first sacral nerve through the sural (external saphenous) nerve. The lateral area is supplied by the fifth lumbar nerve through the lateral sural cutaneous (fibular communicating) branch of the common peroneal (external popliteal) nerve (figs. 807, 811, 812).

The skin of the dorsum of the foot is supplied principally by the fifth lumbar and by the first sacral nerves; the majority of the nerve-fibers travel by the superficial peroneal (musculocutaneous) nerve, but the adjacent sides of the first and second toes are supplied by the femoral (anterior crural) nerve and the side of the dorsum of the little toe is supplied through the sural (external saphenous).

The skin of the region of the heel is supplied by the first sacral nerve, the medial surface and medial part of the under surface by the medial calcaneal branches of the tibial calcaneoplantar) nerve and the posterior, external, and lower aspects by the sural (external saphenous) nerve (fig. 807).

The sole of the foot in front of the heel receives cutaneous fibers from the fifth lumbar and the first sacral nerves; the medial area, which includes the medial three and a half digits, being supplied by the medial plantar nerve which conveys fibers of the fifth lumbar and the first sacral nerves; and the lateral area by the fifth lumbar nerve through the lateral plantar nerve.

The medial side of the foot is supplied by the first sacral and fourth lumbar nerves through the saphenous nerve and the lateral side by the fifth lumbar nerve through the sural (external saphenous) nerve.

The skin of the scrotum and penis is supplied by the first lumbar nerve through the ilioinguinal nerves, and by the second and third sacral nerves through the perineal and dorsal penile branches of the pudendal (pudic) nerve.

The cutaneous areas of the lower extremity which have been demarcated by Head and Thorburn are shown in fig. 811. These do not conform wholly with each other nor with the areas given in more detail in fig. 807, due probably to individual differences in subject and observer and to the difficulties coincident with the overlapping of the areas. Fig. 812 is more general in character and is considered more approximately correct.

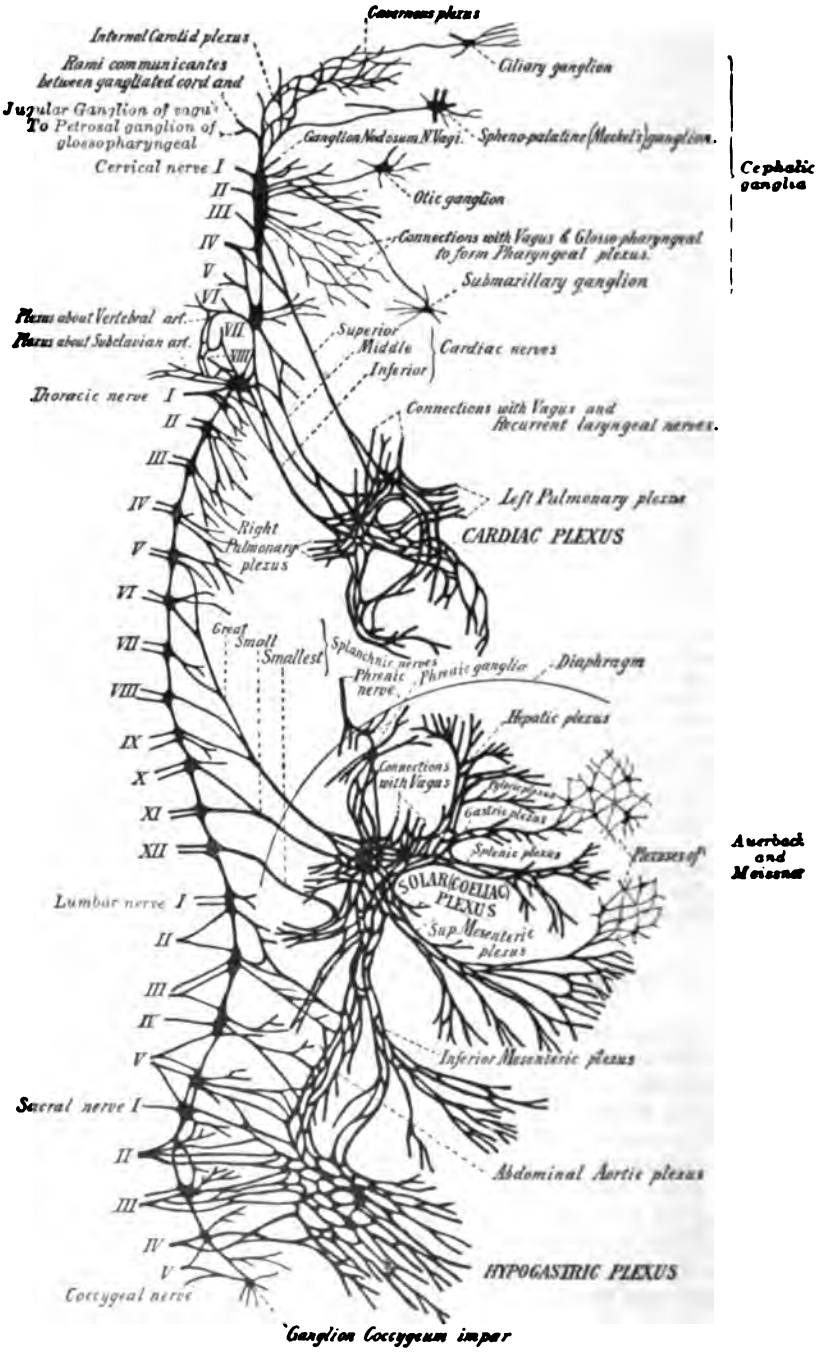
The homology of the parts of the plexuses of the upper and lower extremities is not well carried out in the distribution of the nerves. The radial and great sciatic nerves are similar to the extent that the one arises from the posterior cord of the brachial plexus and the other from the sacral plexus, and that the one is distributed to the dorsal aspect of the arm and the other to the dorsal surface of the lower extremity, but the great sciatic supplies the sole of the foot, and the plantar muscles, whereas the radial does not supply the palm of the hand and the palmar muscles.

THE SYMPATHETIC SYSTEM

The so-called sympathetic system is that collateral division of the peripheral nervous system which is especially concerned in the distribution of impulses to all glands, to the muscle of the heart, and to the plain muscular tissue of the body (including that of blood- and lymph-vessels, of the digestive, respiratory and urogenital apparatuses, integument, etc.). Since these tissues are most abundant in and largely comprise the viscera or splanchnic organs of the body, the largest and most evident of the structures comprising the sympathetic system are found either in or near the cavities containing the viscera. However, the finer divisions of the system ramify throughout the whole body, supplying vasomotor fibers to the blood-vessels throughout their course, controlling the glands of the skin, and supplying pilomotor fibers for the hairs, and forming intrinsic plexuses within the walls of the viscera. Though it seems probable that certain of the simpler reflexes of the splanchnic organs may be mediated by the sympathetic system alone, yet the sympathetic is by no means independent of the craniospinal system, but is rather, both anatomically and functionally merely a part of one continuous whole. Throughout, it shares its domain of termination with craniospinal fibers, chiefly of the sensory variety, and most of its rami and terminal branches carry a few craniospinal fibers toward their areas of distribu-

tion. Likewise the craniospinal nerves carry numerous sympathetic fibers gained by way of rami connecting the two systems.

FIG. 813.—SCHEME SHOWING GENERAL PLAN OF THE COARSER PORTIONS OF THE SYMPATHETIC NERVOUS SYSTEM AND ITS PRINCIPAL COMMUNICATIONS WITH THE CEREBROSPINAL SYSTEM (After Flower, modified.)



Like the craniospinal system, the sympathetic consists of cell-bodies, each of which gives off one axone. In addition, the cell-bodies give off numerous dichotomously branched dendrites by which their receptive surfaces are increased, and they are accumulated into ganglia large and small. The larger ganglia have more or less constant positions, shapes, and arrangements, while the smaller, some of which are microscopic, are scattered throughout the body in a seemingly more indefinite manner. The axones or fibers arising in these sympathetic ganglia

en off in trunks and rami which associate the ganglia with each other or with the cranio-
system, or which pass from the ganglia to be distributed directly upon their allotted
its.

e **sympathetic fibers** arising from the ganglia are, for the most part, either totally non-
ated or partially medullated. Some fibers are completely medullated near their cells
in, but lost their medullary sheaths before reaching their terminations. Some of them
complete medullary sheaths throughout, but in no cases are the sheaths as thick or
veloped as is the rule with the craniospinal fibers. Thus, nerve-trunks and rami in
sympathetic fibers predominate appear grayish in color and more indefinite, as dis-
hed from those of the craniospinal nerves, which always appear a glistening white, due
t being reflected from the emulsified myelin of the sheathes of their fibers.

gin of the sympathetic system.—Not only must the craniospinal and sympathetic
s be considered anatomically continuous and dependent, but also the neurones of the
stems have a common origin, namely, the ectoderm of the dorsal midline of the embryo.
lls of the ganglion crest (see p. 790) become arranged in segmental groups and soon
te into two varieties:—those which will remain near the spinal cord and develop into
nal ganglia, and those which, during the growth processes, migrate and become displaced
r into the periphery and form the sympathetic ganglia.

the development of the sympathetic system the migration from the vicinity
e central system occurs to varying extents, so that in the adult the
comprise three general groups of ganglia situated different distances away
the central nerve axis.—(1) A large portion of the cells remain near the
al system and form a linear series of ganglia which, with the trunks con-
ng them, become two gangliated *sympathetic trunks* extending along each side,
mal to and parallel with the vertebral column; (2) a still larger portion of the
migrate further toward the periphery and are accumulated into *collateral*
ia which assume an intermediate position and which, with the rami asso-
g them with each other and with other structures, form a series of great
tebral plexuses, such as the aortic, cardiac and celiac plexuses; (3) still other
wander even further away from the locality of their origin and invade the
walls of the organs innervated by the sympathetic system. The latter cells
as numerous small *terminal ganglia*, most of which are microscopic and
, with the twigs connecting them, form the most peripheral of the sympa-
plexuses. Examples of these are the intrinsic ganglia of the heart and
eas and the *plexuses of Auerbach* and *Meissner* in the walls of the digestive
. Small, straggling ganglia may be found scattered between these three
al groups. In the head, the sympathetic trunks and great prevertebral
ses are represented by the ciliary, sphenopalatine, otic and submaxillary
ia and the plexuses associated with these.

nstruction of the sympathetic system.—The sympathetic ganglia may be
lered as relays in the pathways for the transmission of impulses from the
in which they arise to the tissues in which they are distributed; the cells
osing the ganglia are the cell-bodies of the sympathetic neurones interposed
various neurone chains performing this function. A fiber arising from a
ody in a given ganglion may pass out of the ganglion and proceed directly to
mination upon a smooth muscle-fiber or gland-cell, or, fibers arising in given
ia may pass uninterrupted through other ganglia and proceed to their re-
ve destinations. Several neurones, only one being sympathetic, may be
ed in the transmission of a given impulse when sent from a region distant
the tissue to which it is distributed.

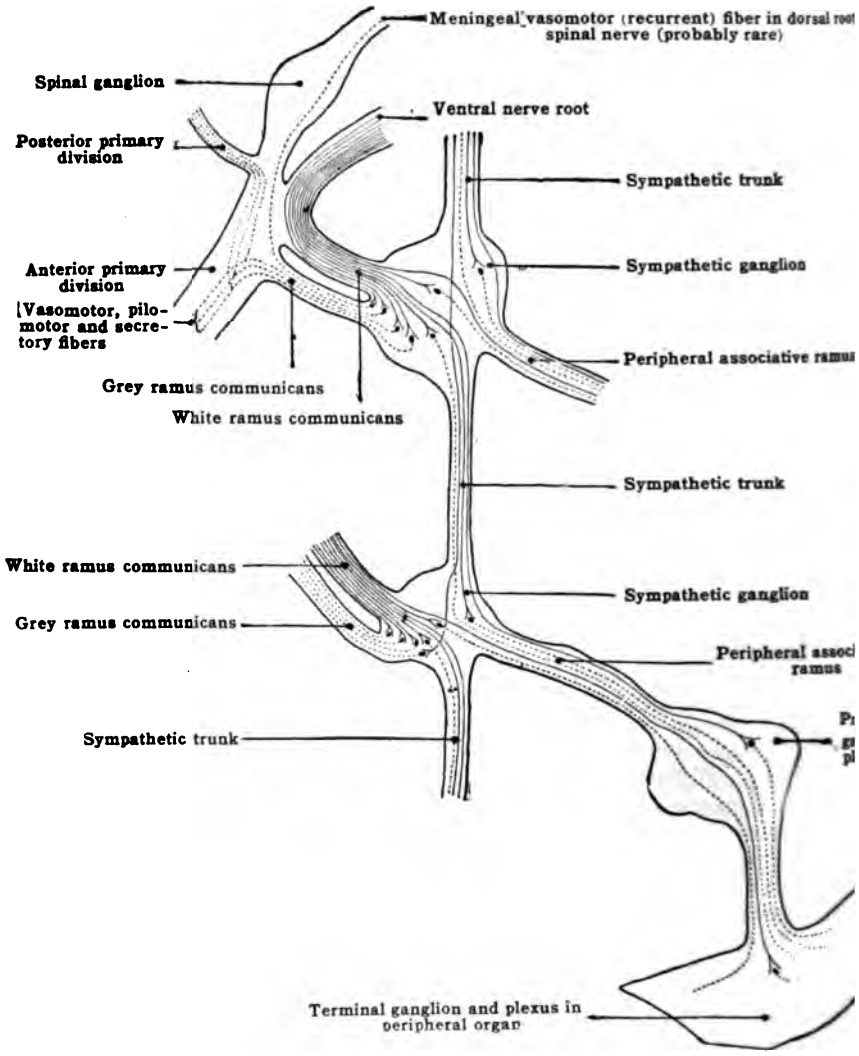
mmunication between the central nervous system and the sympathetic is
lished through both efferent and afferent fibers. In the region of the
l cord both varieties of fibers pass from one system to the other by way of the
communicantes, delicate bundles of fibers connecting the nearby sympa-
trunk with the respective spinal nerves (fig. 779). The cranial nerves are
se abundantly associated with the gangliated cephalic sympathetic plexuses.

e efferent fibers of the rami arise in the ventral horn (dorsolateral cell-group chiefly) of
nal cord, emerge through the ventral roots, enter the rami, and terminate about the cells
sympathetic ganglia. Since these fibers transmit impulses from the central to the sympa-
system, they are known as **visceral efferent** or **preganglionic fibers.** They are of smaller
an is the average for the craniospinal somatic efferent fibers of the ventral root.

ie thoracic and lumbar spinal nerves are each connected with the sympa-
trunk by two rami communicantes. Most of both the visceral efferent and
he visceral afferent fibers (which latter arise in the spinal ganglia) pass
ay of one ramus. These fibers are of craniospinal type and, being medul-

lated, they give the ramus a white appearance meriting the name, **white r communicans.** Fibers of the sympathetic type predominate in the w ramus, the **gray ramus communicans.** The latter consists of (1) fibers cen directed in the nerve and nerve roots to the blood vessels of the central ne system and (2) fibers which join the primary divisions of the nerve trun course in them to the peripheral tissues allotted to the sympathetic (fig. The cervical nerves have gray rami but no distinct white rami.

FIG. 814.—DIAGRAM SUGGESTING THE ORIGIN, COURSE AND CONNECTIONS OF SYMPATHETIC NERVE-FIBERS.



That the cervical nerves have no white rami communicantes is probably due to an ment by which at least most of the visceral efferent fibers arising in the cervical segme spinal cord pass downward in these segments and join the sympathetic through the whi the upper thoracic nerves; others enter the cervical sympathetic trunk and the va through the spinal accessory or eleventh cranial nerve, rather than through individual wh while others pass into the nerves of the brachial plexus to terminate in the minute gan plexuses upon the blood-vessels of the limb.

Vasomotor fibers to the meninges and intrinsic blood-vessels of th cord pass to the spinal nerves by way of the gray rami. Thence they m the meninges by one of three ways:—(1) through the delicate recurrent ingeal branch of the spinal nerve (fig. 779); (2) through the trunk and root of the spinal nerve; (3) probably more rarely, through the trunk an root of the spinal nerve (fig. 814).

Corresponding communications exist between the cranial nerves and the sympathetic, but the corresponding rami usually extend further toward the periphery and in not so regular a manner as the communications between the spinal nerves and the sympathetic system. The mesencephalon, for example, is chiefly connected with the ciliary ganglion of the sympathetic by fibers which are sent through the oculomotor nerve and which enter this ganglion by way of its short root and terminate about its cells. Visceral efferent fibers from the rhombencephalon pass outward to the sympathetic in the roots of the facial, glossopalatine, glossopharyngeal, vagus, and spinal accessory nerves, all of which have more or less irregularly disposed communicating rami. Likewise twigs of other cranial nerves, especially of the trigeminus, connect with (pass through) the small sympathetic ganglia of the head. The meningeal branches given by certain of the cranial nerves contain vasomotor fibers, and these correspond to the sympathetic fibers in the meningeal rami and in the roots of the spinal nerves.

It is known that spinal ganglia and certain of the ganglia of the cranial nerves contain cell-bodies of sympathetic neurones—cell-bodies which, during the period of the migration peripheralward, remained within the confines of these ganglia (fig. 779). These cell bodies receive efferent impulses from ventral root fibers and send their axones further into the periphery just as if in the sympathetic ganglion. Their relative abundance is not known. It is supposed that the ganglia of the vagus, glossopharyngeus, trigeminus and the geniculate ganglion contain a considerable proportion of such sympathetic cell-bodies.

According to the groups of sympathetic ganglia in which they make synapses, the visceral efferent fibers, or chief components of the white rami communicantes, may be described as coursing from their origin in the central system in two general streams:

(1) A *thoracolumbar stream* comprising visceral efferent fibers which pass from their origin in the spinal cord almost wholly by way of the white rami of from the first thoracic to the second lumbar spinal nerves inclusive and terminate (transfer their impulses) for the most part in the ganglia of the sympathetic trunk. Some terminate in the intermediate or collateral ganglia of the prevertebral plexuses. None are said to terminate in the terminal ganglia. Of those terminating in the ganglia of the trunk, some terminate in the nearest ganglia or those corresponding to their respective spinal nerves. Others enter the trunk and ascend or descend in it to terminate in ganglia of higher or lower levels. In general, fibers from the upper white rami of the stream run upward and those from the lower run downward. The fibers of the sympathetic trunks consist largely of these ascending and descending fibers. Fibers arising from the cells of the ganglia of the trunks pass out either by way of their peripheral branches, or, by way of the gray rami, join the spinal nerves to course to their destination in the terminal branches of these.

(2) A *sacral or pelvic stream* which arises from the inferior end of the spinal cord and passes almost wholly by way of the white rami of the second, third and fourth sacral nerves, usually, chiefly by the second and third or the third and fourth. Fibers of this stream do not terminate in the ganglia of the trunk, but pass either by them without connection or over them or through them without interruption, to terminate chiefly in the terminal ganglia. Some may terminate in the collateral ganglia.

The relations of the visceral efferent fibers of the cranial nerves to the sympathetic, when contrasted in this way, suggest the addition of a *cranial stream*. The visceral efferent fibers arising from the brain pass outward almost entirely by way of the vagus, spinal accessory, glossopharyngeal, facial, glossopalatine and oculomotor nerves. If the four pairs of the larger ganglia of the cephalic sympathetic plexus are considered as the superior extensions of the sympathetic trunks of each side, then, the cranial stream is similar to the sacral stream in part only. Most of the visceral efferent fibers of the oculomotor, glossopalatine and facial nerves, and some of those in the glossopharyngeal and probably the vagus terminate in these larger cephalic ganglia, while a very large proportion of those in the vagus and spinal accessory are not concerned at all with the cephalic ganglia, large or small, but pass to terminate in collateral and terminal ganglia below and removed from the region of the head. If, on the other hand, the sympathetic trunk be considered as terminating above with the superior cervical sympathetic ganglion and its branches of distribution to the head, then all the ganglia, large and small, of the cephalic sympathetic plexus must be considered as collateral and terminal ganglia of the sympathetic. Such analogy makes all the visceral efferent fibers of the cranial nerves similar to those of the sacral stream and thus makes possible reference to the two general streams of the body as a *thoracolumbar* and a *craniosacral stream*.

In general, these two streams of visceral efferent fibers are antagonistic in function. By way of them, the visceral organs receive a double innervation, one producing contractions of smooth and cardiac muscle, such as vasoconstrictor, pilomotor and peristaltic activities, the other inhibiting these; or, one exciting muscular contractions antagonistic to the contractions excited by the other. For example, the pupil is contracted by way of the cranial stream while its dilation is accomplished by way of the thoracolumbar stream. Inhibitory impulses are not confined to either stream. The craniosacral stream carries fibers inhibitory to the heart (the vagus proper) and fibers which excite peristalses in the stomach and intestine, while the thoracolumbar stream carries accelerator fibers for the heart and fibers inhibiting peristalses in the stomach and intestine.

For purposes of distinction, some physiologists refer to the neurones of the sacral (or craniosacral) visceral efferent stream, taken together with the sympathetic ganglion neurones with which the former make synapses, as the *parasympathetic system*, and reserve the name, *sympathetic system*, for the thoracolumbar stream, together with the sympathetic neurones with which they are chained. Further, the English physiologists (Langley especially) have suggested

the name, 'Autonomic nervous system,' to include the sum total of all the craniospinal visceral efferent neurones (preganglionic fibers, craniosacral and thoracolumbar) and all the sympathetic ganglion neurones (postganglionic fibers) in the body. This name includes those fibers which arise in sympathetic ganglia and enter and course to their destination in the trunks and branches of the craniospinal nerves; it includes the entire efferent innervation of all gland and cardiac and smooth muscle. As to function implied, the name is as misleading as the old term, 'Sympathetic system,' though it is anatomically more comprehensive. In microscopic anatomy, the visceral efferent preganglionic fibers, included in the name, are considered craniospinal fibers instead of part of the sympathetic system.

Visceral afferent fibers.—The sensory innervation of the visceral organs (enteroceptive) is accomplished by the peripheral processes of spinal ganglion neurones, and those of the ganglia of cranial nerves, which course outward in the nerve trunks to join the sympathetic either by way of the terminal branches of these trunks or by way of the white rami communicantes and thence through the sympathetic nerves and their terminal branches. They are merely craniospinal sensory fibers which collect impulses in the domain of the sympathetic and convey them to the central system by way of the sympathetic rami and the trunks and dorsal roots of the cranial and spinal nerves. Naturally, they pass through sympathetic ganglia without interruption. They serve chiefly to give rise to visceral reflexes. The sensations aroused by the impulses they carry to the central system are usually vague and indefinite, and most of the impulses do not enter consciousness at all. The cranial nerves carrying most visceral afferent fibers are the vagus, glossopharyngeus and trigeminus. There is no satisfactory evidence, once claimed, of afferent or sensory fibers arising from the cells of sympathetic ganglia.

Myenteric visceral reflexes.—There is evidence that purely local reflexes are possible within the walls of the digestive canal. Contractions of reflex character may be induced in the stomach and intestine after all the nerves leading to them have been cut—contractions different from the myogenic contractions which occur upon direct mechanical stimulation of the muscle and much different from the automatic contractions of excised cardiac muscle. They suggest the existence of complete reflex arcs within the wall of the gut. If so, the terminal ganglionated plexuses (of Auerbach and Meissner) within the wall must be concerned in them. They must depend upon an anatomical mechanism different from that of all other reflex arcs, but the mechanism is unknown. All other visceral reflexes involve at least three neurones: a visceral afferent neurone, a craniospinal visceral efferent or preganglionic neurone, and a sympathetic or postganglionic neurone. *Local enteric reflexes* would be a more expressive name for them than myenteric visceral reflexes.

From the above it may be seen that the ganglia and connecting trunks and rami of the sympathetic system may be divided as follows:—(1) The two gangliated **sympathetic trunks** lying adjacent to and parallel with the vertebral column; (2) the **great prevertebral plexuses,** containing the intermediate or collateral ganglia, of which plexuses there are roughly four, one in the head, one in the thorax, one in the abdomen, and one in the pelvic cavity (**fig. 813**), each of which is subdivided; (3) the numerous **terminal ganglia and plexuses** situated either within or close to the walls of the various organs; (4) the **trunks** and **rami** connecting the ganglia with each other and thus contributing to the plexuses, or connecting the ganglia with other nerves or with organs with whose innervation they are concerned. The trunks and rami may be divided into—(*a*) the *rami communicantes,* or *central branches,* connecting the sympathetic with the craniospinal and central systems; (*b*) *communicating trunks,* best considered as those which connect sympathetic ganglia situated on the same side of the body; (*c*) *commissural branches,* or those which pass between ganglia situated on opposite sides of the midline of the body, such as the transverse connecting branches between the sympathetic trunks in the lumbosacral region (**fig. 815**), or all the trunks between the ganglia of plexuses occupying the midregion of the body: (*d*) *terminal* or *peripheral branches,* or those which pass from the ganglia to their final distribution in the tissues they innervate, apparently uninterrupted by other ganglia.

THE SYMPATHETIC TRUNKS

The **sympathetic trunks,** or gangliated cords, of the sympathetic system are two symmetrical trunks with ganglia interposed in them at intervals of varying regularity, and extending vertically, one on each side of the ventral aspect of the vertebral column, from the second cervical vertebra to the first piece of the coccyx (figs. 813, 815). Upon the coccyx the two trunks unite and terminate in a single median ganglion, the **ganglion coccygeum impar.** The various ganglia are connected with the craniospinal nerves by the rami communicantes. Morphologically, each trunk might be expected to possess thirty-one ganglia, one for each spinal nerve, but, owing to the fusion of adjacent ganglia in certain regions, especially in the cervical, there are in the adult only twenty-one or twenty-two ganglia in each trunk. These occur as *three cervical ganglia, ten or eleven thoracic*

glia, four lumbar and four sacral ganglia, and the *ganglion coccygeum impar,* which is common to both trunks.

In the cervical region the sympathetic trunks lie in front of the transverse processes of the vertebræ, from which they are separated by the longus capitis and longus colli; in the thoracic region they lie at the sides of the bodies of the vertebræ and on the heads of the ribs; in the lumbar region they are placed more ventrally with reference to the spinal nerves and more in front of the bodies of the vertebræ and along the anterior borders of the psoas muscles; in the pelvis the ganglia lie between and ventral to the openings of the sacral foramina. In the lower lumbar and sacral region one ganglion may send rami communicantes to two spinal nerves and one spinal nerve may be connected with two ganglia. The ganglia of the trunks throughout give off communicating branches to the ganglia of the prevertebral plexuses and branches to the nearby viscera and blood-vessels. These branches may appear either white or gray according to the predominance of medullated or non-medullated fibers in them. In the lumbosacral region commissural or transverse branches between the ganglia of the two trunks are especially abundant. In trunks having a whiter appearance, the greater part of the medullated fibers producing it are sensory and visceral efferent fibers from the spinal nerves which have passed through the sympathetic ganglia without termination. The nerve trunks connecting the ganglia of the sympathetic trunks all contain three varieties of fibers:—(1) visceral efferent fibers which have entered them in the white rami communicantes from the spinal nerves of higher or lower levels, and which are coursing in them to terminate in other ganglia, either in the trunks above or below or in ganglia not belonging to the trunks; (2) fibers arising in sympathetic ganglia of a higher or lower level and passing upward or downward to issue from the trunk and proceed to the tissues they supply; (3) visceral afferent fibers or sensory fibers arising in the spinal ganglia.

THE CEPHALIC AND CERVICAL PORTIONS OF THE SYMPATHETIC TRUNK

The cephalic portion of the sympathetic system consists of numerous small ganglia and of numerous plexuses connected with the internal carotid nerve, the ascending branch given off by the superior cervical sympathetic ganglion. The cephalic ganglia are all relatively small. There are four considered in the ordinary macroscopic dissections, namely, the ciliary (ophthalmic), the sphenopalatine (Meckel's ganglion), the otic, and the submaxillary. To these may be added a portion of the superior cervical sympathetic ganglion, the sympathetic portions of the nodosal, petrous, geniculate and semilunar ganglia, and the various small ganglia dispersed in the plexuses. These ganglia with their roots or communicating branches have been described in their relations with the divisions of the trigeminus and with the oculomotor, glossopalatine, vagus and facial nerves. (See GANGLIATED CEPHALIC PLEXUS.)

The internal carotid nerve, the **ascending branch** from the superior cervical sympathetic ganglion, may be regarded as an upward prolongation of the primitive sympathetic trunk.

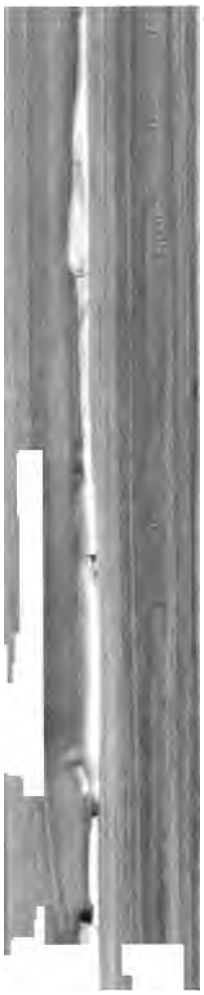
It arises from the upper end of the superior cervical ganglion and passes through the carotid canal into the cranial cavity. It divides into two branches which subdivide to form a coarse plexus, the *internal carotid plexus,* which partly surrounds the internal carotid artery before the latter enters the cavernous sinus (fig. 771 and 815). It passes with the artery to the cavernous sinus, where it forms the finer meshed *cavernous plexus.*

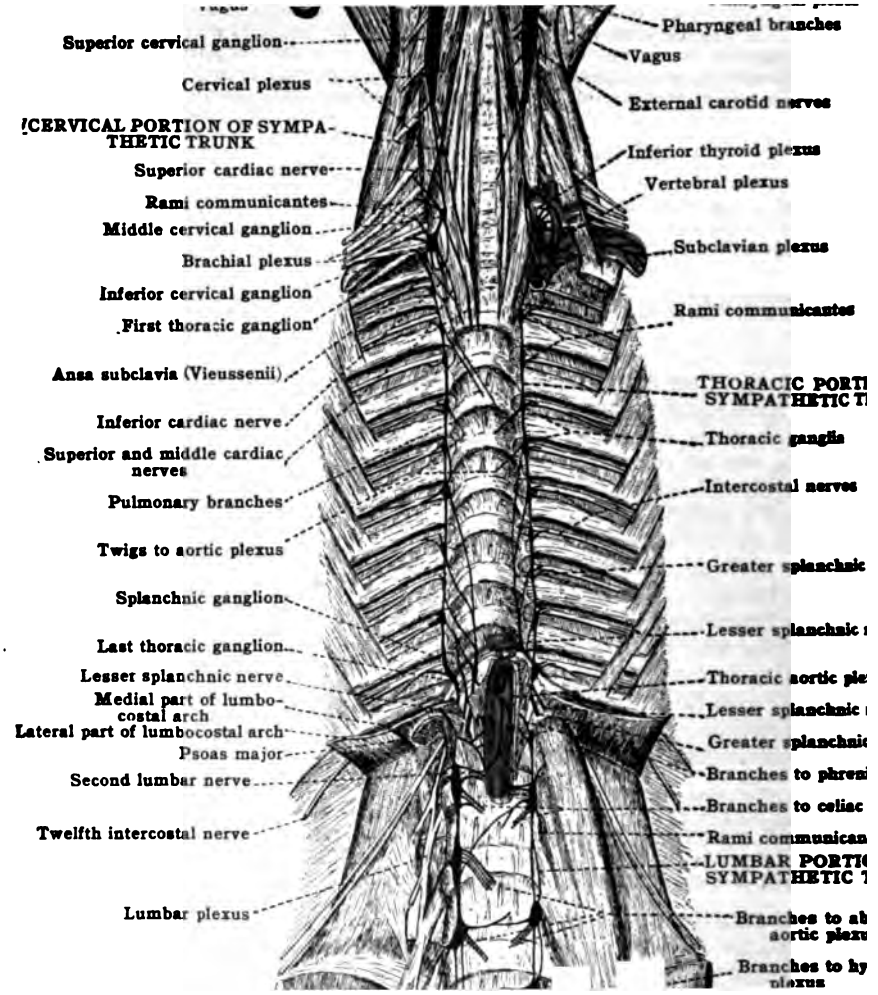
The internal carotid plexus supplies offsets to the artery and receives branches from the tympanic plexus through the inferior caroticotympanic nerve and from the sphenopalatine ganglion through the great deep petrosal nerve. It also communicates by fine branches with the semilunar (Gasserian) ganglion and with the abducens nerve.

The **cavernous plexus** gives branches of communication to the oculomotor and trochlear nerves and to the ophthalmic division of the trigeminus. According to Toldt and Spalteholz, it communicates with the **tympanic plexus** through the superior caroticotympanic (small deep petrosal) nerve. It also communicates with the ciliary ganglion through the *long root of the ciliary ganglion* and usually through a separate *sympathetic root* of this ganglion. These branches may pass through the superior orbital (sphenoidal) fissure either separately or with the nasociliary (nasal) nerve.

The cavernous plexus also give branches to the carotid artery and filaments of the plexus accompany small branches of the artery to the hypophysis (pituitary body) and to the dura mater on the sphenoid bone.

The *terminal branches* of the cavernous plexus consist of delicate filaments that anastomose freely, forming fine plexuses, and pass from the cavernous plexus along the terminal divisions




Superior cervical ganglion
Cervical plexus
CERVICAL PORTION OF SYMPATHETIC TRUNK
Superior cardiac nerve
Rami communicantes
Middle cervical ganglion
Brachial plexus
Inferior cervical ganglion
First thoracic ganglion
Ansa subclavia (Vieussenii)
Inferior cardiac nerve
Superior and middle cardiac nerves
Pulmonary branches
Twigs to aortic plexus
Splanchnic ganglion
Last thoracic ganglion
Lesser splanchnic nerve
Medial part of lumbocostal arch
Lateral part of lumbocostal arch
Psoas major
Second lumbar nerve
Twelfth intercostal nerve
Lumbar plexus
Pharyngeal branches
Vagus
External carotid nerves
Inferior thyroid plexus
Vertebral plexus
Subclavian plexus
Rami communicantes
THORACIC PORTI
SYMPATHETIC T
Thoracic ganglia
Intercostal nerves
Greater splanchnic
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of the internal cartoid artery and their branches. These fine plexuses take the name of the artery on which they lie. The four larger of them are the plexuses of the anterior and middle cerebral arteries, the plexus of the choroid artery, and the ophthalmic plexus.

The cervical portion of the sympathetic trunk extends upward along the great vessels of the neck (fig. 815). No white rami communicantes connect it directly with the spinal cord, but instead it receives visceral efferent fibers from the upper thoracic spinal nerves through the sympathetic trunk, and probably also from the cervical spinal cord through the spinal acessory nerve and the connections with the vagus. . It sends **gray rami communicantes** to each of the cervical nerves. It extends from the subclavian artery to the base of the skull, lying dorsal to the sheath of the great vessels and in front of the longus capitis and longus colli, which separate is from the transverse processes of the cervical vertebræ. It usually has but three **ganglia,** one at each end, the superior and inferior, and one between these two, called the middle ganglion. The latter varies somewhat in position and is sometimes absent.

1. Superior Cervical Ganglion

The superior cervical ganglion (figs. 771, 813, 815) is usually fusiform in shape and is sometimes marked by one or more constrictions. There is ground for the belief that it is formed by the coalescence of four ganglia corresponding to the first four cervical nerves. It varies from 2.5 to 3.7 cm. in length, lying dorsal to the upper part of the sheath of the great vessels of the neck and in front of the transverse processes of the second and third cervical vertebræ. It occasionally extends upward as high as the transverse process of the first vertebra. It is connected with the middle cervical ganglion by the intervening trunk, and it gives off a large number of communicating branches.

Rarely, the ganglion may be double or split with a ventral portion lying superficial to the carotid sheath and a dorsal portion dorsal to the sheath, connected by sympathetic filaments near the superior and inferior extremities of the ganglion.

Communications:—(1) **Four gray rami communicantes** associate the ganglion with the anterior primary divisions of the first four cervical nerves.

(2) **Communicating branches to the cranial nerves.**—An irregular number of small twigs pass between the superior cervical ganglion and the hypoglossal nerve and to the ganglion nodosum of the vagus. A named branch, the *jugular nerve,* runs upward to the base of the skull and divides into two branches, one of which enters the jugular foramen and joins the jugular ganglion of the vagus, and the other passes through or over the petrous ganglion of the glossopharyngeus and contributes to the tympanic nerve and plexus. (See fig. 771.)

(3) Four or five **laryngopharyngeal branches** come from the superior ganglion and the plexus extending downward from it, and pass forward and medialward, lateral to the carotid vessels, to the wall of the pharynx, where they unite on the middle constrictor with the pharyngeal branches of the glossopharyngeus and vagus, forming with them the *pharyngeal plexus,* from which branches are distributed to the walls of the pharynx and to the superior and external laryngeal nerves (fig. 815).

(4) The **superior cervical cardiac nerve** springs from the lower part of the ganglion or from the trunk immediately below it. It passes downward behind the carotid sheath, either in front of or dorsal to the inferior thyroid artery, and in front of the longus colli, and establishes communications with the upper cervical cardiac branch of the vagus, the middle cervical cardiac branch of the sympathetic, and with the inferior and external laryngeal nerves. At the root of the neck the nerve of the *right side* passes in front of or behind the first part of the right subclavian artery, and is continued along the innominate artery to the front of the bifurcation of the trachea, where it joins the deep part of the cardiac plexus. The *left nerve* passes into the thorax along the front of the left common carotid artery, crosses the front of the arch of the aorta immediately anterior to the vagus, and joins the superficial part of the cardiac plexus (fig. 816). Filaments from both the right and left nerves pass to the inferior thyroid plexus.

(5) The **external carotid nerves** (fig. 815) pass forward from the superior cervical ganglion to the external carotid artery, where they divide into branches which anastomose freely to form around the artery the **external carotid plexus.** This plexus extends to the beginning of the artery, and is continued upon the common carotid artery as the **common carotid plexus.** From the external carotid plexus, filaments pass to form secondary plexuses around each of the branches of the external carotid artery. These plexuses take the names of the arteries which they follow, namely, the **superior thyroid plexus, lingual plexus,** etc. Filaments pass from the external carotid plexus to the *glomus caroticum* (the carotid gland), and from the superior thyroid plexus to the thyroid gland.

From the **external maxillary** (facial) **plexus** passes the *sympathetic root of the submaxillary ganglion.*

A part of the **internal maxillary plexus** is continued upon the middle meningeal artery as the **meningeal plexus.** From this plexus filaments pass to the otic ganglion, and sometimes a branch, called by British anatomists the **external superficial petrosal nerve,** passes to the geniculate ganglion.

(6) Small branches to the ligaments and bones of the upper part of the vertebral column.

(7) The internal carotid nerve (ascending branch) and plexus have been described with the cephalic portion of the sympathetic system.

2. The Middle Cervical Ganglion

The middle cervical ganglion is small and somewhat triangular in outline. It is sometimes absent. Its position is variable, but it commonly lies about the level of the cricoid cartilage, in front of the bend of the inferior thyroid artery (fig. 815), and it is associated with the superior cervical ganglion and with the inferior cervical ganglion by the intervening portions of the sympathetic trunk. From the lower part of the middle ganglion some filaments pass dorsal to the subclavian artery, while others pass in front of and beneath that artery and anastomose with the first-mentioned filaments to form a loop, the ansa subclavia (*ansa Vieussenii*) (figs. 782, 815). Filaments from this loop to the inferior cervical ganglion thus form another communication between the middle and inferior cervical ganglia.

Connections.—The middle cervical ganglion gives off four or more rami.

Two (*a* and *b*) are gray rami communicantes which connect the middle ganglion with the anterior primary divisions of the fifth and sixth cervical nerves.

(*c*) One or more peripheral branches pass along the inferior thyroid artery and anastomose with branches from the superior and middle cardiac nerves and from the inferior cervical ganglion, thus taking part in the formation of the inferior thyroid plexus, from which branches pass to the thyroid gland.

(*d*) The middle cardiac nerve arises by one or more branches from the ganglion, or from the trunk, and passes downward dorsal to the common carotid artery and, on the right side, either in front of or dorsal to the subclavian artery, and then along the innominate artery to the deep part of the cardiac plexus (figs. 815 and 816). It is frequently larger than the superior cardiac nerve. On the left side the nerve runs between the subclavian and common carotid arteries. On both sides the nerve communicates with the inferior laryngeal nerve and external laryngeal nerve.

The middle cervical ganglion also gives branches to the common carotid plexus.

3. The Inferior Cervical Ganglion

The inferior cervical ganglion is irregular in form. It is larger than the middle cervical ganglion, and it lies deeply in the root of the neck dorsal to the vertebral artery or the first part of the subclavian artery, and ventral to the interval between the transverse processes of the last cervical and the first thoracic vertebræ (figs. 782, 815). It is connected with the middle cervical ganglion by the sympathetic trunk, and by filaments passing to the ansa subclavia, and it is either blended directly with the first thoracic ganglion or connected with it by a short stout portion of the trunk. It gives rami to the last two cervical nerves and peripheral branches to the vertebral and internal mammary arteries, to the heart, and to the inferior thyroid plexus.

Connections.—(1) The rami to the seventh and eighth cervical nerves are gray rami communicantes.

(2) The branches to the vertebral artery are large and they unite with similar branches from the first thoracic ganglion to form a plexus, the vertebral plexus (fig. 815), which accompanies the artery into the posterior fossa of the cranium, where it is continued on the basilar artery. The plexus communicates in the neck by delicate threads with the cervical spinal nerves. These are probably meningeal rami.

(3) The branches to the internal mammary artery form the internal mammary plexus.

(4) The inferior cardiac nerve may arise from the inferior cervical ganglion, from the first thoracic ganglion, or by filaments from both these ganglia (figs. 815, 816). It communicates with the recurrent laryngeal nerve and with the middle cardiac nerve, and passes to the deep part of the cardiac plexus. On the left side it frequently joins the middle cardiac nerve to form a common trunk.

Construction of the cervical portion of the sympathetic trunk.—This portion of the trunk contains both medullated and non-medullated fibers, and a large part of the former are of craniospinal origin. In the absence of white rami communicantes to this portion of the sympathetic trunk, it is evident that few if any of the craniospinal visceral efferent fibers are contributed to it below the superior ganglion by the cervical region of the spinal cord. Instead, such fibers are known to enter by way of the white rami from the upper thoracic nerves, and to ascend to this portion of the sympathetic trunk. Most of these fibers terminate about the cells of the superior, middle, and inferior cervical ganglia, and these cells in their turn give off sympathetic fibers which pass by way of the branches mentioned above for the cephalic and cervical portions, to their distribution in the structures of the head, neck, and thorax. The visceral efferent fibers which terminate in the superior ganglion especially are among those which mediate—(1) vasomotor impulses for the head; (2) secretory impulses for the submaxil-

lary gland; (3) pilomotor impulses for the hairs of the face and neck; (4) motor impulses for the smooth muscle of the eyelids and orbit, and (5) dilator impulses for the pupil. The sympathetic or gray fibers in the cervical portion of the sympathetic trunk arise from the cells of the upper thoracic and the cervical ganglia, and are passing to enter the peripheral branches and proceed to their terminal distribution.

THE THORACIC PORTION OF THE SYMPATHETIC TRUNK

The thoracic part of the gangliated trunk (figs. 813, 815) is extended on the heads of the ribs from the first to the tenth, and then passes a little ventralward on the sides of the bodies of the lower two thoracic vertebræ. Above it is continuous with the cervical portion at the root of the neck, dorsal to the vertebral artery. Below it leaves the thorax dorsal to the medial lumbocostal arch (arcuate ligament), or sometimes dorsal to the lateral lumbocostal arch, and continues into the lumbar portion of the trunk. It lies behind the costal pleura and crosses over the aortic intercostal arteries.

The number of ganglia in this part of the trunk is variable. There are usually ten or eleven, but the first is sometimes fused with the inferior cervical ganglion (fig. 782) and occasionally other ganglia fuse. The ganglia are irregularly angular or fusiform in shape, and lie on the head of the ribs, on the costovertebral articulations, or on the bodies of the vertebræ. The portions of the trunk connecting the ganglia usually are single, but sometimes they are composed of two or three small cords in juxtaposition. Each ganglion, with the rare exception of the first, receives a *white ramus communicans* from a thoracic nerve and all give off *gray rami communicantes* to these nerves.

The **white rami communicantes,** as they approach the sympathetic trunk, quite often appear double, due to the separation of a large portion of their fibers into two main directions, one passing upward in the sympathetic trunk, and one passing downward. Of the white rami from the upper five thoracic nerves, the upward stream of fibers is much larger than the downward, due to the fact that a greater part of the visceral efferent fibers from these nerves are distributed through the cervical portion of the sympathetic trunk, as noted above in the construction of that portion.

Usually the white rami from the spinal nerves pass directly to the corresponding ganglia of the trunk, and thus lie in company with the corresponding gray rami. Sometimes, however, they may join the intermediate portions of the trunk, and in the lower thoracic region especially a ramus may pass from a nerve to the ganglion corresponding to the nerve above or below. The fibers of the white rami from the lower thoracic nerves are in greater part directed downward in the sympathetic trunk, and also downward in its peripheral branches, to be distributed to the ganglia of the abdominal viscera. In all cases, however, some of the fibers of the thoracic white rami terminate in the ganglia nearest their junction with the trunk, while others pass to the ganglia above or below or into the nearest peripheral branches. In this way the white rami from the thoracic spinal nerves, are directly concerned in the innervation of both the thoracic viscera and also (chiefly through the splanchnic nerves) the abdominal viscera.

The **first thoracic ganglion** is larger than the other ganglia of this region and is irregular in form. It may be narrowly ovoid or semilunar. It lies in front of the neck of the first rib, behind the pleura, and on the medial side of the costocervical trunk (superior intercostal artery), which vessel separates it from the prolongation of the portion of the first thoracic nerve which passes to the brachial plexus. It sometimes fuses with the inferior cervical ganglion, and, on the other hand, sometimes extends to the upper part of the second rib to fuse with the second thoracic ganglion. The result of the latter fusion resembles the stellate ganglion of the carnivora, and when it occurs, is sometimes referred to as the **stellate ganglion.** When well developed, the first ganglion sends a branch to the cardiac plexus, forming the fourth cardiac nerve of Valentin.

The **second thoracic ganglion,** triangular in shape and almost as large as the preceding, is sometimes placed on the costovertebral articulation, and is sometimes partly concealed by the first rib.

The **third to the ninth thoracic ganglia** are usually placed opposite the heads of the corresponding ribs, but the **tenth** and **eleventh** may lie on the bodies of the vertebræ.

The fibers passing from the ganglia form two groups of branches, the *central* and the *peripheral.*

The **central** branches are the **gray rami communicantes,** which pass from the ganglia to the corresponding spinal nerves. After they have joined with the anterior primary divisions of the nerves, the fibers of these rami divide into three

groups:—(1) Fibers which pass medialward along the roots of the nerves to supply vessels of the membranes of the spinal cord, or enter a meningeal or recurrent branch for the same purpose; (2) fibers which pass dorsalward into the posterior primary divisions of the nerves; (3) fibers which pass lateralward in the anterior primary divisions of the nerves. The last two groups of fibers are distributed chiefly to the muscle of the blood-vessels of the body-walls, to the skin-glands, and to the muscles of the hairs of the body.

The **peripheral branches** of the ganglia form two series, an upper and a lower.

Those of the *upper series* pass from the upper four or five ganglia ventralward to be distributed as follows (figs. 813, 816):—

(1) **Pulmonary branches** which accompany the intercostal arteries toward their aortic origin without forming plexuses around them, and pass to the posterior pulmonary plexus.

(2) **Aortic branches,** some of which arise directly from the ganglia and some from the pulmonary branches, and unite with branches from the cardiac plexus and from the splanchnic nerves to surround the aorta as the **thoracic aortic plexus.** This plexus accompanies the aorta into the abdomen and there joins with the celiac (solar) plexus.

(3) **Esophageal branches** join with the esophageal plexus of the vagus.

(4) **Vertebral branches,** some of which pass with the nutrient arteries into the bodies of the vertebræ and some of which pass to the median line and there anastomose with similar branches from the opposite side (commissural branches).

The peripheral ganglionic branches forming the *lower series* consist largely of visceral efferent and afferent fibers from the spinal nerves, which pass through the ganglia and reinforce the sympathetic filaments proper. Thus composed, these branches run ventralward and medialward on the sides of the bodies of the vertebræ and unite to form the *splanchnic nerves* concerned with the abdominal organs. (figs. 640, 813). The visceral afferent fibers serve to collect sensory impulses in this domain of the sympathetic.

(1) The **great splanchnic nerve** is usually formed by branches from all the thoracic ganglia from the fifth to the tenth inclusive, or it may receive fibers from only two or three of these ganglia (figs. 813, 815). The superior branch, usually the largest, receives smaller inferior branches from the lower ganglia as it passes downward on the sides of the bodies of the vertebræ in the posterior mediastinum. The nerve enters the abdominal cavity by passing through the crus of the diaphragm, and joins the upper end of the celiac (semilunar) ganglion of the celiac (solar) plexus. Near the disk between the eleventh and the twelfth thoracic vertebra there is formed on the nerve the **splanchnic ganglion.** Filaments from the nerve and from this ganglion pass along the intercostal arteries to the aorta, esophagus, and the thoracic duct, and some fibers from the right side pass to the vena azygos (major). Sometimes this nerve divides into two cords, giving off numerous branches which anastomose with each other and with the lesser splanchnic nerve to form a plexus, in the meshes of which are found some small ganglia.

(2) **The lesser splanchnic nerve** receives fibers from the ninth and tenth ganglia. Its course is similar to that of the great splanchnic nerve (figs. 813, 815), but on a more dorsal plane, and it joins the celiac (solar) and renal plexuses.

(3) **The least splanchnic nerve,** not always present, arises from the last thoracic ganglion or sometimes from the lesser splanchnic nerve. It passes through the crus of the diaphragm and joins the renal plexus.

Construction of the thoracic portion of the trunk.—Being part of the general *thoracolumbar stream,* the majority of the visceral efferent fibers which pass from the central nervous system enter the thoracic portion of the sympathetic trunk and terminate there in synapsis with the cells of its ganglia, while others merely pass through on their way to terminate in the collateral ganglia. With regard to those which terminate in the ganglia of the trunk, it has been shown that in the dog and cat many end in the ganglion stellatum which corresponds with the last cervical and the upper three or four thoracic ganglia in man. Among these are the fibers conveying secretory impulses to the sweat-glands of the upper limb, which emerge from the spinal cord in the thoracic nerves from the sixth to the ninth, and, in the dog, those which convey and transfer vasoconstrictor impulses to the sympathetic neurones supplying the pulmonary blood-vessels. These visceral efferent fibers leave the spinal cord in the second to the seventh thoracic nerves. Other fibers which terminate upon the thoracic sympathetic ganglion-cells in the dog and cat are the vasoconstrictor fibers for the upper limbs and some of the vasoconstrictor fibers for the lower limbs.

Of the fibers which traverse the thoracic portion of the sympathetic trunk to gain more distant terminations, some ascend to the cervical region (p. 1069), others descend to the lumbar region, and some pass by the immediate peripheral branches to the splanchnic nerves and terminate in the ganglia of the abdominal plexuses.

Among those visceral efferent (preganglionic) fibers which descend to the lumbar region are pilomotor fibers, vasomotor fibers, and secretory fibers to the lower limb, some vasoconstrictor fibers to the abdominal blood-vessels, motor fibers to the circular, and inhibitory fibers to the longitudinal muscle of the rectum. The latter enter the sympathetic trunk by the lower thoracic nerves and pass in the lumbar peripheral branches to the aortic plexus, and terminate around the cells of the inferior mesenteric ganglion.

The visceral efferent fibers which pass through the thoracic ganglia to the splanchnic nerves are

mainly vasomotor fibers to the abdominal blood-vessels; the majority of them probably terminate around the cells of the ganglia in the celic (solar) plexus, but those for the renal blood-vessels no doubt end in the ganglia of the renal plexus. In addition to all the above-mentioned fibers there are in the thoracic part of the sympathetic trunk afferent fibers of the spinal ganglia which pass into the dorsal roots of the thoracic spinal nerves.

THE LUMBAR PORTION OF THE SYMPATHETIC TRUNK

The lumbar portion of each trunk lies on the fronts of the bodies of the vertebræ along the anterior border of the psoas muscle, and nearer to the median line than the thoracic portion. It is connected with the thoracic portion of the sympathetic trunk by a slender intermediate portion of the trunk that may pass through the diaphragm or dorsal to it (figs. 813, 815). The continuation of the lumbar into the sacral portion is also slender, and descends dorsal to the common iliac artery. The right trunk is partly covered by the vena cava inferior and the left by the aorta.

The **ganglia**, which are small and oval, vary in number from three to eight, but are usually four. Rarely they are so fused as to form one continuous ganglion.

White rami communicantes pass to the ganglia from the first two to four lumbar nerves only. This portion of the sympathetic trunk also receives visceral efferent and afferent fibers which are derived from the white rami communicantes of the lower thoracic nerves and continue downward in the trunk.

Branches.—As in the thoracic region, the branches from the ganglia are central and peripheral. The central are **gray rami communicantes.** There may be two rami to a nerve or one ramus may divide so as to join two adjacent spinal nerves. Sometimes a spinal nerve may receive as many as five gray rami from the sympathetic trunk.

The peripheral branches (sympathetic and visceral afferent and efferent fibers) include:—(*a*) Branches passing to the aorta and taking part in the formation of the aortic plexus; (*b*) branches which descend in front of the common iliac artery to the hypogastric plexus; and (*c*) branches to the vertebræ and ligaments.

THE SACRAL PORTION OF THE SYMPATHETIC TRUNK

The sacral part of each trunk passes downward in front of the sacrum, immediately lateral to the medial borders of the anterior sacral foramina. It is continuous above with the lumbar portion of the trunk, and below it anastomoses freely in front of the coccyx with the trunk of the other side to form a plexus in the terminus of which is the **coccygeal ganglion** (*ganglion coccygeum impar*) (fig. 815). Like the cervical and lower lumbar portions of the sympathetic trunk, the sacral part receives no white rami communicantes from the spinal nerves. The visceral efferent fibers arising from this portion of the spinal cord form the sacral part of the general *craniosacral stream.* They pass by the ganglia of the trunk to terminate in the terminal ganglia of the visceral organs, and to some extent in the collateral ganglia.

The sacral **ganglia** are small in size, and usually four in number. The variation both in size and number is more marked in this portion of the trunk than in the two parts above.

Branches.—The branches of the sacral ganglia include:—

(1) Gray rami communicantes to the sacral nerves.

(2) Branches to the front of the sacrum which anastomose with their fellows of the opposite side (commissural branches).

(3) Branches which enter into the formation of the plexus on the middle sacral artery.

(4) Branches which join the pelvic plexuses.

(5) Branches given off by the ganglion coccygeum impar to the coccyx and its ligaments and to the *glomus coccygeum* (coccygeal gland).

Construction of the lumbar and sacral portions of the gangliated trunk.—The ganglia of both these portions of the trunk are very variable in shape, size, position, and number. There are usually four ganglia belonging to each portion, but sometimes as many as eight may be distinguished in the lumbar and at other times there may be as many as six in the sacral portion. In the majority of cases, especially in the sacral region, these masses of cells are so fused that their number is less than the number of the spinal nerves with which they are associated. As noted above, only the first two to four lumbar spinal nerves send white rami which enter these ganglia directly as such. However, visceral efferent fibers descend this entire stretch of the trunk, through both the lumbar and sacral portions, from the white rami of the lower thoracic and the upper lumbar nerves above. These fibers terminate in the various ganglia of the trunk here; a few pass uninterrupted to the more distant sympathetic cell-bodies which are concerned in impulses that are vasomotor to the genital organs, motor for the uterus, the ductus deferens, and the muscular coats (circular coat especially) of the bladder. Also, some of them convey secre-

tory, pilomotor, and vasomotor impulses for the glands, skin, and vessels of the lower extremity in addition to the similar impulses conveyed in the peripheral branches from the lower part of the thoracic portion of the sympathetic trunk. The motor impulses for the uterus or ductus deferens and for the bladder pass, in most part probably, by way of the peripheral branches from the lumbar portion of the trunk, through the aortic plexus to the inferior mesenteric ganglion; others, the vasomotor impulses to the genital organs especially, pass by way of the sacral ganglia and the peripheral branches from them to the hypogastric or pelvic plexus and the appropriate subplexuses of this region. Of the vasomotor fibers for the penis, some of the constrictor fibers pass down the sacral portion of the sympathetic trunk and terminate about the cells of the sacral ganglia, and these cells send out sympathetic fibers which join and course in the pudic nerve (n. pudendus).

All of both the lumbar and sacral spinal nerves receive gray rami from the gangliated trunk. These, just as those from the other portions of the trunk, consist of—(1) vasomotor fibers to vessels of the meninges and the vertebral canal; and (2) those which reach their destination via the branches of the trunks of the spinal nerves.

In addition to the visceral efferent fibers, the branches of the lumbosacral portion of the sympathetic trunk carry visceral afferent fibers—sensory fibers arising in the spinal ganglia of this and the lower thoracic region.

There are no white rami proper passing from the sacral spinal nerves to course or terminate in the sympathetic trunk. Visceral efferent fibers are given off by these nerves in abundance, but, instead of entering the trunk and its ganglia, they form bundles which pass over the trunk and directly into its peripheral branches and to end for the most part upon the cells of the terminal ganglia. The bundles passing from the second, third, and fourth sacral nerves are large and especially definite. While homologous to white rami, such bundles are better known as the *visceral branches* of the sacral nerves or the **plevic splanchnics.** They contain some spinal sensory fibers, but consist for the most part of visceral efferent, conveying impulses, vasomotor (vasodilator, chiefly) to the genital organs, both motor and inhibitory for the rectum, uterus, and bladder (longitudinal coat especially), and secretory for the prostate gland. These fibers contribute to the hypogastric plexus and its subplexuses, named according to the various urogenital organs concerned.

THE GREAT PREVERTEBRAL PLEXUSES

The great prevertebral plexuses, in the body cavities, are three in number—the cardiac, the celiac (solar or epigastric), and the hypogastric or pelvic (fig. 813). Their ganglia belong to the intermediate or collateral group. The cardiac plexus lies behind and below the arch of the aorta, and the celiac and hypogastric plexuses are situated in front of the lumbar vertebræ. Each plexus receives not only sympathetic fibers which have passed from the ganglia of the sympathetic trunks of either side, but also both visceral afferent and efferent nerve-fibers derived directly from the spinal nerves. In addition the cardiac and celiac plexuses receive both visceral efferent and visceral afferent fibers from both vagus nerves.

1. The Cardiac Plexus

The cardiac plexus is formed by the cardiac branches from both vagus nerves and from both sympathetic trunks. It lies beneath and dorsal to the arch of the aorta, in front of the bifurcation of the trachea, and extends a short distance upward on the sides of the trachea. It is composed of a superficial and a deep part (fig. 816).

The **superficial part of the cardiac plexus** is much smaller than the deep part, and lies beneath the arch of the aorta in front of the right pulmonary artery. It is formed chiefly by the cardiac branches of the left vagus and by the left superior cardiac nerve, but sometimes receives filaments from the deep cardiac plexus. The **cardiac ganglion (ganglion of Wrisberg,)** usually found connected with this plexus, lies on the right side of the ligamentum arteriosum.

Branches.—From this plexus some branches pass to the left half of the deep cardiac plexus, and others accompany the left pulmonary artery to the *left anterior pulmonary plexus.* It also sends branches to the *right anterior coronary plexus.*

The **deep portion of the cardiac plexus** lies dorsal to the arch of the aorta at the sides of the lower part of the trachea and in front of its bifurcation. It consists of two lateral parts, more or less distinct, connected by numerous branches, which pass around the lower part of the trachea. It is formed by the superior, middle, and inferior cervical cardiac branches from the right sympathetic trunk, the middle and inferior cervical cardiac branches from the left trunk, and all the cervical and thoracic cardiac branches of the vagus except the superior cervical cardiac branch of the left vagus. It also receives branches from the superficial cardiac plexus.

The *left part of the deep cardiac plexus* gives branches to the left atrium (auricle) of the heart, to the left anterior pulmonary plexus, to the left coronary plexus, and sometimes to the superficial part of the cardiac plexus.

The *right part of the deep cardiac plexus* gives branches to the right atrium, to the right anterior pulmonary plexus, and to the right and the left coronary plexuses (fig. 816). The branches to the left coronary plexus pass behind the pulmonary artery. Some of those to the right coronary plexus pass anterior and some posterior to the right pulmonary artery.

The **coronary plexuses** are formed by branches given off by the cardiac plexus. They accompany the coronary arteries and are right and left.

The *right (anterior) coronary plexus* receives filaments from the superficial part of the cardiac plexus, but is formed chiefly by filaments from the right portion of the deep cardiac plexus (fig. 816). Its distribution to the heart follows that of the right coronary artery.

The *left (posterior) coronary plexus* is larger than the right plexus, and is formed for the most part by filaments from the left portion of the deep cardiac plexus, but it receives some filaments from the right portion of the deep cardiac plexus (fig. 816). Its distribution to the heart follows that of the left coronary artery.

The cardiac plexus and the network of nervous structures in the walls of the atria are the remains of the primitive plexuses found in the embryo, which are called the *bulbar*, the *intermediate*, and the *atrial* plexuses, terms which sufficiently indicate their relative positions. The bulbar plexus gives off the coronary nerves and is transformed into the superficial part of the deep cardiac plexus; the remainder of the deep cardiac plexus is formed by the intermediate plexus, and the atrial plexus becomes the network of the atrium.

The fibers which pass to the cardiac plexus are medullated and non-medullated; the former are the so-called inhibitory, the latter motor. The inhibitory impulses leave the central nervous system by the vagus and spinal accessory nerves and are transferred by synapses to the nerve cells of the intrinsic terminal ganglia of the heart. The accelerator fibers leave the spinal cord by the ventral roots and white rami communicantes of the thoracic nerves and terminate about the cells of the ganglia of the sympathetic trunk; some probably about cells in the ganglia of the intervening plexuses. From the cells of these ganglia arise the non-medullated (gray) fibers of the plexus and these are thought to terminate directly upon the fibers of cardiac muscle.

2. The Pulmonary Plexuses

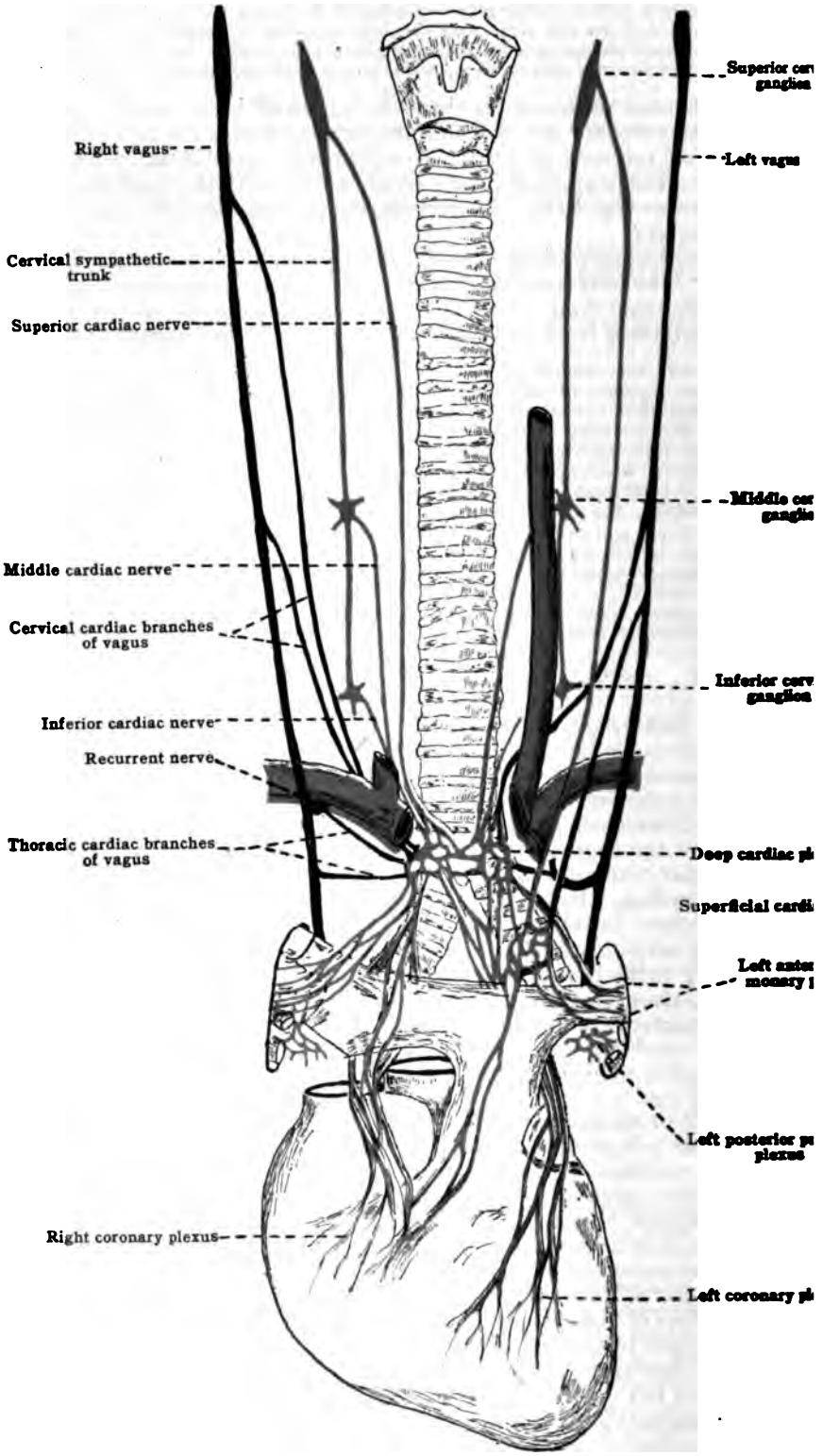
The **pulmonary plexuses** are a continuation of the cardiac plexuses. The two are so intimately joined that it is difficult to distinguish them as separate plexuses. The pulmonary are formed by fibers from both the vagus and sympathetic nerves. The anterior and posterior pulmonary branches of the vagus unite, dorsal to the bifurcation of the trachea, with fibers from the second, third and fourth ganglia of the thoracic portion of the sympathetic trunk to form the anterior and posterior pulmonary plexuses that lie ventral and dorsal to the bifurcation of the trachea. Here the pulmonary plexuses of both sides connect with each other freely. Leaving the trachea, the plexuses pass into the lungs along the pulmonary arteries (figs. 774, 816). The parts of the plexus of each side are named according to their position anterior or posterior to the right and left pulmonary arteries; thus, there is a **right anterior** and a **right posterior**, a **left anterior** and a **left posterior pulmonary plexus.**

3. The Celiac Plexus

The **celiac** (solar or epigastric) **plexus** [plexus cœliacus] is the largest of the prevertebral plexuses. It is unpaired, and is continuous above with the aortic plexus of the thorax and below with the abdominal aortic and superior mesenteric plexuses. It lies in the epigastric region of the abdomen behind the bursa omentalis (lesser sac) and the pancreas, upon the crura of the diaphragm and over the abdominal aorta, and around the origin of the celiac and the superior mesenteric arteries. It occupies the interval between the suprarenal glands and extends downward as far as the renal arteries. It is joined by the great and the lesser splanchnic nerves of both sides, by celiac branches of the right vagus, and by filaments from the upper lumbar ganglia of the sympathetic trunk. It sometimes receives celiac branches from the left vagus. It contains two large collateral ganglia, the right and left celiac (semilunar) ganglia (fig. 817).

The **celiac (semilunar) ganglia** are two large, flat, irregularly shaped masses, separable into a varying number of ganglia. These two masses, or rather the smaller ganglia which compose them, are connected by a varying number of communicating branches. Each mass, right and left, lies upon the corresponding crus

FIG. 816.—CARDIAC, PULMONARY, AND CORONARY PLEXUSES. (Schematic.)
(Modified from Cunningham.)



of the diaphragm, at the medial border of the corresponding suprarenal gland, being sometimes overlapped by this body. The right mass lies behind the inferior vena cava. Each celiac ganglion receives at its upper border the greater splanchnic nerve, and, near its lower border, lying over the origin of the renal artery, is a more or less detached part, known as the **aorticorenal ganglion.** This ganglion receives the lesser splanchnic nerve and may seemingly give origin to the greater part of the renal plexus. Another part of the celiac ganglion, often found dorsal to the origin of the superior mesenteric artery, is known as the **superior mesenteric ganglion** (fig. 817).

From the celiac plexus and its ganglia subordinate plexuses are continued upon the aorta and its branches. These comprise both paired and unpaired plexuses. The paired plexuses are the phrenic, suprarenal and renal, the spermatic in the male, and, in the female, the ovarian plexuses. The unpaired plexuses are the aortic, hepatic, splenic, superior gastric, inferior gastric, superior mesenteric, and inferior mesenteric.

That part of the celiac plexus surrounding the celiac artery was formerly described as the *celiac plexus*. It is better considered as an unnamed part of the larger celiac (solar) plexus. This part of the plexus receives fibers from both vagus nerves, and gives filaments that form plexuses around the branches of the celiac artery and their ramifications.

The paired subordinate plexuses of the celiac.—(1) The **phrenic (diaphragmatic) plexuses** consist of fibers from the upper part of the celiac ganglia, which follow the inferior phrenic arteries and their branches on the under surface of the diaphragm (fig. 817). Filaments are given off by the roots of the plexuses to the suprarenal bodies, and others unite with the terminal branches of the phrenic nerves. The point of junction with the right phrenic nerve is marked by the **phrenic ganglion,** from which branches are distributed to the inferior vena cava, to the right suprarenal body, and to the hepatic plexus.

(2) The **suprarenal plexuses** are comparatively large plexuses, formed mainly by branches from the celiac (semilunar) ganglia. However, fibers come to them from the celiac plexus along the suprarenal arteries, from the phrenic plexus along the inferior phrenic arteries, and from the renal plexus along the inferior suprarenal arteries. They are distributed to the substance of the suprarenal glands. Cell-bodies of sympathetic neurones are enclosed within the suprarenal gland forming intrinsic ganglia. The medulla of the suprarenal is of ectodermal origin and considered as derived from embyronic components of the sympathetic nervous system.

(3) The **renal plexuses** (fig. 817) receive fibers from the lower part of the celiac ganglia and from the celiac and aortic plexuses. They also receive filaments from the least splanchnic nerves, when these nerves are present, and sometimes filaments from the lesser splanchnic nerves and from the first lumbar ganglion of the sympathetic trunk. These plexuses pass along the renal arteries into the substance of the kidneys. Most of the fibers of each renal plexus are gray or postganglionic fibers, and as they pass to the kidneys small *renal ganglia* are present upon them. Both renal plexuses give branches to the corresponding spermatic plexuses and to the ureter, and the right renal plexus gives filaments also to the inferior vena cava.

(4a) The **spermatic plexuses** (fig. 817) are formed by fibers from the renal and aortic plexuses. They accompany the spermatic arteries and are joined at the abdominal inguinal (internal abdominal) ring by fibers that have passed along the ductus deferens from the pelvic plexuses. Their terminal filaments (chiefly postganglionic fibers) are distributed to the testis and the epididymis.

(4b) The **ovarian plexuses** are formed in the female like the spermatic plexuses in the male. They accompany the ovarian arteries and, in the broad ligament, receive fibers from the uterovaginal plexus. They supply the ovaries, the broad ligaments, and the Fallopian tubes, and send some fibers to the fundus of the uterus, where they become continuous with the uterovaginal plexus.

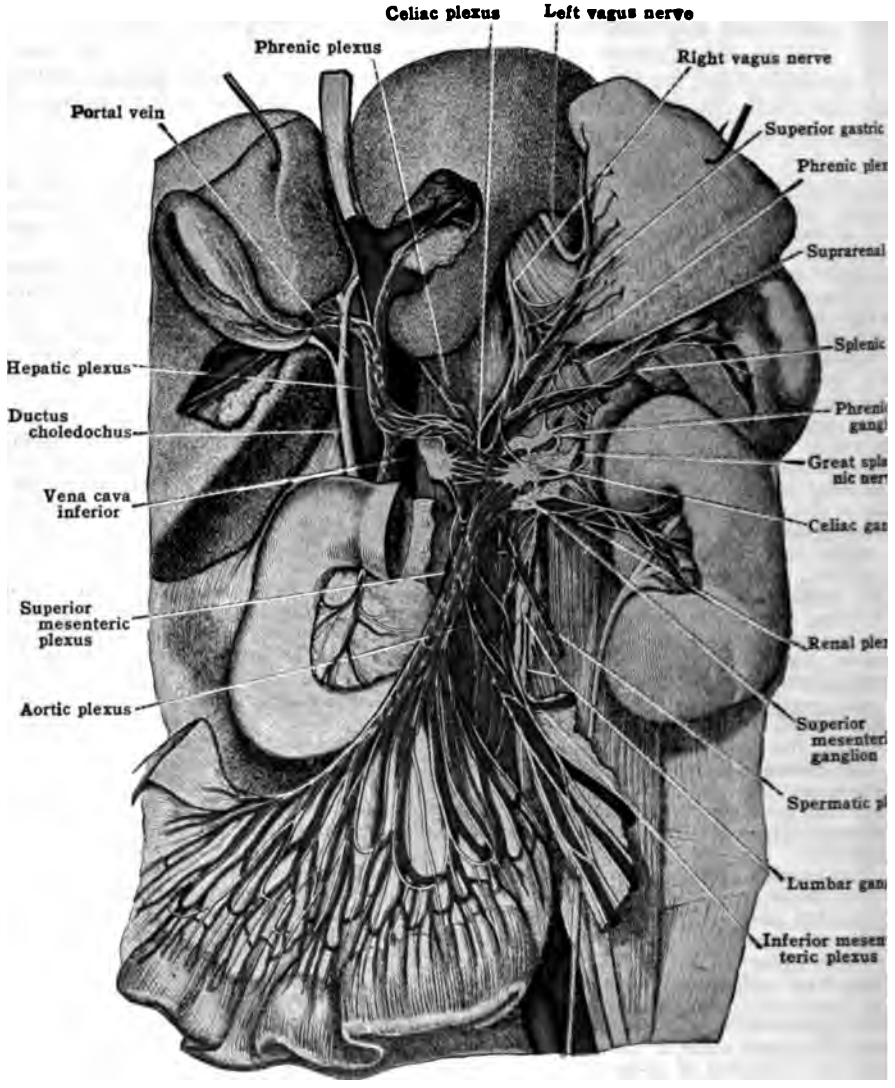
The unpaired subordinate plexuses:—(1) The **abdominal aortic plexus** is formed by two strands of fibers which descend along the sides of the aorta and communicate with each other across its ventral aspect. It is connected above with the renal plexuses, and it receives peripheral branches from some of the lumbar ganglia of the sympathetic trunk on each side. It often contains a number of ganglia, which are situated at the points where the peripheral branches join the plexus, and it terminates below, chiefly by anastomoses with the hypogastric plexus (figs. 817 and 818). Besides giving filaments to the inferior vena cava, it also gives fibers that form plexuses along each of the branches of the aorta. The fibers that pass from the lower end of the aortic plexus upon the common iliac artery form the **iliac plexus,** which is continued along the femoral artery as the **femoral plexus,** and still further along the popliteal artery as the **popliteal plexus.**

(2) The **superior gastric (coronary) plexus,** receiving filaments from the celiac plexus, accompanies the left gastric (coronary) artery along the lesser curvature of the stomach. Its filaments anastomose with filaments of the vagus nerves and with the plexus that accompanies the right gastric (pyloric) artery (fig. 817), and it gives three varieties of fibers to the walls of the stomach:—(1) visceral afferent fibers, derived chiefly from the vagi; (2) sympathetic or postganglionic fibers, and (3) visceral efferent fibers (craniosacral, chiefly exciting peristalses), which terminate within the walls, about the cell-bodies of the delicate gangliated plexus myentericus and plexus submucosus (plexuses of Auerbach and Meissner). These fibers innervate the glandular epithelium and the smooth muscle of the stomach walls and its vessels.

(3) The **inferior gastric plexus** receives from the splenic plexus filaments that accom the left gastroepiploic artery. It gives filaments to the walls of the stomach, which term as in the superior gastric plexus. It receives filaments from the vagus nerves and from plexus that accompanies the right gastroepiploic artery.

(4) The **hepatic plexus** receives filaments from the celiac plexus and from the left v It accompanies the hepatic artery and gives fibers that form plexuses on the branches artery and on their ramifications within the liver and gives secretory fibers to the liver It also gives filaments to the portal vein (fig. 817).

FIG. 817.—ABDOMINAL PLEXUSES OF THE SYMPATHETIC. (After Toldt, 'Atlas of H Anatomy,' Rebman, London and New York.)



The **splenic** or **lienal plexus** is formed by filaments from the celiac plexus, the lef (semilunar) ganglion, and from the right vagus. It accompanies the splenic artery ar filaments which form plexuses on the branches of this artery, and which pass with the b to supply fibers to the stomach and the pancreas (fig. 817).

(5) The **superior mesenteric plexus** is formed chiefly by filaments from the low of the celiac plexus, but it also receives fibers from the right vagus and fibers direct fr celiac (semilunar) ganglia. At the origin of this plexus, dorsal to the superior me artery, lies the *superior mesenteric ganglion* (fig. 817). The filaments of the plexus, wl white and firm, accompany the superior mesenteric artery and, following its branches a ramifications, are distributed to the walls of the small intestine, the cecum, and the as and transverse colon. From the *secondary plexuses* that accompany the branches of th fibers pass to form still other plexuses that lie near the wall of the intestine, between the b of the artery and between the layers of the mesentery. Filaments pass with the bran the arteries and from plexuses between them into the intestinal wall, and there join, l

the longitudinal and circular muscle-layers of the intestine the fine gangliated **plexus myentericus** (plexus of Auerbach), and filaments from this plexus join, in the submucosa, the delicate **plexus submucosus** or plexus of Meissner. From these latter plexuses fibers arise which terminate upon the gland cells and smooth muscle-fibers of the intestinal wall and its vessels. The white appearance of the filaments of the superior mesenteric plexus is due to the large number of visceral efferent and afferent fibers (from the vagi and sacral nerves, especially) in it.

(6) The **inferior mesenteric plexus** is derived chiefly from the left side of the aortic plexus. It descends upon the inferior mesenteric artery and gives off filaments which accompany the branches of the artery and are distributed to the descending colon and to the sigmoid colon (figs. 817 and 818). The filaments which accompany the left colic branch of the inferior mesenteric artery anastomose with the filaments of the superior mesenteric plexus which accompany the middle colic artery. The filaments which accompany the superior hemorrhoidal artery form the **superior hemorrhoidal plexus.** This plexus gives off the *superior hemorrhoidal nerves* (fig. 818) which supply the upper part of the rectum and anastomose with the *middle hemorrhoidal plexus.*

4. The Hypogastric Plexus

The hypogastric plexus lies partly in the abdominal cavity and partly in the pelvic cavity. It is formed chiefly by filaments continued downward from the aortic plexus, and by the pelvic splanchnics and peripheral branches from the lumbar and sacral nerves and sympathetic trunk (figs. 813, 818). The *abdominal part* of this plexus consists of plexiform bundles of fibers descending between the common iliac arteries and interlacing in front of the fifth lumbar vertebra to form a broad, flattened, plexiform mass. In its extent it receives branches from the lumbar ganglia of the sympathetic trunk. This plexiform mass then divides into two parts, right and left, which descend into the pelvic cavity and which, by British authors, are frequently designated as the *pelvic plexuses.*

The *pelvic parts* of the hypogastric plexus (pelvic plexuses) lie at the sides of the rectum in the male, and at the sides of the rectum and the vagina in the female. They receive peripheral branches (postganglionic) from the sacral ganglia of the sympathetic trunk and visceral efferent fibers (preganglionic) by way of the *pelvic splanchnics* from the second and third or third and fourth sacral spinal nerves. Each pelvic part of the plexus accompanies the corresponding hypogastric (internal iliac) artery, and gives off secondary plexuses that continue on the branches of the artery to the pelvic viscera. Of these secondary plexuses, the middle hemorrhoidal and the vesical plexus are common to both sexes and are paired.

The **middle hemorrhoidal plexus** passes on each side along the middle hemorrhoidal artery to the rectum, where it receives the superior hemorrhoidal nerves and sends filaments into the wall of the rectum (fig. 818).

The **vesical plexus** receives some branches from the pelvic parts of the hypogastric plexus, but is largely reinforced with spinal nerve fibers by way of the pelvic splanchnics, from the third and fourth sacral nerves. On each side it passes along the corresponding vesical arteries to the bladder, and gives off two sets of branches, namely, the *superior vesical nerves* (fig. 818), which supply the upper part of the bladder-wall and send some branches to the ureter, and the *inferior vesical nerves,* which supply the lower part of the bladder and, in the male, give secondary **deferential plexuses** to the ductus deferens. These plexuses surround the ductus deferens and the vesiculæ seminales and anastomose with the spermatic plexuses.

The **prostatic plexus,** found only in the male, is formed in two parts by nerves of considerable size, and lies chiefly on the sides of the prostate gland between it and the levator ani (fig. 818). Each of these parts supplies the gland and the prostatic part of the urethra, and sends offsets to the neck of the bladder and the vesiculæ seminales. This plexus is continued forward on either side to form the **cavernous plexus of the penis** (fig. 818), which anastomoses with branches of the dorsal nerve of the penis, gives off branches to the membranous part of the urethra, and also gives origin to two sets of nerves, namely, the large and the small cavernous nerves of the penis.

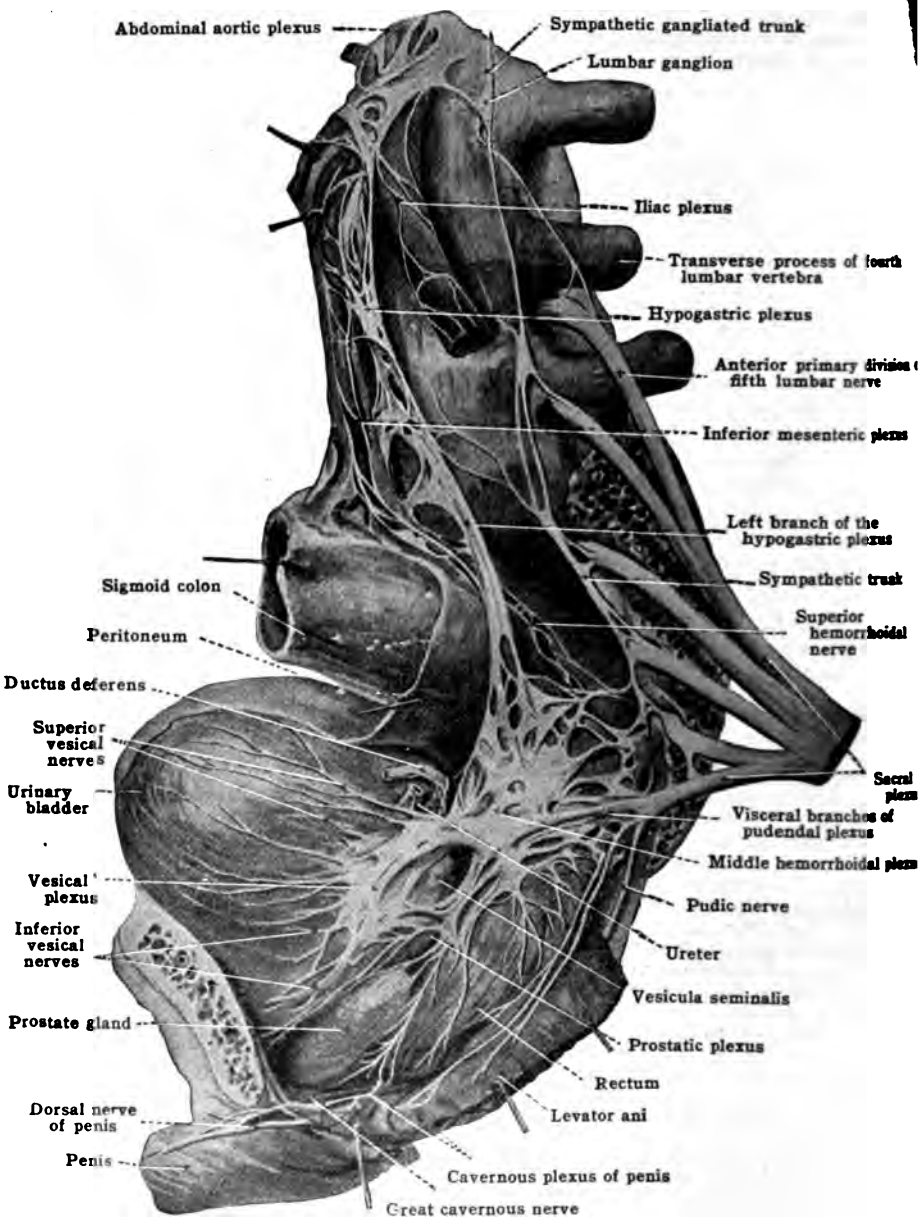
The **large cavernous nerve** [n. cavernosus penis major], one on each side, runs forward to the middle of the dorsum of the penis where it anastomoses with the dorsal nerve of the penis on the corresponding side, and ends in twigs which are distributed chiefly to the walls of the sinuses of the corpus cavernosum penis, but some of the terminal filaments supply the corpus cavernosum urethræ (corpus spongiosum) (fig. 818).

The **small cavernous** nerves [nn. cavernosi penis minores], are small filaments which pierce the urogenital diaphragm and the sphincter urethra, and enter the posterior part of the corpus cavernosum.

The **uterovaginal plexus,** found in the female, is formed in its *upper part* on each side largely by fibers derived from the pelvic part of the hypogastric plexus, but it receives some fibers from the pelvic splanchnics of the third and fourth sacral nerves. The nerves from this part of the plexus accompany the uterine arteries as they pass between the layers of the broad ligament. Some accompany each uterine artery and its branches to their termination, but a considerable number of fibers leave the artery and pass into the body of the uterus to supply its lower part and cervix. Between the layers of the broad ligament this plexus anastomoses with the ovarian

plexus and sends some filaments to the uterine tube (Fallopian tube). The lowe[r] of the plexus uterovaginalis receives some fibers on each side from the pelvic part o[f] hypogastric plexus, but it is formed chiefly by visceral efferent fibers from the second, th[ird] and fourth sacral nerves. These fibers terminate in contact with intrinsic nerve cell-b[odies] whose axones supply the wall and mucous membrane of the vagina and urethra. From [the] plexus on the anterior surface of the vagina fibers pass to form the **cavernous plexus o[f] clitoris,** which gives off the great and lesser **cavernous nerves of the clitoris** for the supply o[f] clitoris. The uterovaginal plexus of the female corresponds to the prostatic plexus of the m[ale].

FIG. 818.—THE HYPOGASTRIC AND SUBPLEXUSES OF THE PELVIC CAVITY. (After Spalteh[olz])



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SECTION IX

SPECIAL SENSE-ORGANS

REVISED FOR THE SIXTH EDITION

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GENERAL CONSIDERATIONS

THE term special sense-organs is applied to the peripheral instruments of the senses of smell, vision, hearing and taste. These structures are specialized to respond to forms of stimulation to which the other afferent nerves are insensitive. The organs of smell, vision and hearing may convey information concerning objects and events at some distance from the body. Hence these three organs have been called *distance receptors* by Sherrington to distinguish them from the other sensory nerves which collect information from the organism itself and especially from the skin.

The essential difference between what is termed general sensibility and the special senses lies in the fact that the organs of special sense are each sensitive to a specific stimulus which does not affect any other part of the body.

Thus the waves of light or of sound, chemical substances which excite a consciousness of taste, or stimulate the olfactory epithelium—all these varied stimuli create no impression when they come into contact with the sensitive general surface of the body or sense-organs other than those specially adapted to each kind of stimulus. The vibration of sound-waves present in an organ-pipe may indeed be felt by the hand, but the sensation is that of vibration and not of sound.

This difference in function between the ordinary and the special senses as well as the difference between the individual organs of special sense, is associated with a difference in structure; for each special sense-organ has a characteristic receptive mechanism of cells highly specialized in form and structure, which receive the stimuli coming from without, and transmit their effects upon the nerve-endings to the brain in the form of a nerve-current. These cells are all derived directly or indirectly from the surface of the body. The eye and ear are highly complex in structure because an elaborate mechanical arrangement is necessary for receiving the external stimulus and converting it into a form fitted to affect the sensory cells proper.

It must always be borne in mind that sensation itself is a function of the brain—it is the response in consciousness to the afferent impressions transmitted to the brain by the sensory nerves and profoundly modified during their passage through the central nervous system. Further, the *quality* of the sensation does not arise in the sense organ, but in the brain itself. Thus, stimulation of the trunk of the optic nerve by mechanical means produces sensations of light, apart from stimulation of the retina.

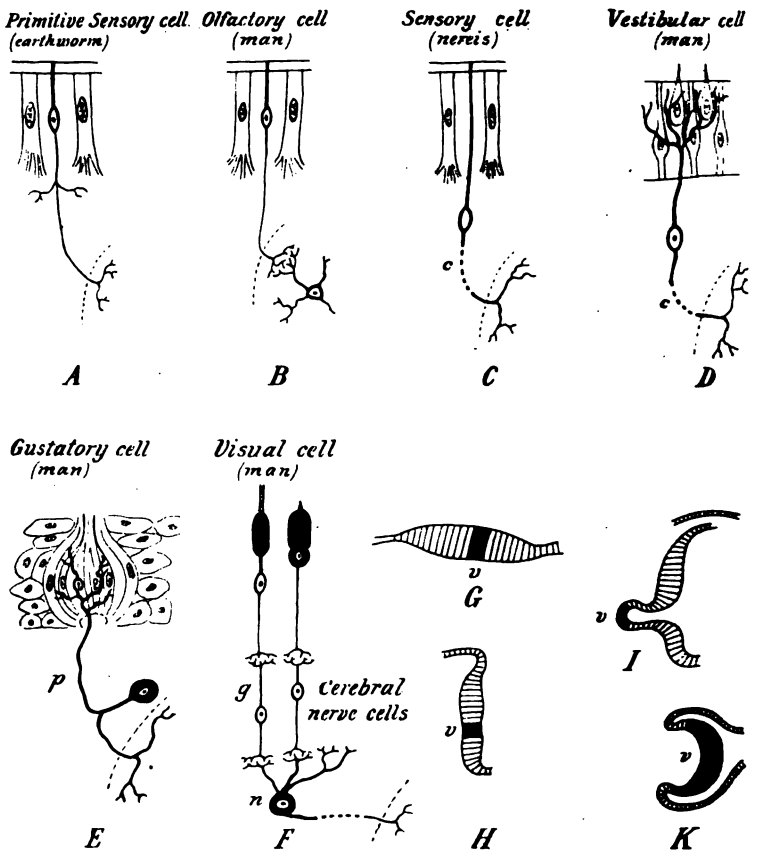
In the lowliest animals equipped with a nervous system certain of the epithelial cells distributed in the skin over the whole surface of the body are specialized as *sensory cells* (fig. 819A). They become specially sensitive to changes in the animal's environment and each gives off a long slender branch or sensory nerve which transmits the effects of stimulation to nerve-cells connected directly or indirectly with the motor mechanisms of the animal. At first every sensory cell is capable of responding to a variety of forms of stimulation; but in the more highly organized animals they become specialized so as to react more efficiently to various stimuli (olfactory, gustatory, auditory, visual, etc.).

Figure 819 illustrates the various types of sensory cells. The olfactory cells (B) preserve the morphological characters of the most primitive kind of sensory cell (A). The vestibular (D)

and cochlear cells, and the taste-cells (E) are only slightly more specialized; but the visual (F) undergo profound changes and become very intimately associated with certain supp nerve-cells to form a composite sensory membrane, the retina. The changes in the posi of this membrane (V) from the time when it was part of the skin, i.e., of the embryonal medul plate (G), then part of the neural tube (H), and then protruded to become the retina (I and will explain how its structure is reversed so that the sensory cells point away from the so of the stimulus.

The sensory cells that are specially adapted to the particular forms of stimulation con ated are found only in certain localized areas in the region of the head (fig. 820), but the of the sensory cells are distributed in the skin over the surface of the body and elsew (muscles, tendons, joints), and are differentiated into categories associated with con sensation, pressure, heat, cold and pain.

FIG. 819.—TYPES OF SENSORY CELLS (A TO F) AND ORIGIN OF VISUAL CELLS (G TO I



The former localized groups form the essential parts of the organs of the special senses taste, vision, hearing and equilibration. Of these organs those of smell and taste co little more than the special sensory cells (fig. 819) without any elaborate accessory mec Moreover the morphological characters of the cells are not only simple but also mor primitive than those of the ordinary sensory cells (see fig. 819, compare A, B, C, The olfactory cells in fact preserve the features of the most primitive type of sensory cel in the lower invertebrata.

The olfactory area arises as a thickening of the skin on the lower surface of the forem of the head. This *olfactory plate* is at first on the same plane as the rest of the skin (fig but the growth of the mesoderm soon pushes out the skin surrounding the olfactory pl B, at L and M), so that a nasal pit is formed the roof of which consists of the olfactory epi (see C). The medial extremity of the olfactory plate becomes separated from the res form the organ of Jacobson, which remains upon the lower and anterior part of the nasal while the rest of the olfactory epithelium is being drawn further and further away f external nares into the superior meatus. For further account of the development of t see pp. 49, 1238.

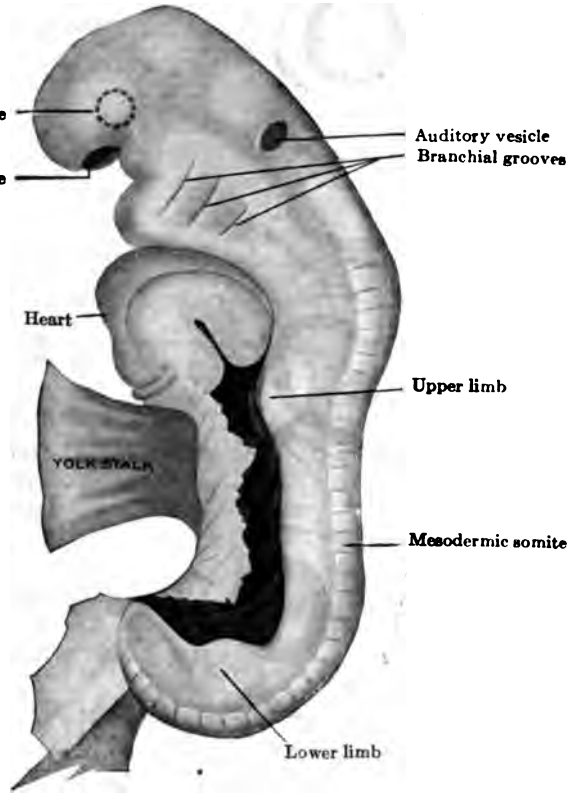
The peripheral ends of the nerves of taste are found mainly in association with th buds (Fig. 819, E). In the latter half of the fetal period these structures are found to l more widely distributed than they are in the adult—in connection with the vallate, fungi foliate papillæ, and the inferior surface of the tongue, on both surfaces of the epiglottis

the palatine arches (pillars of the fauces) as well as on the soft palate. After birth ıem begin to atrophy; and in the adult the taste-buds are concentrated chiefly on f the vallate and foliate papillæ and on some only of the fungiform papillæ. A few retained on the posterior aspect of the epiglottis.

te-buds make their appearance during the second month of fetal life as thickenings dermal epithelium. The epithelial cells become elongated and differentiated into *cells* and *taste-cells*.

ential part of the **organ of hearing and equilibration** can be recognized in human 2 mm. as an ectodermal thickening on each side of the hind brain. This becomes l to form the *otic vesicle* (fig. 822). As its ventral part expands the communication

320.—Human Embryo of 4.2 mm., Showing Sites of Special Sense-organs. (Modified from His.)



ırface persists as a narrow tube which remains open in fishes; but in man and all animals it closes and forms the endolymphatic duct. Two groups of sensory cells ıw out of the medial wall of the otic vesicle, the ventral is the cochlear ganglion and erve of hearing, the dorsal is the vestibular ganglion and nerve (fig. 823).

ɔeripheral apparatus of the different sense-organs be compared with one another, ıund that the *retina*, which is the sensory mechanism of the *eye*, differs from the re- tion of the other sense-organs in the fact that it is composed not only of sensory cells ɔones) such as are found in the cochlear, vestibular and gustatory ganglia and the rea, but also true nerve-cells (the granule layer and the nerve-cell layer of the retina

The true optic nerve —in the strictly morphological sense—consists of the central f the rods and cones. The rest of the retina is really a part of the brain and its cells .neurones. Hence the fibers which these cells transmit to the brain are not homol- ı true cerebral nerves but with such tracts of fibers as the lateral lemniscus. Just as arries acoustic impulses to the medial geniculate body and the inferior colliculus so lemniscus,' which is usually called the optic nerve, carries impulses to the lateral body and the superior colliculus.

mplexity of structure in the retina is determined primarily by the consideration that generated in the rods and cones by the stimulus of light is so feeble that a peripheral (the granule and nerve-cell layers) is necessary to reinforce the impulse before it d to the brain. The composite structure of the retina (partly sensory cells and partly f the central nervous system) is built up during development by profound modifica- ɔ method of formation that is adopted in the case of other sensory nerves. In the ıt of the latter the sensory cells, derived from the ectoderm adjoining the medullary

plate, are not absorbed into the latter when it becomes transformed into the neu
but remain outside the central nervous system, either as ganglia such as the spiral or ve
or as scattered olfactory cells occupying their primitive position in the skin. But in th
the visual apparatus the cells from which the rods and cones are derived are swept
neural tube, and afterward are carried out to the periphery in the optic vesicle along wi

FIG. 821.—DEVELOPMENT OF THE OLFACTORY ORGAN.

A. Transverse section of the head of a human embryo 5 mm. long to show the
plates.

B. Embryo of 6.5 mm. The nasal processes are beginning to grow out at M an
to form a nasal pit, the roof of which is the olfactory plate or area (C and D).

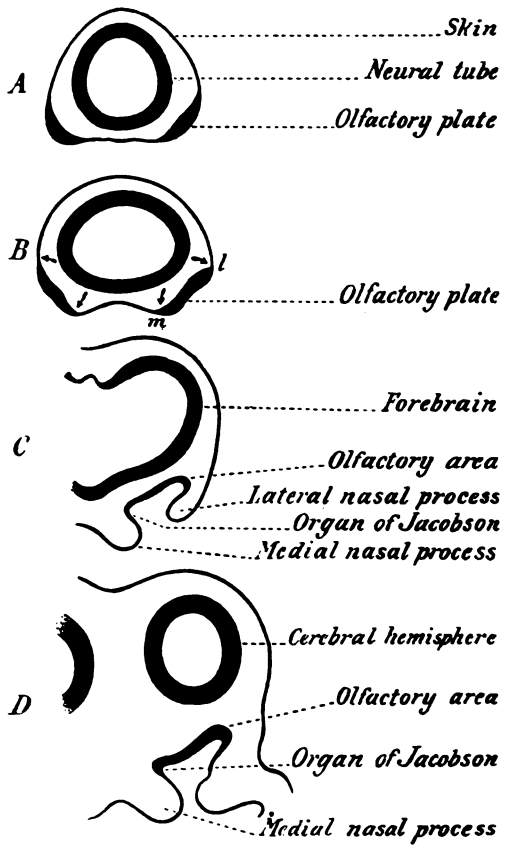
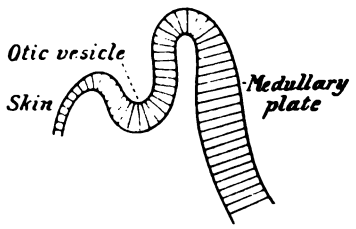


FIG. 822.—DIAGRAM TO SHOW THE RELATIONSHIP OF THE OTIC VESICLE TO THE SKIN
MEDULLARY PLATE.



neuroblasts more strictly belonging to the central nervous system. From these the
granule-layer and the nerve-cell layer are derived. This enables us to understand
why the mode of development of the optic nerve is so different from that of oth
nerves.

The commencement of the evagination of part of the lateral wall of the forebra
the optic vesicle can be seen in human embryos of 2.5 mm. By the time the embry
long it is possible to detect a differentiation between a narrower proximal part of the

DIAGRAM TO SHOW THE RELATIONS OF THE COCHLEAR AND VESTIBULAR GANGLIA TO THE OTIC VESICLE AND MEDULLA OBLONGATA.

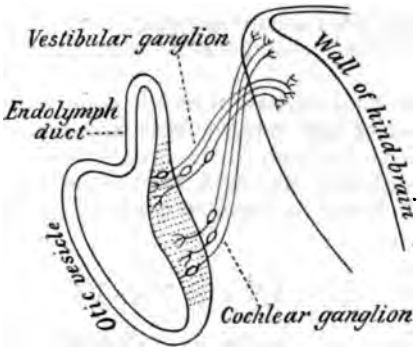


FIG. 824.—DIAGRAM OF RETINAL STRUCTURE.

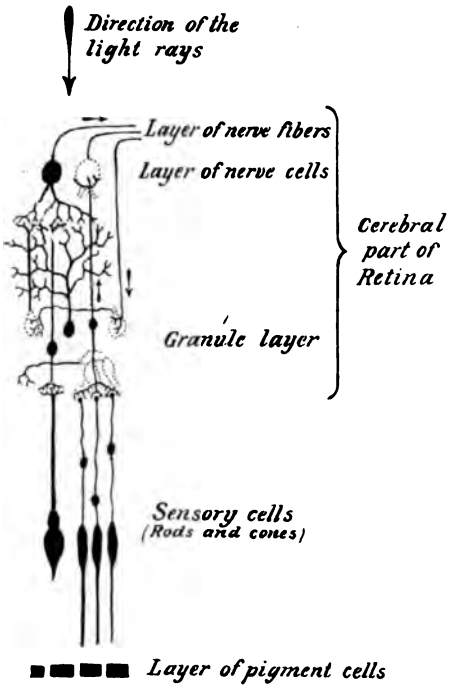
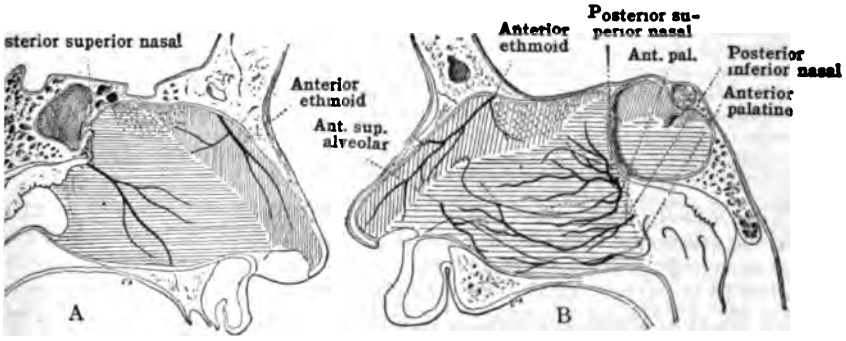

Direction of the light rays
Layer of nerve fibers
Layer of nerve cells
Cerebral part of Retina
Granule layer
Sensory cells (Rods and cones)
Layer of pigment cells

DIAGRAM OF THE DISTRIBUTION OF THE NERVES IN THE NASAL CAVITY. (After and Charpy.) The olfactory area is represented by fine dots. A, septum; B, wall of nasal cavity.



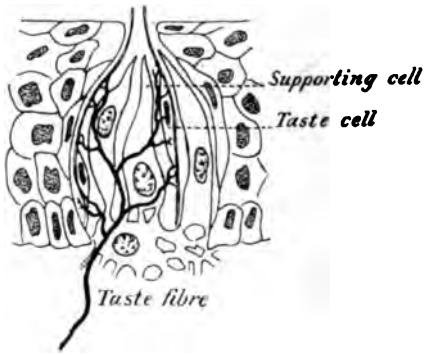
columnar cells (fig. 819, B).

ORGAN OF TASTE

The **taste-organs** [organon gustus] consist of minute epithelial struc **taste-buds** [calyculi gustatorii], situated mainly in the epithelial cover tongue and also of the epiglottis.

In the tongue, the taste-buds are collected mainly on the walls of t papillæ (see p. 1140), but they are found to a slight extent scattered whole area of distribution of the glossopharyngeal nerve, as well as on t of the foliate and fungiform papillæ, and on the plicæ fimbriatæ on the face of the tongue corresponding to the distribution of the taste-fib chorda tympani, which arise in the geniculate ganglion of the glossopalati nerve. Taste-fibers from the same ganglion pass to the palate in superfical petrosal nerve and its continuation in the palatine nerves.

FIG. 826.—DIAGRAM ILLUSTRATING THE STRUCTURE OF THE TASTE-BUI



Each **taste-bud** (fig. 826) is a somewhat conical or oval **structure,** .07–.08 mm. in length. At one end it opens by **a small channel, t pore-canal,** which passes to the surface between **adjacent epithelial** surface opening is termed the *outer pore* and the opening **at the tas** *inner taste-pore*

erical structure, whose wall is formed externally by a fibrous tunic he **sclera** (the white of the eye), and the **cornea** (the transparent area erior aspect of the eyeball). Internal to the tunic formed by these is a pigmented **vascular tunic,** which includes posteriorly the **choroid,** rly the **iris,** or the colored part of the eye.

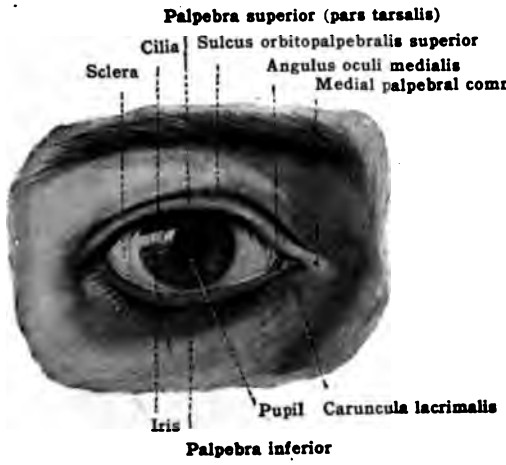
eater part of the space enclosed by these tunics is occupied by the **dy,** in a depression on the front of which the **crystalline lens** is found. in front of the lens is incompletely subdivided by the iris into anterior or chambers.

dy of the eye is best undertaken by examining the eye in the living, and ly by the dissection of specimens, and that order is followed in this

General Surface View

eyes are situated nearly in the line where the upper and middle thirds of the face e right and left of the root of the nose, the most prominent part of the front of ing about 3 cm. (1¼ in.) from the midline of the face. Each eye is overshadowed ponding eyebrow, and is capable of being concealed by its eyelids, upper and lower. al margin may be traced all round with the finger. At the junction of the medial liate thirds of the upper margin the supraorbital notch (incisura supraorbitalis) e felt, and the supraorbital nerve passing through it can sometimes be made to to side under the finger. The medial margin is the most difficult to trace in this because it is more rounded off than the others, partly because it is bridged over by **medial palpebral ligament**), passing medially from the medial angle of the eyelids; and, however, a sharp bony crest is felt, which lies anterior to the lacrimal sac. e eye is protected by the rim of the orbit, above and below, if we lay a hard flat

Fig. 827.—View of the Eye with Eyelids Open.



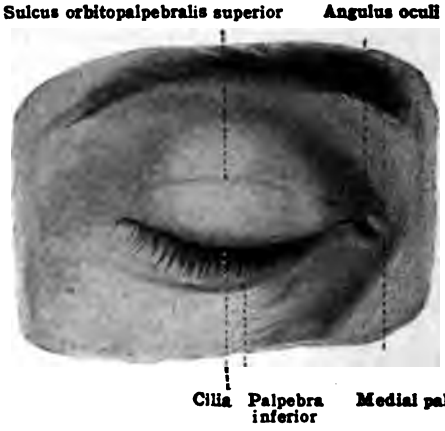
e orbital opening, it will rest upon the upper and lower bony prominences, and will e surface of the globe. Medially, the eye is protected from injury mainly by the nose; laterally it is most readily vulnerable, as here the orbital rim is compara- With one finger placed over the closed upper lid, press the eyeball gently backward t, and observe the elastic resistance met with, due to the fact that the globe rests n a pad of fat.

e between the free edges of the upper and lower lids is known as the **palpebral** ıa palpebrarum]: it is a mere slit when the lids are closed; but when they are open roughly, that of an almond lying with its long axis horizontal, and about thirty h.

e eyes are directed to an object straight in front of them, this aperture is about wide, but its width varies with upward and downward movements of the eyeball, t on looking strongly upward, diminishing gradually as the eye looks progressively **angles** formed by the meeting of the lids at each end of the palpebral aperture spectively the lateral and medial angles (or canthi) [angulus oculi lateralis, medi- h the lateral is sharp, while the medial is rounded off. On a closer inspection, it that, for the last five mm. or so before reaching the medial angle the edges of the lmost parallel course, and are here devoid of lashes. Through the open palpebral front of the eyeball comes into view, extending quite to the lateral, but not reach- the medial, angle; just within the latter we find a small reddish prominence, the ıncle [caruncula lacrimalis]; and between this and the eyeball a fold of conjunctiva e **plica semilunaris.** While the eye is open, press one finger on the skin, a little ateral angle, and draw it firmly away from the middle line; observe that the upper

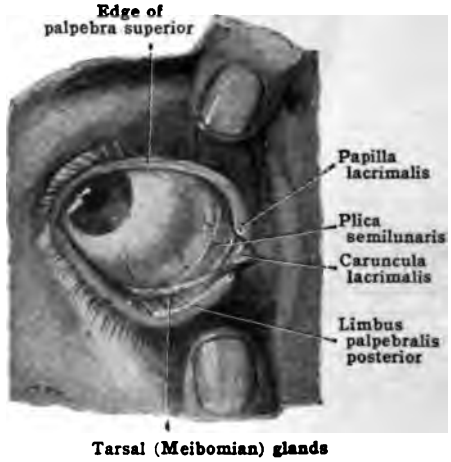
lid then falls over the eyeball, and that the outline of a firm band already referred medial palpebral ligament) becomes evident, passing between the medial angle and t The falling of the lid is caused by our dragging upon a ligament (the lateral palpebral which the lateral end of its tarsus is attached, and so putting the lid itself upon the If, while the eyeball is directed downward, we place one finger on the lateral end of th eyelid and draw it forcibly upward and laterally, we can usually cause the lower di the lacrimal gland to present just above the lateral angle.

FIG. 828.—VIEW OF THE EYE WITH EYELIDS CLOSED.



The upper eyelid [palpebra superior] is much broader than the lower, extending as far as the eyebrow. The skin covering it is loosely attached to the subjacent tissue but more firmly below, nearer the free margin, where it overlies a firm fibrous tissue tarsus superior. When the eye is open, a fold is present at the upper border of this l tightly applied portion of skin, called the superior palpebral fold, and by it the lid is into an upper or orbital, and a lower or tarsal, division. The presence of the tar readily appreciated on our pinching horizontally the entire thickness of the eyelid palpebral fold. The lower eyelid [palpebra inferior] is similarly divided anatomica tarsal and an orbital part, but the demarcation is sometimes unrecognizable on th

FIG. 829.—VIEW OF MEDIAL REGION OF THE EYE, WITH THE EYELIDS WIDELY S AND THE EYEBALL TURNED LATERALLY.



though a fold or groove (the inferior palpebral) is usually visible when the eye is wid There is no precise limit of this lid below, but it may be regarded as extending to the lower margin of the orbit. Numerous very fine short hairs are seen on the anterio both eyelids. Each eyelid presents an anterior and a posterior surface, separate margin with two edges:—(*a*) An anterior, rounded edge [limbus palpebralis ant which the stiff cilia, or eyelashes, are closely placed in a triple row; and (*b*) a sha edge [limbus palpebralis posterior] which is applied to the surface of the globe (s The cilia of both eyelids have their points turned away from the palpebral apert the upper ones curve upward, and the lower downward; the cilia of the upper lid are t and those in the middle of each row are longer than those at each end. Between th

just described, the lid-margin has a smooth surface, on which is a single row of minute apertures, the openings of large modified sebaceous glands, the **tarsal** or **Meibomian glands.** These must not be confused with the sebaceous glands associated with the hair-follicles that are superficial to the tarsal plate. It is by these glistening, well-lubricated surfaces that the opposite lids come into apposition when they are closed. The secretion of these glands is known as the *sebum palpebrale.* The sharp posterior edge of the lid-margin marks the situation of the transition of skin into mucous membrane. Near the medial end of the margin of the lids we find a prominence, the **lacrimal papilla,** on the summit of which is a small hole [**punctum lacrimale**], the opening of the lacrimal duct (ductus lacrimalis) for the passage of tears into the lacrimal sac. The lower punctum is rather larger than the upper, and is placed further from the medial angle of the eye.

If we now examine the posterior surface of the eyelids—*e. g.*, of the lower—we observe that it is lined by a soft mucous membrane, the **palpebral conjunctiva** [tunica conjunctiva palpebrarum]. Over the tarsal part of the lid the conjunctiva is closely adherent, but beyond this it is freely movable along with the loose submucous tissue here present. On tracing it backward, we find that it covers the whole posterior surface of the lids, and is then continued *forward* over the front of the eyeball, forming the conjunctival tunic of the globe [tunica conjunctiva bulbi]. The bend it makes as it changes its direction here is called the **conjunctival fornix** [fornix conjunctivæ superior or inferior]. Numerous underlying blood-vessels are visible through the palpebral conjunctiva, and under cover of its tarsal part we can see a series of nearly straight, parallel, light yellow lines, arranged perpendicularly to the free margin of the lid—the tarsal glands. The conjunctiva over the medial and lateral fourths of each lid is not quite so smooth as elsewhere, and is normally of a deeper red color; we shall find later that there are glands well developed in these positions.

When the eyelids are opened naturally, we see through the palpebral aperture the folowing: the greater part of the transparent cornea, and behind it the colored iris with the pupil in its center; white sclera to the medial and lateral sides of the cornea; the semilunar fold and lacrimal caruncle at the medial angle. The extent of the eyeball visible in this way varies according to its position. Thus, with the eyes looking straight forward, the lower margin of the upper lid is nearly opposite to the top of the cornea, or, more strictly, to a line midway between the top of the cornea and the upper border of the pupil, while the lower lid corresponds with the lower margin of the cornea. When the eyes are directed strongly upward, the upper lid is relatively on a slightly higher level, as it is simultaneously raised, but the lower lid now leaves a strip of sclera exposed below the cornea. On looking downward the upper lid covers the upper part of the cornea as low down as the level of the top of the pupil, while the lower lid is about midway between the pupil and the lower margin of the cornea.

If we draw the eyelids forcibly apart, we expose the whole cornea, and a zone of sclera about eight and a half mm. in breadth above and below, and ten mm. in breadth to the lateral and medial sides—altogether about one-third of the globe; all the eyeball thus exposed is covered by the **ocular conjunctiva** [tunica conjunctiva bulbi]. Over the sclera the conjunctiva is freely movable, and through it we see superficial blood-vessels that can be made to slip from side to side along with it (episcleral vessels). Occasionally other deeper vessels may also be seen which do not move with the conjunctiva, but are attached to the sclera (anterior ciliary arteries and veins). Near the corneal border the conjunctiva ceases to be freely movable, and it is closely adherent to the whole anterior surface of the cornea, giving the latter its characteristic bright, reflecting appearance; no blood-vessels are visible through it here in health. When the lids are shut, the space enclosed between their posterior surfaces and the front of the eyeball is thus everywhere lined by conjunctiva, and is known as the **conjunctival sac.**

Not unfrequently the tendinous insertions of some or all of the recti muscles into the sclera may be seen through the conjunctiva, each insertion appearing as a series of whitish parallel lines running toward, but terminating about seven mm. from the corresponding corneal border.

The **cornea** appears as a transparent dome, having a curvature greater than that of the sclera; the junction of the two unequally curved surfaces is marked by a shallow depression running around the cornea, known as the **scleral sulcus** [sulcus scleræ]. In outline the cornea is nearly circular, but its horizontal diameter is slightly greater than its vertical. Between it and the iris a space exists, whose depth we can estimate roughly by looking at the eye from one side; this space, or anterior chamber [camera oculi anterior] is occupied by a clear fluid, the aqueous humour. Almost the whole anterior surface of the iris is visible, its extreme preiphery only being concealed by sclera.

In color the **iris** varies greatly in different individuals. Near its center (really a little above and medially) a round hole exists in the iris, the black *pupil* [pupilla], whose size varies considerably in different eyes, and in the same eye according to temporary conditions, such as exposure to light, etc.

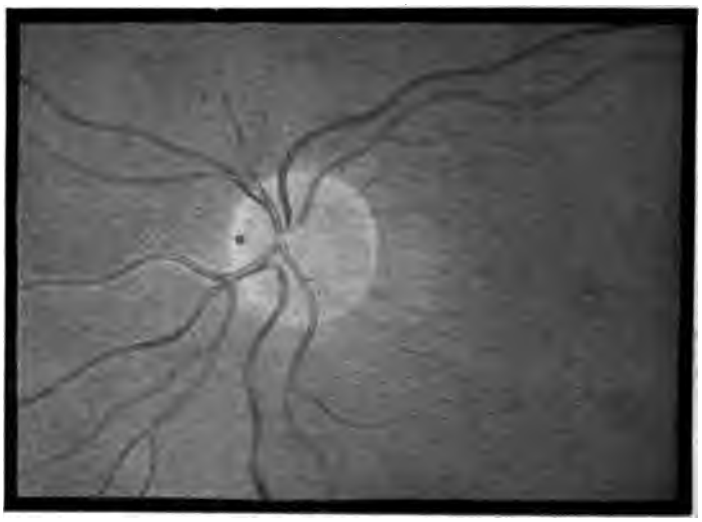
On the surface of the iris we see a number of ridges [plicæ iridis] running more or less radially; adjoining ones occasionally unite and interlace to some extent, so as to leave large depressed meshes at intervals. These are the *crypts* of the iris. The radial ridges coming from the edge of the pupil, and those coming from the more peripheral part of the iris, meet in a zigzag elevated ridge concentric with the pupil, called the *corona iridis*, and by this ridge the iris is roughly marked off into two unequal zones—an outer, the **greater** [annulus iridis major] and an inner, the **lesser** [annulus iridis minor]. The border next the pupil [margo pupillaris] is edged with small, roundish, bead-like prominences of a dark brown color, separated from one another by depressions, so that it presents a finely notched contour. Not infrequently, in a light-colored iris, we may see the sphincter muscle through the anterior layers, in the form of a ring about one mm. in breadth around the pupil. The annulus iridis major may be described as consisting of three parts:—(*a*) A comparatively smooth zone next the zigzag ridge; (*b*) a middle area, showing concentric but incompletely circular furrows; (*c*) a small peripheral darker part, presenting a sieve-like appearance. On the floor of the large depressed meshes,

or *crypts*, parallel radial vessels can be traced, belonging to the iris-stroma. The zigzag mentioned above corresponds to the position of the circulus arteriosus minor. Occasionally especially in a light iris, superficial pigment spots of a rusty brown color occur.

(In examining the living eye, the ophthalmoscope may now be used, so as to gain a view of the fundus, and to study the termination of the optic nerve, the distribution of the blood retinal vessels, etc. See fig. 830.)

The general red reflex obtained from the fundus is due to the blood in a capillary net (**choriocapillaris**) situated in the inner part of the choroid. To the nasal side of the center the fundus is a paler area of a disk shape corresponding to the intraocular end of the optic and known as the **papilla of the optic nerve** [papilla n. optici]. This papilla (or 'optic d is nearly circular, but usually slightly oval vertically; it is of a light orange-pink color, w characteristic superficial translucency; its lateral third segment is paler than the rest as n fibers and capillaries here are fewer in number. About its center we often observe a marked whitish depression [excavatio papillæ n. optici], formed by the dispersion of the n fibers as they spread out over the fundus; at the bottom of this depression a sieve-like ap ance may be seen, due to the presence of the **lamina cribrosa scleræ**, which consists of a fibrous tissue framework, with small, roundish, light-gray meshes in it, through which nerve-fiber bundles pass. Also near the center of the papilla, the retinal blood-vessels come into view, the arteries narrower in size and lighter in color than the veins; they d dichotomously as they are distributed over the fundus. The retina proper is so transp as to be ophthalmoscopically invisible, but its pigment-epithelium gives a very finely gr or darkly stippled appearance to the general red reflex. In the center of the fundus, and fore to the lateral side of the papilla, the ophthalmoscope often shows a shifting halo o

FIG. 830.—THE NORMAL FUNDUS OF THE EYEBALL. (Parsons.)



playing round a horizontally oval, comparatively dark enclosed area; this latter cor to the **yellow spot** [macula lutea] region, and about its center a small pale spot usual the position of the **fovea centralis.**

Two structures visible at the nasal end of the palpebral aperture have been p mentioned, and should now be examined more narrowly. The **lacrimal caruncle** is of modified skin, and fine hairs can commonly be detected on its surface, and it conta ceous and sweat glands. Lateral to it and separated from it by a narrow groove, is **lunar fold of conjunctive** it rests on the eyeball, and is a rudiment of the third eyelid ting membrane, present in birds and well represented in many other vertebrates.

EXAMINATION OF THE EYEBALL

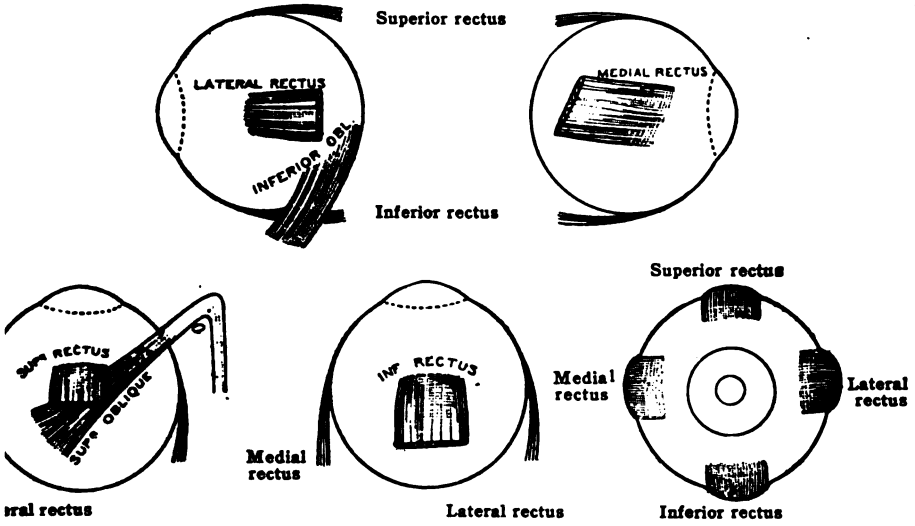
(In the following account, the structure of the eyeball is described as i appear upon dissection.)

The **eyeball** [bulbus oculi] is almost spherical, but not perfectly so, ma cause its anterior, clear, or *corneal* segment has a greater curvature than th the eye. Considering it as a globe, it has an **anterior pole** [polus anter a **posterior pole** [polus posterior]; the former corresponding to the cente front of the cornea, the latter to the center of the posterior curvature. A inary straight line joining the two poles is called the **axis of the eyeba equator** of the eye is that part of its surface which lies midway between poles. The various **meridians** are circles which intersect the poles. The axis of the globe is the greatest (about 24.5 mm.), the vertical equatorial t

rt 23.5 mm.), and the transverse equatorial axis is intermediate in length rt 23.9 mm.), so that the eyeball is in reality an ellipsoid, flattened slightly above downward. These figures refer to the adult male; in the female the ll is .5 mm. smaller in all axes. Again, if the globe is divided in its mid- al plane, the nasal division will be found to be slightly smaller than the tem- . The optic nerve joins the globe three or four mm. to the nasal side of the rior pole.

he shape of the eye depends on, and is preserved by, the outermost tunic, ed conjointly by the **cornea** and **sclera**, the entire outer surfaces of which are in view. The anterior or corneal part has already been examined. All nd the cornea there remains a little adherent conjunctiva; elsewhere, the a is directly exposed, except for some loose connective tissue which adheres to it, cially around the optic nerve entrance. In front of the equator we see the inous insertions of the four recti muscles. Behind the equator are the inser- of the two oblique muscles—that of the superior oblique tendinous, and er forward, under the superior rectus; that of the inferior more fleshy, and ed between the optic nerve and the lateral rectus.

FIG. 831.—DIAGRAMMATIC VIEW OF THE INSERTIONS OF THE OCULAR MUSCLES.



is difficult to recognize the different recti muscles by their insertions if we do not know ner the eye examined is a right or a left one. To determine this we should hold the globe the optic nerve toward us, and in the natural position with the superior oblique tendon most. The inferior oblique tendon will now point to the side to which the eye belongs, ve can consequently determine the different recti muscles.

he medial [m. rectus medialis] rectus is inserted nearest (5.5 to 7 mm. from) the corneal r; the superior [m. rectus superior] rectus commonly, sometimes the lateral [m. rectus lis], is inserted furthest from it (7.7 to 8 mm.). All the recti tendons are broad and thin, hat of the medial is the broadest (8 to 10.3 mm.); those of the lateral and inferior the west (6 to 9.2, or 9.8 mm., respectively). The greatest interval between two neighboring ns is that between the superior and medial recti (about 12 mm.); the least is between uperior and lateral (7 mm.). The form of the lines of insertion of the different tendons s considerably, the inferior being almost straight, the superior and lateral convex forward, nedial further removed from the corneal border below than above.

he insertions of the oblique muscles [mm. obliqui] are at more than double the average nce of the insertions of the recti from the corneal border. That of the superior oblique is l on the superior surface of the sclera, about sixteen mm. from the corneal edge, in the form ine 10.7 mm. long sloping from before backward and medially. The inferior oblique has a fleshy insertion lying between the lateral rectus and the optic nerve entrance; the posterior f the insertion, which is also the higher, is only about five to six mm. from the optic nerve, rom this point it slopes forward, laterally, and slightly downward.

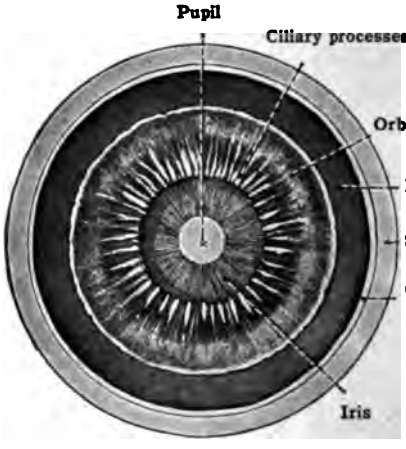
Several small nerves and two arteries may be seen running forward and ulti- ly perforating the sclera not far from the entrance of the optic nerve. The arteries are the long posterior ciliary [aa. ciliares posteriores longi]; they both rate the globe in the horizonal meridian, 3.5 mm. from the optic nerve, one he lateral, the other on the medial, side. The short ciliary arteries [aa. ciliares

posteriores breves] are too small to be seen in an ordinary examination. The nerves are the long and short ciliary [nn. ciliares longi, breves]. Nearer the equator large venous trunks emerge; they can be traced for some distance in front of their exit as dark lines, running anteroposteriorly internal to the sclera. The optic nerve is seen in section, surrounded loosely by a thick outer sheath; in the center of the nerve-section, a small red spot indicates the position of the central retinal blood-vessels [a. et v. centralis retinæ].

(The following structures appear in an eyeball divided into anterior and posterior halves by cutting through it in the equatorial plane.)

1. **Posterior hemisphere** seen from in front.—This is much the same view that the ophthalmoscope affords us. Unless the eye be very fresh, however, the **retina** will have lost its transparency, and will now present the appearance of a thin whitish membrane, detached in folds from the external coats, but still adherent at the optic papilla. The vitreous jelly lying within the retinal cup may be torn away. In the human eye the retina next the posterior pole is stained yellow [**macula lutea**]. On turning the retina over, a little pigment may be seen adhering to its outer surface here and there. Cut through the retina close to the optic disk all around and remove it: note how easily it is torn. We now see a dark brown surface, consisting of the **retinal pigment layer** [stratum pigmenti retinæ] adherent to the inner surface of the choroid. Brush off the retinal pigment under water. The **choroid** thus exposed can for the most part be fairly easily torn away from the thick sclera, as a lymph-space exists between them, but the

FIG. 832.—ANTERIOR HEMISPHERES OF EYEBALL, VIEWED FROM BEHIND.



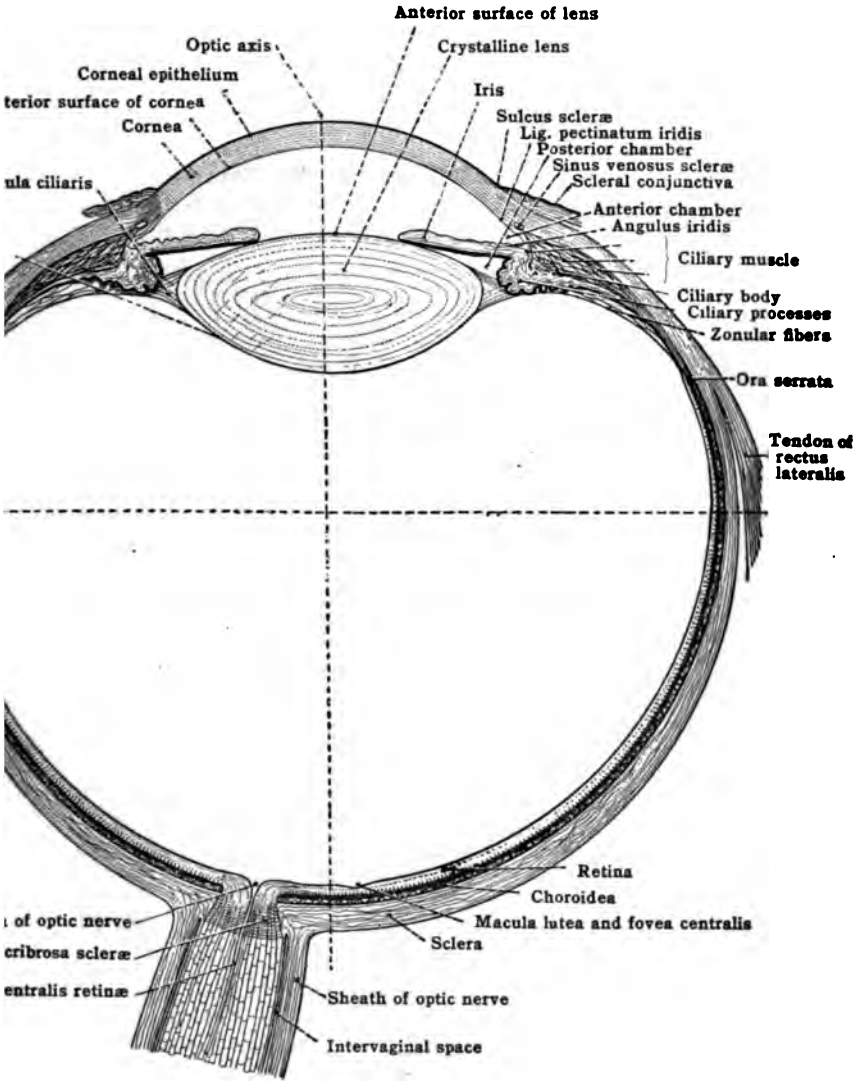
attachment is firm around the optic nerve entrance, and also where the arteries and nerves join the choroid after penetrating the sclera. The choroid is darkly pigmented, of a brown color with markings on its surfaces corresponding to the distribution of its large veins. The inner surface of the sclera is of a light brownish color, mainly from the presence of a delicate pigmented layer, the **lamina suprachoroidea**, which adheres partly to it, partly to the choroid, giving to their adjacent surfaces a flocculent appearance when examined under water.

2. **Anterior hemisphere** viewed from behind (fig. 832).—The round opening of the pupil is visible in the middle, in front of the large clear **crystalline lens**. The retina proper extends forward a little way from the line of section, and then ends abruptly in a wavy line called the **ora serrata**, beyond which it is represented only by a very thin membrane [**pars ciliaris retinæ**]. Outside the periphery of the lens are a number of **ciliary processes** arranged closely together in a circle concentric with the pupil, and each radially elongated; posteriorly they are continuous with numerous fine folds, also radial, which soon get very indistinct as they pass backward, but reach almost to the ora serrata [**plicæ ciliares**]. Between the front of the ciliary processes and the edge of the pupil lies the **iris**. On removal of the retina the inner surface of all this region is seen to be darkly pigmented, but especially dark in front of the position of the ora serrata. Vitreous probably still adheres to the back of the lens, and by pulling upon it the lens can be removed along with its capsule and suspensory ligament; some pigment will now be found adhering to the front of the vitreous, torn from the ciliary processes, which are consequently now lighter in color than before. The **lens-capsule** is transparent, and has a smooth glistening outer surface; through it a gravish, star-shaped figure [**radii lentis**] may be observed on the anterior and posterior surfaces of the lens. The **suspensory ligament** is a transparent membrane attached to the capsule of the lens about its equator, and is best seen by floating the lens in water in a glass vessel placed on a dark ground. On opening the capsule we expose the lens itself, which is superficially soft and glutinous to the touch, but becomes firmer as we rub off its outer layers and approach its center. Carefully tear the choroid and iris from the sclerotic as far as possible; a firm adhesion exists just behind the corneal periphery. The outer surface of the choroid thus exposed is found to be also rather darkly pigmented, but it shows a white ring corresponding to the adhesion just mentioned, and a pale area behind this ring indicates the position of the **ciliary muscle** [m. ciliaris]. On this surface numerous white nerve-cords are

ning forward. Observe that the iris, the ciliary processes, etc., and the choroid are all arts of the same ocular tunic—mere local modifications of it. Similarly the sclera are seen to blend together to form one outer coat.

ball should now be placed for half an hour in a freezing mixture of crushed ice and ill thus become quite hard, and should at once be divided into two parts by cutting osteriorly through the center of the cornea and the optic nerve. We thus gain ew of the relations of parts, the position of the lens between the aqueous and vitreous etc. On removing the lens, vitreous, and retina, and brushing off its pigment, the ings corresponding to the choroidal veins (**venæ vorticosæ**) should be noted, and their n studied. Usually four vortices or fountain-like markings are found in the whole

FIG. 833.—HORIZONTAL SECTION OF THE EYEBALL. × 4.



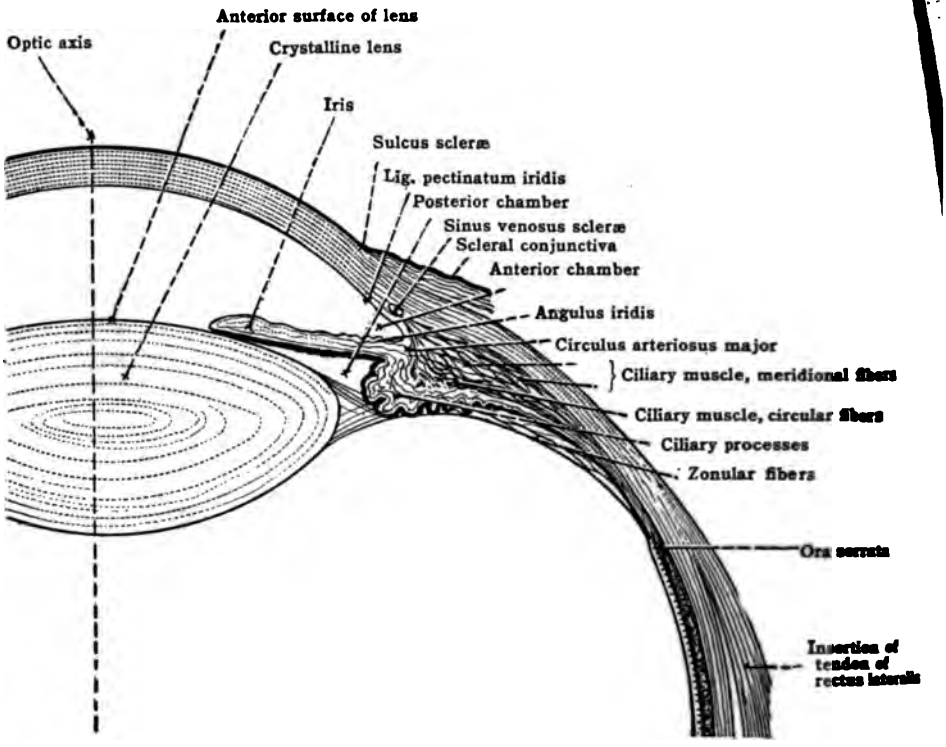
eir points of junction situated at approximately equal distances from one another at line where the posterior and middle thirds of the globe meet. These sections should r reference while following the further description of the ocular tunics.

coats of the eyeball.—1. The **outer, fibrous coat of the eye** [tunica culi] is formed by the **sclera** and **cornea,** which pass into one another leral sulcus. It consists throughout mainly of fine connective tissue ranged in interlacing bundles, with small lymph-spaces at intervals them. The naked-eye appearance of the two divisions of this fibrous however, quite different, the cornea being transparent, while the sclera and opaque.

The **sclera** encloses the posterior five-sixths or so of the eyeball. It is perforated by the entrance of the optic nerve, and the opening in the sclera, only partially bridged across by fibers from the inner layers, forms the **lamina cribrosa**.

The fiber-bundles composing the sclera are arranged more irregularly than in the cornea and run mainly in two directions, viz., anteroposteriorly and circularly; the circular fibers are particularly well developed just behind the sulcus. It is thickest (about 1 mm.) posteriorly, where it is strengthened chiefly by the outer sheath of the optic nerve, and partly also by the tissue surrounding the ciliary vessels and nerves. It becomes gradually thinner as it passes forward, up to the line of insertion of the recti muscles, where it is .3 mm. thick. In front of that line it is again reinforced by their tendinous fibers becoming incorporated with it and its thickness increases to .6 mm. In children the sclera is often so thin as to allow the underlying choroidal pigment to show through, its color then appearing bluish white. In the aged, again, it is sometimes yellowish. It always contains a few pigment-cells, but these are in the deep layer termed the *lamina fusca*, and only become visible externally where the sclera is pierced by vessels and nerves going to the choroid. It is almost non-vascular, but quite at its anterior end the **sinus venosus scleræ** or **canal of Schlemm** [canalis Schlemmi (Lauthi)] runs in its deeper layers circularly around the cornea. Just in front of this sinus, at the corneal limbus, the sclera merges into the cornea, its inner layers changing first, and finally the outer ones.

FIG. 834.—PORTION OF FIG. 833, ENLARGED.



The **cornea** forms the anterior sixth of the eyeball. It is thickest at its periphery (1.1 mm.) and becomes gradually thinner toward its center (0.8 mm.); the curvature of its posterior is consequently greater than that of its anterior surface, but even the latter is more curved than the surface of the sclera.

In the cornea proper, fiber-bundles are arranged so as to form a series of superposed lamellæ each of which is connected here and there to the adjacent ones by fibers passing from one to the other, so that they can only be torn apart with difficulty. The corneal lymph-spaces communicate with one another by very fine canals, and thus a thorough lymph-circulation is provided for. The cornea contains no blood-vessels, with the exception of a rich plexus at its extreme periphery, on which its nutrition is ultimately dependent. It is richly supplied with nerves, however, especially in its most superficial layers.

The outer surface of the cornea is covered by an extension of the ocular conjunctiva, with an epithelium several layers deep. The most anterior part of the true cornea appears homogeneous, even when highly magnified and constitutes the anterior elastic lamina, Bowman's membrane. Posteriorly, the cornea is lined by a firm, thin, glass-like layer (posterior elastic lamina, membrane of Descemet), distinct from the corneal tissue both anatomically and chemically. At the periphery this membrane breaks up into a number of fibers, which mainly arch

...r to join the base of the iris and form part of the **ligamentum pectinatum iridis.** The pectin... ligament is an open network of interlacing fibers, directly continuous with the circular ... longitudinal bundles of sclera surrounding the venous sinus of Schlemm (Henderson). ... interstices between these fibers constitute spaces (**spaces of Fontana**) [spatia anguli iridis ...ontanæ)] freely communicating with the aqueous chamber on the one hand, and indirectly ...th the venous sinus of the sclera on the other. The posterior elastic lamina is in turn lined ...y a single layer of flat cells, which are continuous peripherally with cells lining the spaces of the ...le and the anterior surface of the iris which form the endothelium of the anterior chamber. ...e relation of the spaces and chanbers in the circulation of fluids is considered later (p. 1101) ...der the *filtration angle.*

2. The dark, **middle,** or **vascular coat of the eye** [tunica vasculosa oculi] is formed by the **iris, ciliary body,** and **choroid.** It is closely applied to the sclera, but actually joins it only at the anterior and posterior limits of their course together, viz., at the scleral sulcus, and around the optic nerve entrance. It is separated from the sclera between these two points by a narrow slit-like lymph-space [spatium perichoroideale]. In front of the sulcus, the middle coat is separated from the outer (i. e., the iris from the cornea) by the *anterior aqueous chamber* (fig. 839). The vascular coat has two openings in it; a larger one in front, the *pupil,* and a smaller one behind, for the passage of the optic nerve. Its structure is that of a pigmented connective tissue, supporting numerous blood-vessels and containing many nerves and three deposits of smooth muscle-fibers.

The **choroid** [choroidea] forms the posterior part of the vascular coat, and extends, with slowly diminishing thickness, forward as far as the ora serrata. Its outer and inner surfaces are both formed by non-vascular layers; that covering the outer, the **lamina suprachoroidea** is pigmented, arranged in several fine loose lamellæ; that covering the inner surface is a thin, transparent, homogeneous membrane, called the **basal lamina** of the choroid. The intervening choroidal stroma is very rich in blood-vessels, which are of largest size next its outer surface constituting the **lamina vasculosa.** These become progressively smaller toward the basal lamina, next to which is a layer of closely placed wide capillaries, called the **lamina choriocapillaris.** The pigment becomes less in amount as we pass inward, and finally ceases, being absent entirely from the choriocapillary and basal laminæ.

In front of the ora serrata the vascular coat becomes considerably modified, and the part reaching from the ora serrata of the retina to the iris is termed the ciliary region of the tract, or **ciliary body** [corpus ciliare]. Its superficial aspects have been already briefly described. In front, the ciliary processes, about seventy in number, project toward the interior of the eye, forming the **corona ciliaris.** Behind this part lies the **orbiculus ciliaris,** whose inner surface is almost smooth, faint radial folds [plicæ ciliares] only being present, three or four of which join each ciliary process.

The more minute structure of this ciliary region resembles closely that of the choroid, except that the choriocapillaris is no longer present, that the stroma is thicker and richer in blood-vessels, and that a muscular element (ciliary muscle) exists between the vascular layer and the lamina suprachorioidea. On anteroposterior section the ciliary body is triangular; the shortest side looks forward, and from about its middle the iris arises; the two long sides look respectively inward and outward, the inner having the ciliary processes upon it, while the outer is formed by the **ciliary muscle.** This muscle possesses smooth fibers and consists of an outer [fibræ meridionales (Brueckei)] and an inner division [fibræ circulares (Muelleri)]. The meridional fibers take origin from the outer fibrous coat of the eye at the sclerocorneal junction in front, and passing backward to join the outer layers of the orbiculus ciliaris and choroid; the circular fibers are situated next to the ciliary processes. The entire muscle is destitute of pigment, and therefore is recognizable in the section by its light color. The whole thickening of the vascular tunic in this region, muscle and folds and processes together, is named the **ciliary body.** It includes the corona ciliaris, formed of the ciliary processes and folds, and the orbicularis ciliaris containing the ciliary muscle.

The **iris** projects into the interior of the front half of the eye in the form of a circular disk, perforated in the middle. The appearance of its anterior surface has already been described. The anterior surface is covered with a layer of endothelium except at the crypts near the ciliary border. Thus the lymph-spaces between the stroma-cells communicate directly with the anterior chamber. Its posterior surface exhibits numerous radial folds running from the ciliary processes to near the pupillary margin; a thick layer of black pigment covers it and curls around this edge, so as to come into view all around the pupil as seen from in front. The *ciliary border* of the iris is continuous with the front of the ciliary body, and there it also receives fibers from the ligamentum pectinatum iridis; in other respects the iris is quite free, merely resting on the front of the lens-capsule near the pupil.

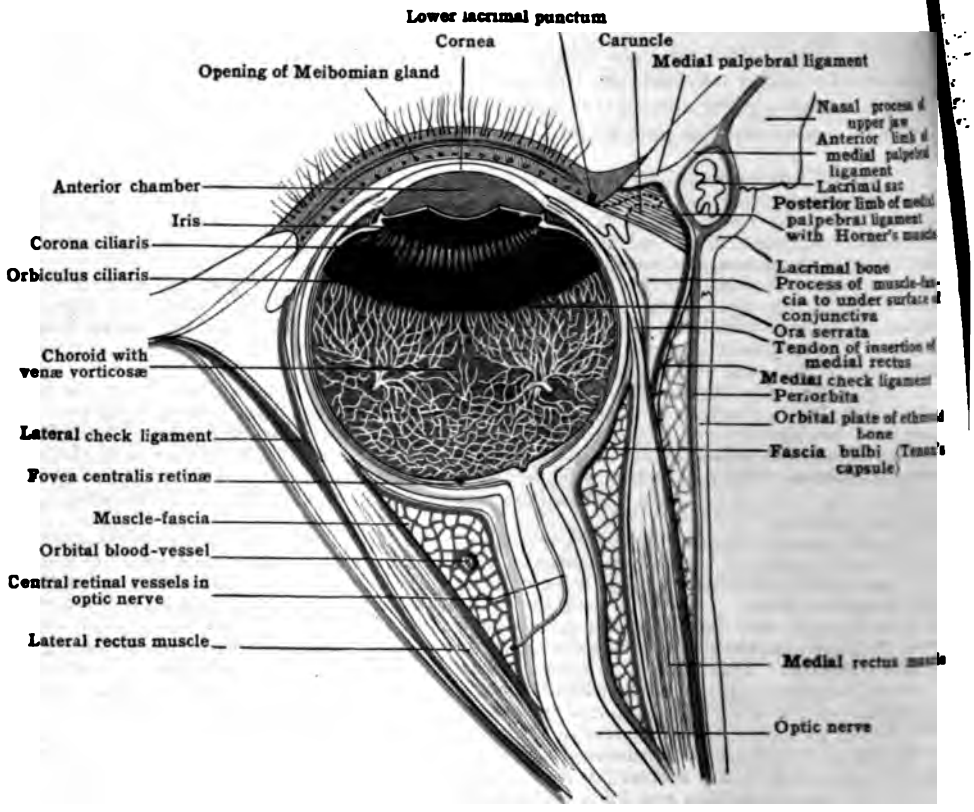
Its stroma [stroma iridis] is spongy in character, being made up of vessels, running from the periphery to the pupillary border, with interspaces filled by branching *pigment-cells,* which are particularly abundant near the front surface. Deep in the stroma, running around near the pupillary border, we find a broad flat band of smooth muscle-fibers, constituting the **m. sphincter pupillæ.** Immediately behind the vascular tissue lies a thin membrane, consisting of fine, straight fibers running radially from the ciliary border to the stroma behind the sphincter. These comprise the **m. dilatator pupillæ.**

The *m. sphincter pupillæ* and the *ciliary muscle* are supplied indirectly by the oculomotor nerve through the ciliary ganglion. The preganglionic fibers of the nerve end in the ciliary ganglion, from the cells of which arise the fibers which innervate the ciliary and sphincter

pupillæ muscles. They are unique among postganglionic fibers in being medullated. The dilatator pupillæ is supplied by *sympathetic fibers*, which have their origin from the cells of the superior cervical ganglion. Thence they ascend in the carotid and cavernous plexuses, and join the ophthalmic division of the trigeminal nerve, passing to the eyeball by way of the long ciliary nerves. The preganglionic sympathetic fibers leave the spinal cord by the motor roots of the first two or three thoracic nerves, and ascend the sympathetic trunk to the superior cervical ganglion without interruption (fig. 744).

The posterior surface of the iris is coated by pigment already mentioned, consisting of two layers of pigmented cells, representing the extension forward of the two walls of the optic cup, retina and pigment layer, respectively. The anterior surface of the iris is covered by a delicate epithelial layer, continuous with the cells of the posterior elastic lamina of the cornea. The variations in the color of the iris in different individuals depend upon the amount of stroma pigment.

FIG. 835.—DIAGRAMMATIC HORIZONTAL SECTION OF EYEBALL AND ORBIT.
(After Fuchs, much modified.)
Periorbita *green;* muscle-fascia *red;* Interfascial (Tenon's) space *yellow.*



3. **The retina.**—The inner surface of the vascular coat is everywhere lined by a layer of pigment of corresponding extent, which usually adheres to it closely on dissection.

Developmentally this general pigment lining is quite distinct from the vascular coat, and represents the *outer wall* of the secondary optic vesicle or embryonic retina; it consists of a single layer of pigmented epithelial cells, the *stratum pigmenti*. In the ciliary region these cells have recently been described as lining numerous narrow tubular depressions in the inner part of the vascular tract, and they are said to have here a special function, viz., that of secreting the intraocular fluid.

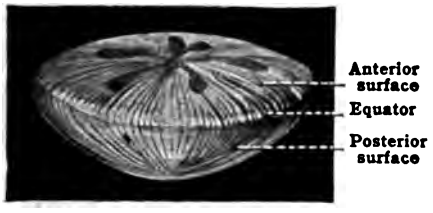
From the manner in which the secondary optic vesicle, or *optic cup*, is formed, its two walls are necessarily continuous in front, at what may be termed the *lip* of the cup; we have just observed that the outer wall lines the vascular coat everywhere and corresponds in extent; consequently, the lip must be looked for at the edge of the pupil, *i.e.*, at the termination of this coat anteriorly. The inner wall of the cup, consequently, reaches from the lip, or pupillary edge, in front to the optic stalk or nerve behind, and is in close apposition to the pigment-epithelium: unlike the outer, however, this wall is represented in the developed eye by tissues

milar in structure in different parts of its extent. Tracing it backward pupillary edge, we find that over the whole posterior surface of the iris it a single layer of pigmented epithelium, the two layers of the cup having uced a double layer of pigment cells. At the root of the iris the single r of cells still exists; but now they become destitute of pigment, and this obtains over the entire ciliary region, constituting what is known as the **is retinæ.** At the line of the ora serrata the tissue derived from the inner ptly increases in thickness, and rapidly acquires that complexity of characteristic of the **retina proper,** which extends from here to the optic is termed the *pars optica retinæ.* It consists of several layers—nerve-rve-cells, and nerve-epithelium—held together by a supporting frame-elicate connective tissue.

hological **detachment of the retina** is really a separation of the two layers of the

inal nerve-epithelium is on the outer surface, immediately applied to the pigment- at the posterior pole of the eye a small spot [**fovea centralis**] exists, where this is the layer represented, and where consequently the retina is extremely thin. The nerve- n the inner surface of the retina and are continuous with those of the optic nerve; itute the only retinal layer that is continued into the intraocular end of the e nerve-cells are found between these surface layers. The larger blood-vessels of the n the inner layers, and do not encroach on the layer of nerve-epithelium.

FIG. 836.—THE LENS. (Side view; enlarged.)



the coats mentioned, the interior of the eyeball is fully occupied by con- ich are divided into three parts, named according to their consistence omical form. They are all transparent, as through them the light ss so as to gain the retina. Of these, the only one that is sharply and ntly outlined is the lens, which is situated in the anterior half of the he level of the ciliary processes, where it is suspended between the other which fill respectively the space in front of it and the space behind it. in front of the lens called the aqueous chamber; that behind the lens is us chamber.

ns [lens crystallina] (fig. 834, 836) is a biconvex disk, with its surfaces nteriorly and posteriorly; these surfaces meet at its rounded-off edge or æquator lentis] which is near (but does not touch) the adjacent ciliary

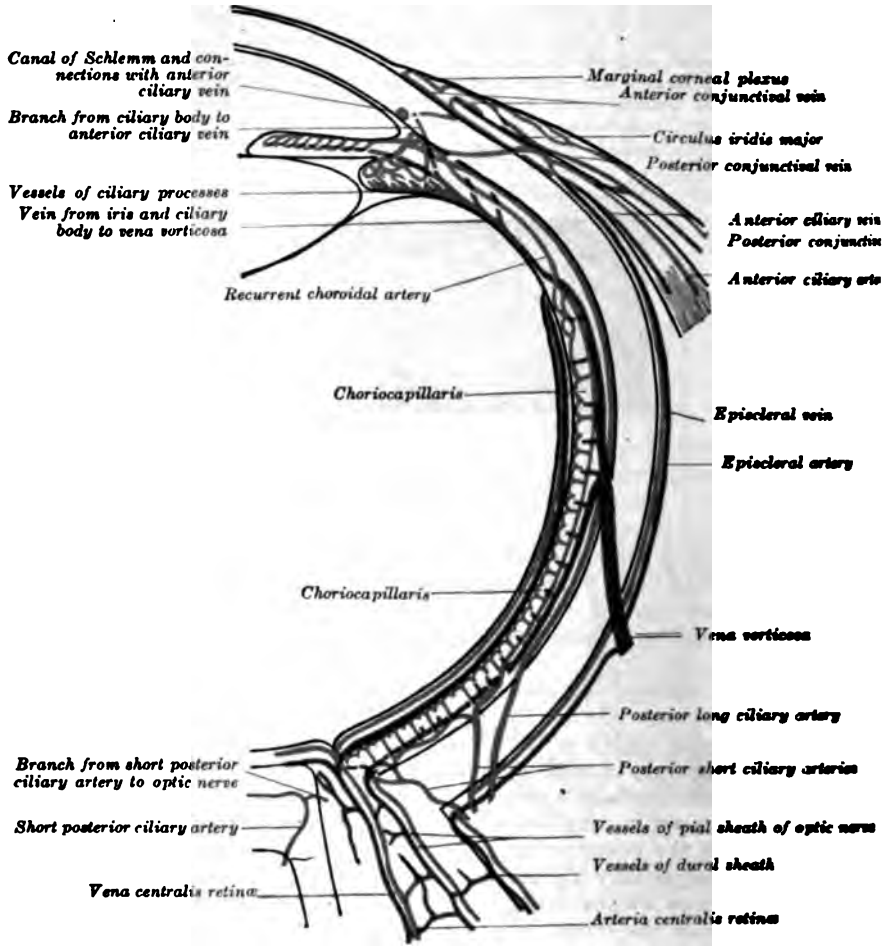
The posterior is considerably more convex than the anterior surface; l point on each surface is called its **pole** [polus anterior; polus posterior]. s closely encased in a hyaline elastic **capsule** [capsula lentis] thicker over or than over the posterior surface. Thus enclosed, it is held in position be by a **suspensory ligament,** attached to the lens-capsule near the f the eye, and swung from the ciliary region. Posteriorly, the lens cup formed by the front part of the vitreous, while its anterior capsule ct with the aqueous fluid and lies close against the back of the pupillary the iris. When in position the lens measures nine mm. across, and r mm. between its poles.

surface a series of fine, sinuous, gray lines can be seen radiating from the pole to- quator, called respectively the anterior and posterior **stellate figures** [radii lentis]. or lines are always so placed as to be intermediate with those on the anterior surface, viewing them *through the lens* they occupy a position corresponding to the intervals e lines on the anterior surface. The lens-capsule is comparatively brittle, and can ut through when scraped with a sharp-pointed instrument; on doing so the divided outward, away from the lenticular substance. When removed from its capsule, rtion of the lens is found to be soft and glutinous, but its substance gets progressively e approach the center. This harder central part is known as the **nucleus** [nucleus the surrounding softer matter as **cortex** [substantia corticalis]. The cortical part idency to peel off in successive layers. It consists of long fibers, the ends of which nt and behind at the anterior and posterior stellate figures.

Histologically the capsule is not in immediate contact with the cortex over the front surface of the lens, a single layer of cells intervening, called the **epithelium lentis.**

The **zonula ciliaris or suspensory ligament of the lens** is formed by a number of fine zonular fibers [fibræ zonulares] passing from the ciliary body. They are attached to the lens-capsule a little in front of and behind the equator, and the spaces included between the fibers of the ligament are termed the *zonular spaces* [spatia zonularia]. A continuous space, which can be injected after death round the margin of the lens is known as the *canal of Petit.* This space is bridged across by fine intermediate suspensory fibers, and is occupied by fluid.

FIG. 837.—DIAGRAMMATIC REPRESENTATION OF THE BLOOD-VESSELS OF THE EYEBALL. (Leber.)
Arteries *red;* veins *blue.*


Canal of Schlemm and connections with anterior ciliary vein
Branch from ciliary body to anterior ciliary vein
Vessels of ciliary processes
Vein from iris and ciliary body to vena vorticosa
Recurrent choroidal artery
Marginal corneal plexus
Anterior conjunctival vein
Circulus iridis major
Posterior conjunctival vein
Anterior ciliary vein
Posterior conjunctival
Anterior ciliary artery
Choriocapillaris
Episcleral vein
Episcleral artery
Choriocapillaris
Vena vorticosa
Posterior long ciliary artery
Posterior short ciliary arteries
Branch from short posterior ciliary artery to optic nerve
Short posterior ciliary artery
Vessels of pial sheath of optic nerve
Vessels of dural sheath
Vena centralis retinæ
Arteria centralis retinæ

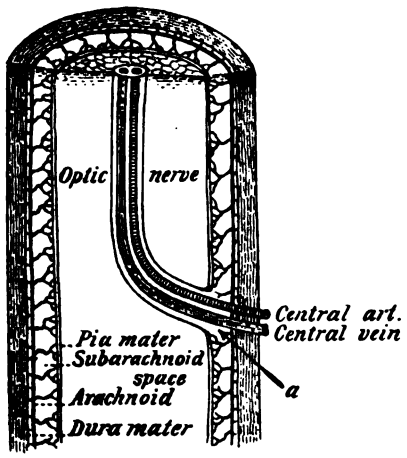
The **vitreous body** [corpus vitreum] is a transparent, colorless, jelly-like mass, the **vitreous humor,** enclosed in a delicate, clear, structureless membrane, the *hyaloid membrane.* This latter is closely applied to the back of the posterior lens-capsule and of the suspensory ligament, and to the inner surface of the ciliaris retinæ, retina proper, and optic papilla.

Although possessing some degree of firmness, the vitreous humor contains quite 98% of water, and has no definite structure. Membranes have been described in it, but these are artificial products. In certain situations spaces exist in the vitreous mass, the most distinct of which runs in the form of a canal from the optic papilla to the posterior pole of the lens, corresponding to the position of the fetal hyaloid artery (hyaloid canal or canalis hyaloideus), which occasionally persists in the adult. Other very fine spaces are described running concentrically in the peripheral part of the vitreous concentric with its outer surface. Microscopic wandering cells are found in the vitreous, which often here assume peculiar forms which the observer can, not infrequently, study subjectively.

ous humor is a clear, watery fluid, occupying the space between the
e one hand, and the ciliary body, zonula ciliaris, and lens on the other.
jecting into this space, has both its surfaces bathed in the aqueous;
ıer part rests on the lens, it is regarded as dividing the space into two
erior larger, and a **posterior** smaller, **aqueous chamber** [camera oculi
ıterior], which communicate freely through the pupil.
erves of the eyeball.—The long and short ciliary nerves, after per-
sclera, run forward between it and the choroid to the ciliary region,
ɔrm a plexus, from which proceed branches for the ciliary muscle, the
cornea.

of the iris enter it at its ciliary border, and run toward its pupillary edge, losing
r sheath sooner or later, and supplying especially the sphincter muscle. The
form an annular plexus near the limbus, from which a few twigs proceed to the
unctiva, while most of the offsets enter and run radially in the corneal stroma,
anastomosing so as to form a plexus. The nerves entering the cornea are about
r.

LATIONS OF CENTRAL RETINAL VESSELS TO OPTIC NERVE. *a*. Point where rise
essure in the subarachnoid space affects the central vein of the retina. (Wolff.)



ıseis of the eyeball.—The eyeball receives blood from two sets of the **retinal** and the **ciliary arteries,** as described in the section on ASCULAR SYSTEM. (See figs. 837, 839.)

ia centralis rétinæ either comes direct from the ophthalmic artery, or from one near the apex of the orbit. Entering the optic nerve about fifteen mm. behind is forward in its axis to enter the eye, and then divides into branches which run ers of the retina, and divide dichotomously as they radiate toward the equator. nches lie more deeply in the retina, but none penetrate into the nerve-epithelium, a centralis is non-vascular. *In the retina, the branches of the central artery do not th any other arteries.* Therefore embolism of the central artery causes profund retinal function and even total blindness. But (*a*) minute twigs from it, which the axial part of the nerve, communicate with those running in the septa derived heath. Again, as the nerve passes through the sclera, it is surrounded by a ircular vasculosus n. optici (Halleri)], formed of fine branches derived from the ciliary arteries; fine twigs passing inward from this ring to the optic nerve join ıe pial sheath, and (*b*) an indirect communication is thus brought about between ciliary vessels. Finally, as the nerve passes through the choroid, there is (*c*) a ɔn between these two sets of vessels, the capillary network of the optic nerve tinuous with the choriocapillaris. Not infrequently, a branch from a short ' artery pierces the optic papilla, and then courses over the adjoining retina tery), supplying the latter in part in place of the central artery.
ɛs of the a. centralis retinæ in the retina are: arteriola temporalis retinæ supe-
emporalis retinæ inferior, arteriola nasalis retinæ superior, arteriola nasalis
arteriola macularis superior, arteriola macularis inferior, arteriola retinæ

ntralis retinæ returns the blood of the corresponding artery and has branches o those of the artery.
walled central vein of the retina leaves the optic nerve it crosses the subarach-
so becomes exposed to the effects of any rise of pressure to which the fluid in be subject (fig. 838). Thus in patients suffering from cerebral tumor the rise

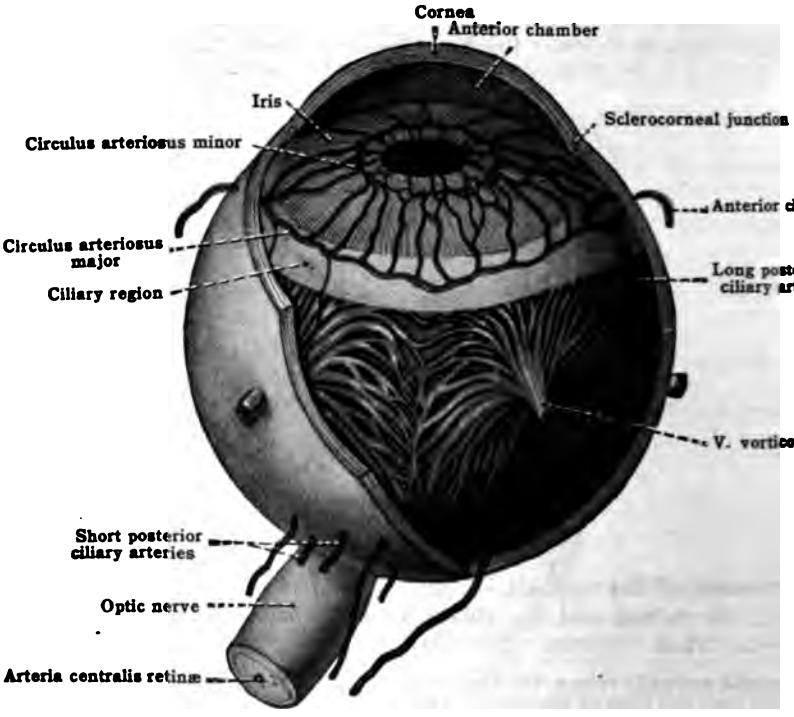
of pressure in the subarachnoid fluid may impede the escape of blood from the retina, producing a condition known as 'choked disk.'

2. **The ciliary system of blood-vessels** (see *Blood-Vascular System*).—There are three sets of arteries belonging to this system, all derived directly or indirectly from the ophthalmic artery.

(1) **Short posterior ciliary arteries** twelve to twenty in number, pierce the sclera around the optic nerve entrance, and are distributed in the choroid. Before entering the eyeball, small twigs are given off to the adjoining sclera and to the dural sheath of the optic nerve.

(2) Two **long posterior ciliary arteries**, medial and lateral, piercing the sclera further from the nerve than the short ciliaries, run horizontally forward between the sclera and choroid, one on each side of the globe. On arriving at the ciliary body, they join with the anterior ciliary arteries, forming the **circulus arteriosus major**, which sends off branches to the ciliary processes and the iris. The long ciliaries also give twigs to the ciliary muscle, and small recurrent branches run backward to anastomose with the short ciliary arteries. The arteries of the iris run radially toward the pupillary border, anastomosing with one another opposite the outer border of the sphincter and forming there the **circulus arteriosus minor.**

FIG. 839.—BLOOD-VESSELS OF THE EYEBALL, LATERAL VIEW.



(3) The **anterior ciliary arteries** come from the arteries of the four recti muscles, one or two from each; they run forward, branching as they go, and finally pierce the sclera near the corneal border. Externally to the globe they send twigs to the adjoining sclera, to the conjunctiva, and to the border of the cornea. After passing through the sclera the arteries enter the ciliary muscle, where they end in twigs to the muscle and to the circulus arteriosus major, and in recurrent branches to the choroid.

Veins.—The venous blood from almost the whole middle coat (choroid ciliary processes and iris, and part of the ciliary muscle) ultimately leaves the eyeball by—(1) the venæ vorticosæ which have been already noticed in describing an anteroposterior section through the globe. One large vein passes backward from each vortex, piercing the sclera obliquely; it is joined by small episcleral veins when outside the globe.

(2) The anterior ciliary veins commence by the junction of a few small veins of the ciliary muscle; they pass outward through the sclera near the corneal border, receiving blood from the veins in connection with the sinus venosus of the sclera, and afterward from episcleral and conjunctival veins, and from the marginal corneal plexus. Finally they join the veins running in the recti muscles.

Lymphatic system of the eyeball.—Apart from those in the conjunctiva there are no lymphatic *vessels* in the eyeball, but the fluid is contained in *spaces* of various sizes. These are usually divided into an anterior and a posterior set. (fig. 841.)

1. Anteriorly, we have the anterior and posterior aqueous chambers (together composing the aqueous chamber of the eye), which communicate freely through the pupil. The aqueous humor is formed in the posterior of these chambers by transudation from the vessels of the ciliary body and posterior surface of the iris (see also page 1095). The stream passes mainly forward through the pupil into

FIG. 840.—DIAGRAM TO ILLUSTRATE THE COURSE OF THE STREAM FROM THE CILIARY BODY TO THE FILTRATION ANGLE. (Based on Arthur Thomson's figures.)

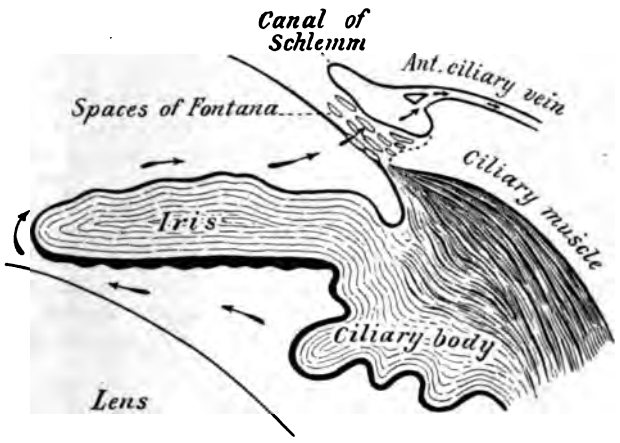
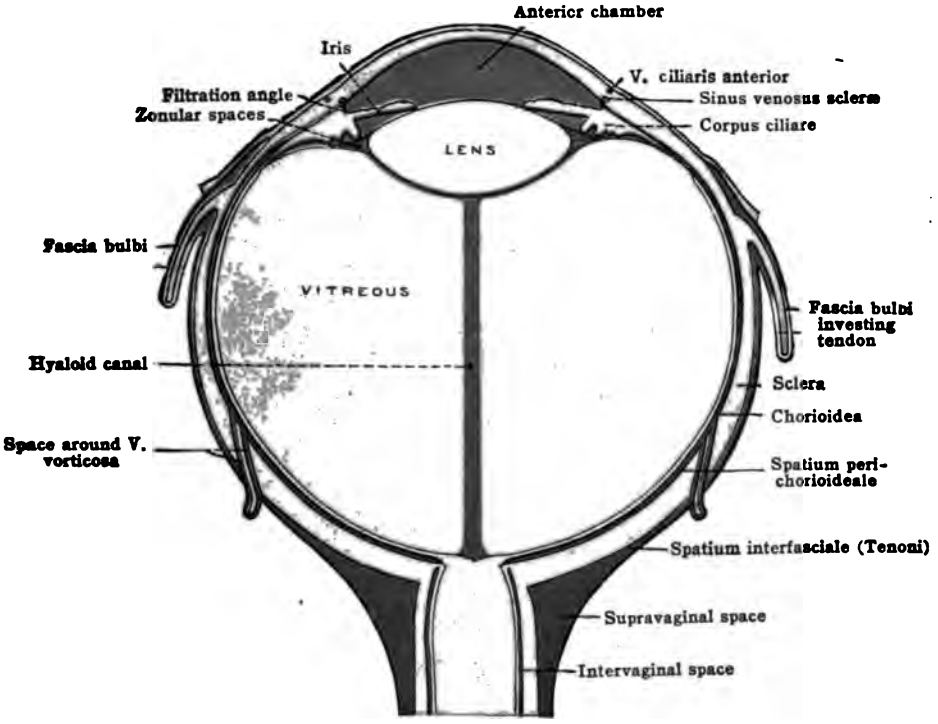


FIG. 841.—LYMPHATIC SPACES OF THE EYEBALL (in green).



the anterior aqueous chamber, whence it escapes slowly by filtering from the spaces of Fontana into the canal of Schlemm and thence into the anterior ciliary veins. Part of the lymph-stream passes from the posterior aqueous chamber backward into the zonular spaces, out of which fluid can pass in front of the vitreous body to the hyaloid canal.

The space between the iris and the cornea where the fluid in the anterior chamber makes its escape into the spaces of Fontana has been called the **filtration angle.** Any interference with the

normal outflow of fluid in this area will raise the tension of the eyeball, and may produce *glaucoma*. According to Thomson, contraction of the ciliary muscle tends to dilate the spaces of Fontana and the canal of Schlemm (fig. 840), and hence facilitates the flow of fluid into the latter.

In the **cornea** the lymph travels in the spaces already mentioned as existing between the fiber-bundles, and in the nerve-channels and at the periphery of the cornea it flows off into the lymphatic vessels of the conjunctiva.

In the **iris** there is a system of lymphatic spaces opening anteriorly into the crypts of the surface, and communicating peripherally with the spaces of the angle of the iris.

2. **Posteriorly,** we have (*a*) the hyaloid canal, between the posterior pole of the lens and the place of entrance of the optic nerve, and (*b*) the perivascular canals of the retina; the lymph from both of these situations flows into the spaces of the optic nerve, which communicate with the intervaginal spaces of the nerve, and thus with the great intracranial spaces. Further, between choroid and sclera we have (*c*) the perichoroidal space, which gets the lymph from the choroid, and communicates with the interfascial space (of Tenon) outside the sclera by perforations corresponding to the vasa vorticosa and posterior ciliary arteries, and with the intervaginal spaces around the optic nerve entrance. The interfascial space of Tenon, again, is continuous with the supravaginal space around the optic nerve, which communicates both with the intervaginal spaces, with the lymph-spaces of the orbit, and directly with the intracranial spaces at the apex of the orbit.

CAVITY OF THE ORBIT

General Arrangement of its Contents (Figs. 842, 843, 844)

The anterior wider half of the cavity is mainly occupied by the eyeball, which lies almost axially, but is rather nearer to the upper and lateral than it is to the other walls. The posterior two-thirds of the globe are in relation with soft parts, chiefly muscles and fat, and its posterior pole is situated midway between the base (or opening) and the apex of the orbital cavity. The anterior third of the eyeball is naturally free, except for a thin covering of the conjunctiva, and projects slightly beyond the opening of the oribit, the degree of prominence varying with the amount of orbital fat, and also to some extent with the length of the globe. A straight line joining the medial and lateral orbital margins usually cuts the eye behind the cornea—laterally behind the ora serrata, medially further forward, at the junction of the ciliary body and iris. The globe is held in position by numerous bands of connective tissue. The lacrimal gland lies under the lateral part of the roof of the orbit anteriorly. The orbit fat occupies the spaces between the orbital muscles, and is in greatest amount immediately behind the eyeball; it also exists between the muscles and the orbital walls in the anterior half of the cavity. The optic nerve with its sheaths passes from the optic foramen to the back of the eyeball, surrounded by the orbital fat, and more immediately by a loose connective tissue. Among the contents of the cavity are also to be enumerated many vessels and nerves and fibrous tissue septa, while its walls are clothed by periosteum(periorbita).

Six muscles, viz., the four recti, the superior oblique, and the levator palpebræ superioris, arise at the apex of the orbit, and diverge as they pass forward. The recti muscles—superior, inferior, lateral, and medial—run each near the corresponding orbital wall, but the superior is overlapped in part by the levator palpebræ. The superior oblique lies about midway between the superior and medial recti. A seventh muscle, the inferior oblique, has a short course entirely in the anterior part of the orbit, coming from its medial wall and passing below the globe between the termination of the inferior rectus and the orbital floor.

Of the seven muscles of the orbit, six are *ocular, i.e.*, are inserted into the eyeball and rotate it in different directions. These ocular muscles are arranged in opponent pairs, viz., superior and inferior recti, superior and inferior obliques, lateral and medial recti. With the exception of the short inferior oblique, they all arise from the back of the orbit along with the seventh orbital muscle, the levator palpebræ superioris. All these long muscles take their origin from the periosteum in the vicinity of the optic foramen. The four recti muscles arise from a fibrous ring, the annulus tendineus communis, which arches close over the upper and medial edge of the foramen, and extends down and out so as to embrace part of the opening of the superior orbital

Their origins may be said at first to form a short, common, tendinous tube, from which vidual muscles soon separate, taking the positions indicated by their respective names. ral rectus has two origins from bone, one on either side of the superior orbital fissure.

. 842.—Horizontal Section of the Orbital Region, Viewed From Above.

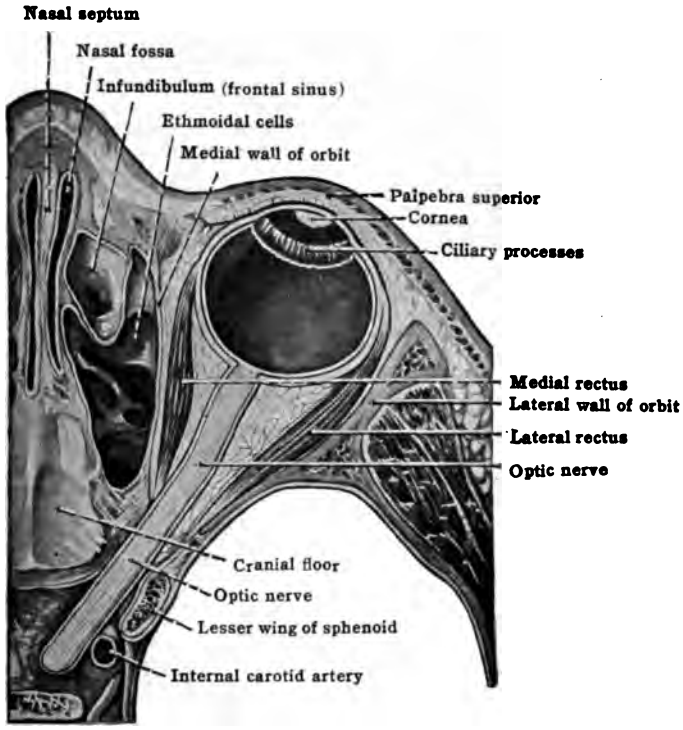
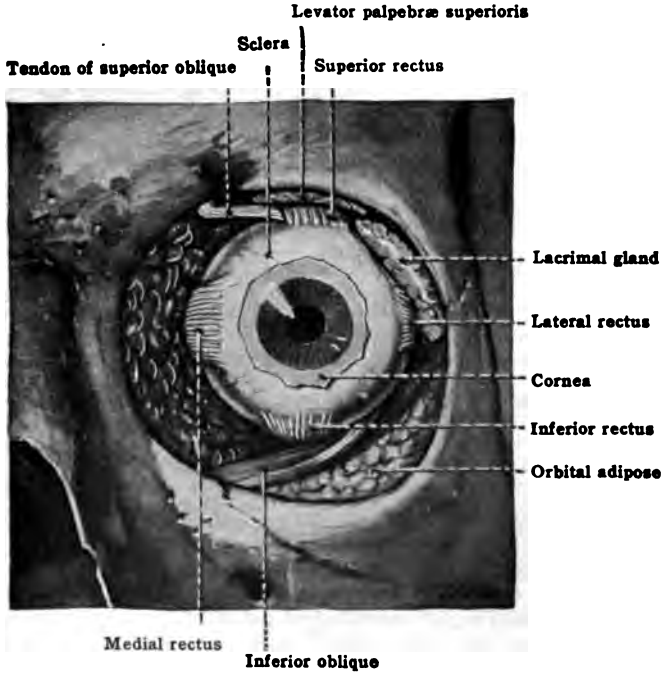


Fig. 843.—Dissection of the Left Orbit from in Front.

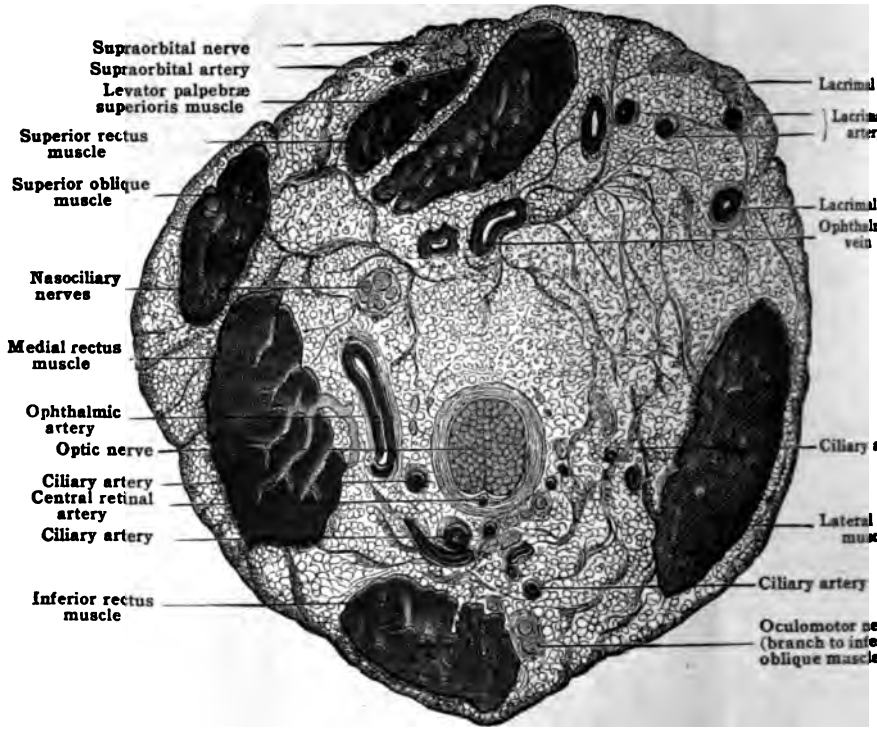


the fresh state the fissure is here bridged across by fibrous tissue, from which this rectus ings, so that its origin is in reality continuous. The part of this fibrous ring nearest men (corresponding to the origins of the superior and medial recti) is closely connected

with the outer sheath of the optic nerve. The remaining two long muscles arise just outside the upper and medial part of the above-mentioned ring, and are often partially united; the levator palpebræ tendon is in close relation to the origin of the superior rectus, while the superior oblique arises from the periostum of the body of the sphenoid bone one or two mm. in front of the origin of the medial rectus.

The four recti muscles (figs. 843, 846) lie rather close to the corresponding orbital walls for the first half of their course, the superior rectus, however, being overlapped in part by the levator palpebræ; they then turn toward the eyeball, running obliquely through the orbital fat, and are finally inserted by broad, thin tendons into the sclera in front of the equator. From their respective positions in the orbit, the axis of this cone of muscles is oblique to the anteroposterior axis of the eyball. The thickest of these muscles is the medial rectus, next the lateral, then the inferior, and the superior rectus is the thinnest. As regards length, the muscular belly of the superior rectus has the longest course, and the others diminish in the order—medial, lateral, and inferior rectus. The lateral rectus is supplied by the abducens nerve. The other three recti muscles are all supplied by the oculomotor nerve.

FIG. 844.—CROSS-SECTION RIGHT ORBIT 8–11 MM. BEHIND THE EYEBALL; VIEWED FROM BEHIND (After Lange.)



The levator palpebræ superioris (figs. 843–846) courses along the roof of the orbit close to the periosteum for the greater part of its course, partially overlapping the superior rectus; it finally descends through the orbital fat, and widens out to be inserted into the root of the upper lid. It may be briefly described as being inserted in two distinct layers separated by a horizontal interval. The upper or anterior layer of insertion is fibrous, and passes in front of the tarsus, where it comes into relation with fibers of the orbicularis. The lower layer consists of smooth muscle (Müller's superior tarsal muscle), and is inserted along the upper border of the tarsus. The levator has also connections with the sheath of the superior rectus. These different insertions of the muscle will be referred to later along with the description of the orbital fasciæ and of the upper eyelid. It gets its nerve supply from the oculomotor nerve, but the smooth muscle developed in its lower layer of insertion is supplied by the sympathetic nervous system. As its name expresses, its *action* is to raise the upper lid and to support it while the eye is open.

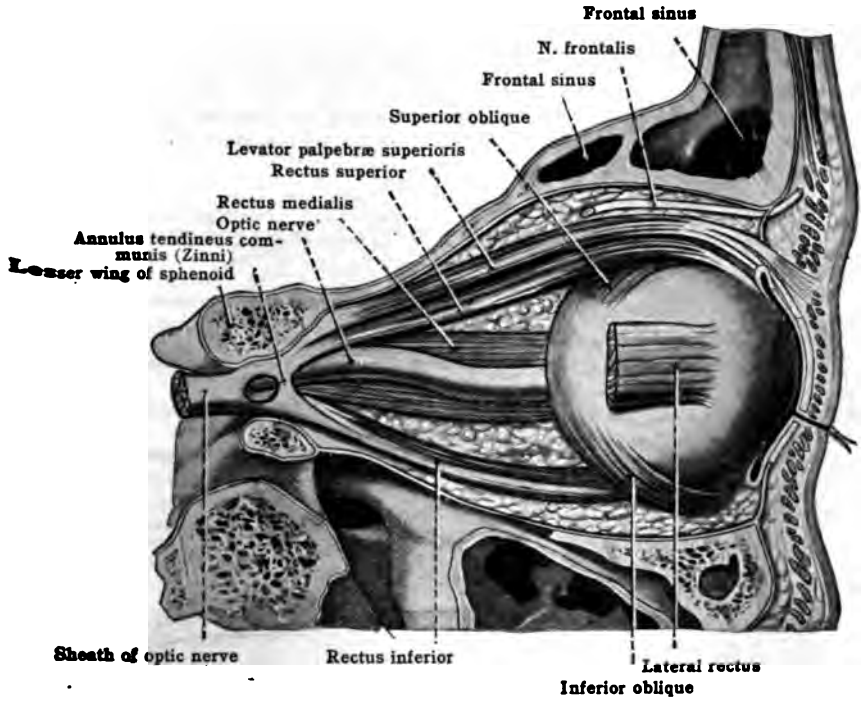
The superior oblique (figs. 843, 846) runs forward close to the medial part of the orbital roof until it reaches the fovea trochlearis near the medial angular process, where it becomes tendinous and passes through a fibro-cartilaginous pulley attached to the fovea just named. On passing through this pulley, or trochlea, the tendon bends at an angle of 50°, running posteriorly and laterally under the superior rectus to its insertion into the sclera. It is supplied by the trochlear nerve.

The inferior oblique (figs. 843, 845) arises from the front of the orbit, about the junction of its medial and inferior walls, just lateral to the lower end of the lacrimal groove. It runs, in a sloping direction, laterally and posteriorly, lying at first between the inferior rectus and the orbital floor, then between the lateral rectus and the globe; finally it ascends slightly, to be inserted by a short tendon into the sclera at the back of the eye. Its nervous supply is derived from the oculo-

[illegible]tor nerve, a long branch of which extends forward on the floor of the orbit alongside the [illegible]ral border of the inferior rectus (fig. 844) and enters the inferior oblique muscle on its lower [illegible]face. The precise manner of insertion of the different ocular muscles has been described above [illegible]. 1091). For muscles of the eyelids and eyebrows, see pp. 370 and 1111.

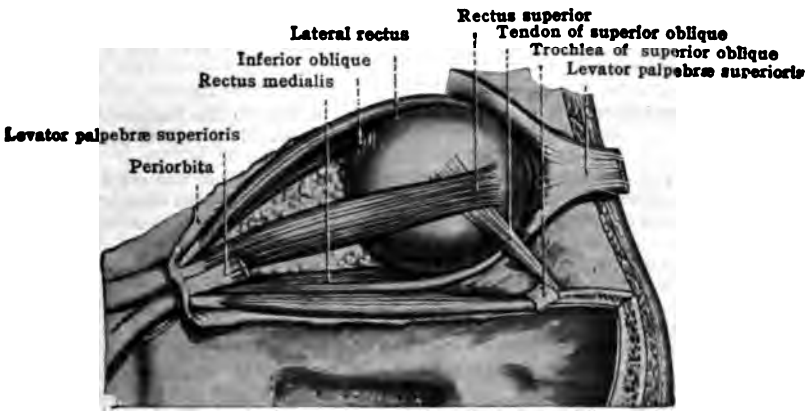
Action of the ocular muscles.—Tenon's capsule forms a socket in which the eyeball is said to [illegible]work when the muscles move the eye so as to turn the cornea in different directions. The

FIG. 845.—DISSECTION OF THE MUSCLES OF THE RIGHT ORBIT, LATERAL VIEW.



position of this socket (and of the contained eyeball) in the orbit is not subject to alteration: it is merely the direction and not the situation of the eye that changes when the muscles act. The movements that take place can be described in reference to three principal axes passing through the center of the roughly spherical eyeball. These axes are (1) vertical, (2) frontal horizontal (transverse or equatorial) and (3) anteroposterior or sagittal horizontal. The

FIG. 846.—DISSECTION OF THE MUSCLES OF THE LEFT ORBIT, FROM ABOVE.



movements that occur may be analyzed into upward and downward (around the frontal horizontal axis), medial and lateral (around the vertical axis), and rotation (i. e. wheel rotation around the anteroposterior axis). Taking twelve o'clock in a dial as the moving point rotation may be described as medial (nasalward) or lateral (temporalward).

Confusion is often introduced into the description of eye movements by using the term 'rotation' for any movement of the globe. It is important clearly to distinguish between movements of the eye in a definite radial direction and those in which the cornea is rotated clockwise.

The only two muscles that move the eyeball merely on one axis are the lateral rectus and the **medial rectus**; their names, lateral and medial, describe the effects in the cornea. The action of the superior and inferior recti is complicated by the obliquity of the axes of muscle and globe previously mentioned.

The chief action of the **superior rectus** is to make the eye look upward and somewhat medially.

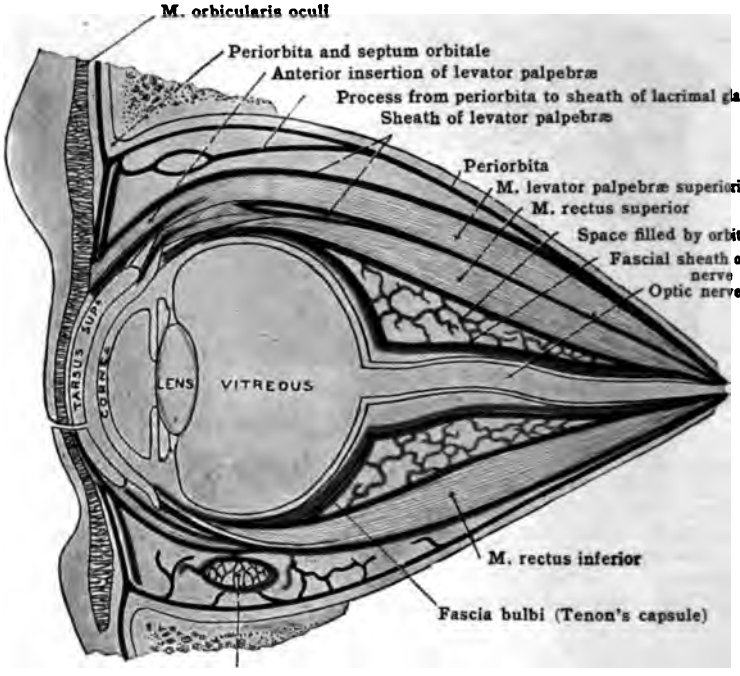
The **inferior rectus** makes the eye look downward with a slight inclination medially.

The chief action of the **superior oblique** is to move the eye as as to make it look downward and laterally, at the same time rotating it medially.

The **inferior oblique** mainly turns the eye so as to make it look upward and laterally, at the same time rotating it laterally.

The fasciæ of the orbit [fasciæ orbitales].—The orbital contents are bound together and supported by fibrous tissues, which are connected with one another, but which may conveniently be regarded as belonging to three systems. These are:—(1) Those lining the bony walls; (2) the tissue which partially encapsules the eyeball; and (3) those ensheathing the muscles.

FIG. 847.—DIAGRAM REPRESENTING THE ORBITAL FASCIÆ IN VERTICAL SECTION. Periorbita *black;* muscular sheaths *violet;* Interfascial (Tenon's) space *green.*



1. The **orbital periosteum** [periorbita], is closely applied to the bones forming the walls of the cavity, but may be stripped off with comparative ease. It presents openings for the passage of vessels and nerves entering and leaving the orbit.

Posteriorly this tissue is very firm, being joined by processes of the dura mater at the optic foramen and superior orbital fissure; at the optic foramen it is also connected with the dural sheath of the optic nerve. As it covers the inferior orbital (sphenomaxillary) fissure its fibers are interwoven with smooth muscle, forming the **orbital muscle of Müller.** From its inner surface processes run into the orbital cavity, separating the fat lobules. One important process comes from the periorbita about midway along the roof of the orbit, runs forward to the back of the upper division of the lacrimal gland, and there becomes continuous with the fibrous tissue forming the gland-capsule; this capsule is joined at its medial border by other periorbital bands coming off near the upper orbital rim, and forming the suspensory ligament of the gland. On the side of the orbit the periorbita sends fibrous processes to the trochlea of the superior oblique, which keep it in position. On arriving at the lacrimal groove the periorbita divides into two layers, a thin posterior one continuing to line the bone forming the floor of the groove, whilst the thicker anterior layer bridges over the groove and the sac which lies in it, forming the limbs of the medial palpebral ligament (pp. 1087, 1113).

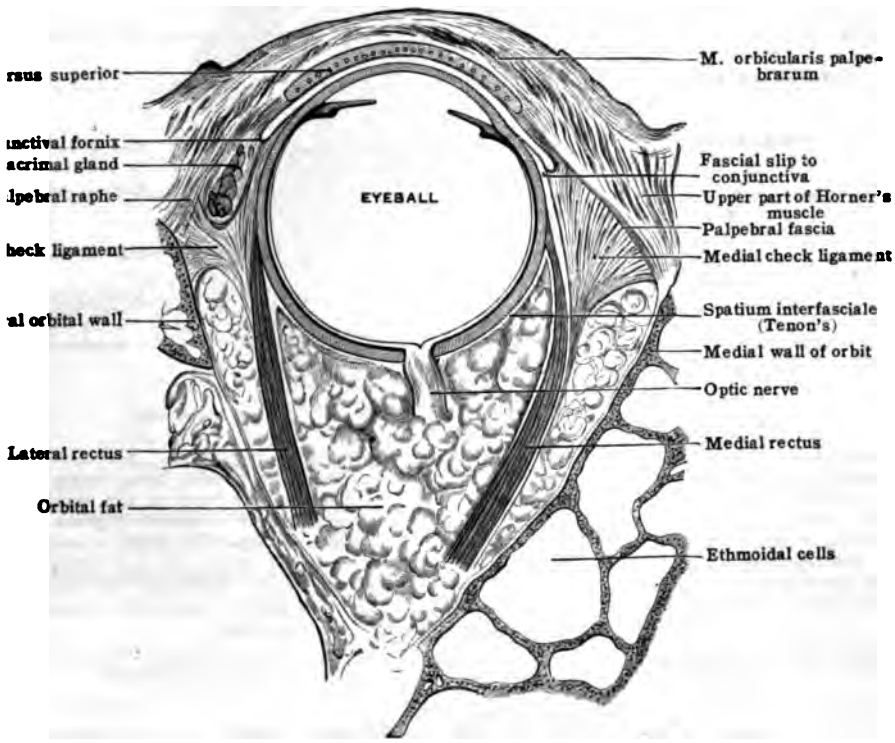
Quite anteriorly, at the rim of the orbit, the periorbita sends off a membranous process which aids in forming the fibrous tissue of the eyelids (**orbitotarsal ligament, or palpebral fascia**), and is itself continuous with the periosteum of the bones outside the orbital margin.

2. The hollow in the front of the orbital fatty tissue is lined by a layer of fibrous tissue known as the **fascia bulbi** or **capsule of Tenon** (figs. 835, 847), which covers the posterior

arths of the eyeball and becomes continuous with the sheath of the optic nerve. The rface of the fascia is smooth and is connected with the sclera only by a loose, wide- areolar tissue. This interval between the sclera and fascia, known as the **interfascial s) space** (figs. 835, 841, 847, 848), is a lymph-space, which permits free movements yeball within the capsule. The space of Tenon extends as far forward as the conjunctiva e corneal margin, the fascia bulbi being attached to the conjunctiva anterior to the n of the recti muscles into the sclera. Posteriorly, however, it approaches the optic forming the supravaginal space, and communicates with the subdural (intervaginal) space around the nerve which in turn opens into the corresponding intracranial lymph- Around the place where the posterior ciliary vessels and nerves perforate the sclera ce of Tenon is obliterated.

he tendons of the recti perforate the fascia bulbi to reach the sclera and the fascia s thickened to form a ring by means of which the muscles are prevented from compress,

FIG. 848.—HORIZONTAL SECTION THROUGH LEFT ORBIT, VIEWED FROM ABOVE. (After von Gerlach.)



so distorting the eyeball when they contract. These rings of thickened fascia are ious with the sheaths of the muscles. Bands of fibrous tissue connect the fascia of the r rectus to the tendon of the levator palpebræ superioris, and that of the inferior passes to the inferior border of the tarsal plate of the lower eyelid (fig. 847). From eaths of the medial and lateral recti respectively strong bands of connective tissue, the **medial** and **lateral check ligaments** (figs. 835, 845) pass to the walls of the orbit rmer to thecrest of the lacrimal bone and the latter to the orbital surface of the atic bone. A thickening of the lower part of the fascia bulbi, attached medially and later- he lacrimal and zygomatic bone respectively, forms the **suspensory ligament.** (Lockwood.)

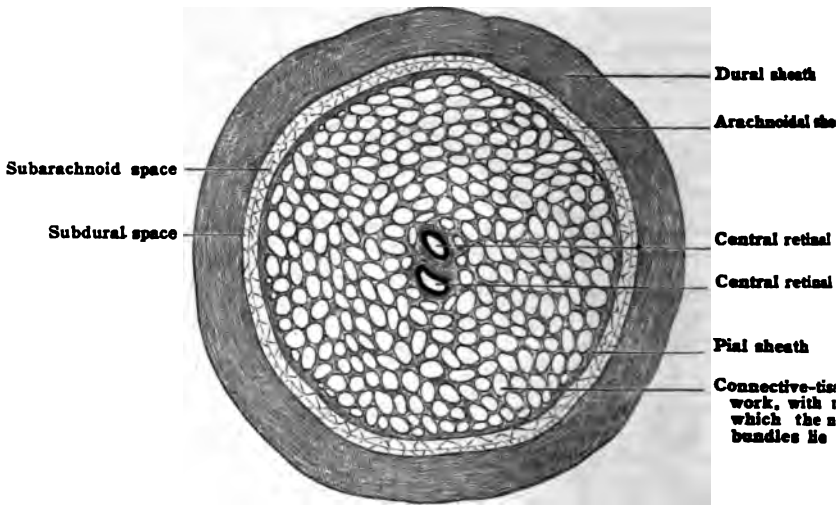
THE OPTIC NERVE

e part of this nerve with which we have here to do lies within the orbit, ex- g from the eyeball to the optic foramen (figs. 841, 845, 849, 850). The of this portion of the nerve is from 20 to 30 mm. and its diameter about . Its course is somewhat S-shaped.

leaving the globe 3 or 4 mm. to the medial side of its posterior pole, the optic nerve directly backward: then it becomes slightly curved, with the convexity of the curve l medially, and finally it undergoes a more pronounced deflection with its convexity ard and laterally before it leaves the orbit by the optic foramen. As the nerve passes, r fibrous sheath blends with the periorbita, and the composite structure becomes con- with the dura mater. In the orbit the outer or **dural sheath** loosely surrounds the erve, which through the optic foramen is closely enveloped by a vascular covering

derived from the pia mater, named accordingly the **pial sheath.** The space between th two sheaths is subdivided by a fine prolongation of the arachnoid (the **arachnoidal tha** into two parts, termed the intervaginal spaces [spatia intervaginalia], viz., an outer, nam *subdural*, and an inner, wider, *subarachnoid space*, communicating with the correspon intracranial spaces and also with the supravaginal (interfascial) spaces of the orbit. The ar noidal sheath is connected with the sheath on each side of it by numerous fine processes w bridge across the intervening spaces. The pial sheath sends processes inward, which fo framework separating the bundles of nerve-fibers; between the enclosed nerve-fibers and

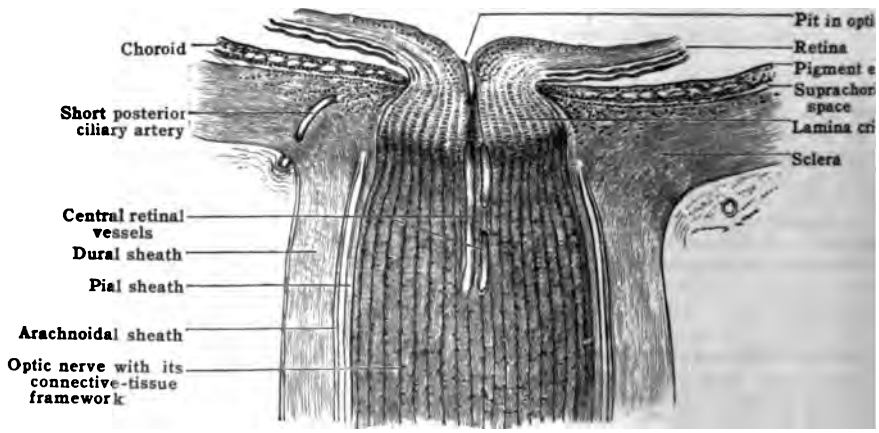
FIG. 849.—TRANSVERSE SECTION THROUGH OPTIC NERVE, SHOWING THE RELATIONS OF SHEATHS AND CONNECTIVE TISSUE FRAMEWORK.



mesh of this framework there is a narrow interval occupied by lymph. The nerve-f medullated, but have no primitive sheath. About fifteen or twenty mm. behind t the central vessels enter, piercing obliquely the lower lateral quadrant of the nerve, run forward in its axis. They are accompanied throughout by a special process of sheath, which forms a fibrous cord in the center of the nerve (figs. 838, 849).

On reaching the eyeball, the dural sheath is joined by the arachnoid, and turns av the nerve to be continued into the outer two-thirds of the sclera. Similarly the pial sh here leaves the nerve, its greater part running into the inner third of the sclera, while a

FIG. 850.—LONGITUDINAL SECTION THROUGH RETINAL END OF OPTIC NERVE.



fibers join the choroid; the intervaginal spaces consequently end abruptly in the sclera the nerve-entrance. In this locality the connective tissue framework of the nerve thicker and closer in its meshwork, and has been already alluded to as the lamina scleræ. It is formed by processes passing out from the central fibrous cord at its ter and by processes passing inward from the pial sheath, sclera, and chorioid. It does straight across the nerve, but follows the curve of the surrounding sclera, being therefor convex backward. The nerve-trunk here quickly becomes reduced to one-half its form eter, the fibers losing their medullary sheaths. Apart from the consequent loss of t

stological change may be readily recognized macroscopically in a longitudinal section of the erve (fig. 850), its aspect here changing from opaque white to semi-translucent gray. The art of the nerve within the lamina cribrosa has already been noted in the ophthalmoscopic xamination of the living eye (p. 1090).

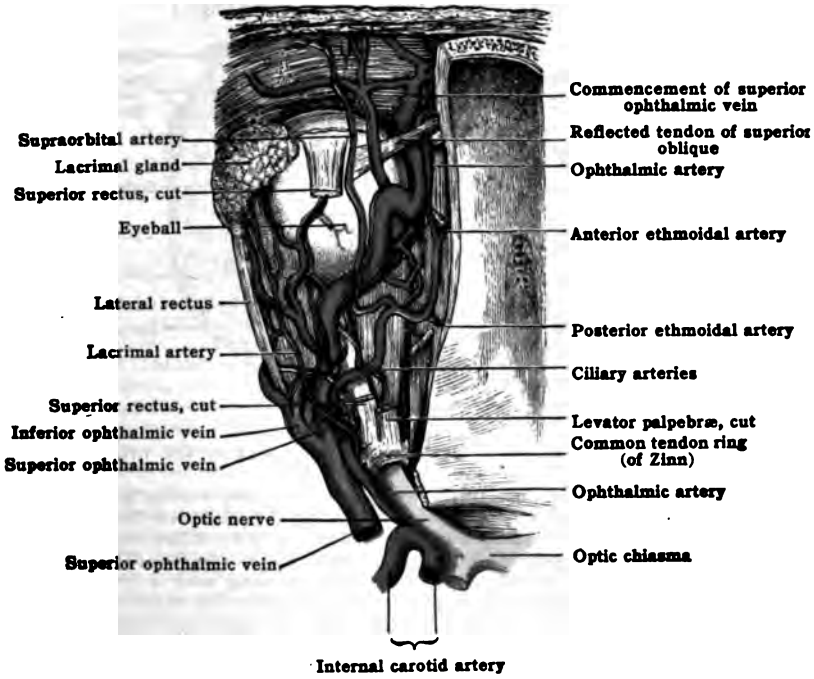
The optic nerve is mainly nourished by fine vessels derived from those of the pial sheath, hich run into the substance of the nerve in the processes above mentioned. In front of the ntrance of the central retinal artery this vessel aids to some extent in the blood-supply of the xial part of the nerve.

The Blood-vessels and Nerves of the Orbit

As these structures will be more particularly described in other sections of this work, a very short general account will suffice here.

Arteries.—The main blood-supply is afforded by the **ophthalmic artery,** a branch of the internal carotid, which gains the orbit through the optic foramen, where it lies below and lateral to the nerve. On entering the orbit it ascends and passes obliquely over the optic nerve to the medial wall of the orbit; in this early part of its course it gives off most of its branches, which

Fig. 851.—The Blood-vessels of the Left Orbit, viewed from above.



vary much in their manner of origin and also in their course. The arteries of the orbit are remarkable for their tortuous course, for their delicate walls, and for their loose attachment to the surrounding tissues. The ophthalmic artery gives off special branches in the orbit to the lacrimal gland, the muscles, the retina (through the optic nerve), and the eyeball, as well as to the meninges the ethmoidal cells, and the nasal mucous membrane. Twigs from all the different branches go to supply the fat, fasciæ, and ordinary nerves of the orbit. Branches which leave the orbit anteriorly ramify on the forehead and nose, and also go to the supply of the eyelids and the tear-passages The ophthalmic artery has many anastomoses with branches of the external carotid. The contents of the orbit are also supplied in part by the **infraorbital artery,** a branch of the internal maxillary; in particular this artery supplies part of the inferior rectus and inferior oblique muscles in the cavity, and also gives a branch to the lower eyelid.

Veins.—Branches, corresponding generally to those of the artery, unite to form the **superior and inferior ophthalmic veins,** which ultimately, either separately or united into one trunk, pass through the superior orbital fissure and empty into the cavernous sinus. The inferior vein is connected with the pterygoid plexus by a branch which leaves the orbit by the inferior orbital fissure.

Nerves of the orbit.—These are (A) **motor,** (B) **sensory,** and (C) **sympathetic,** and all enter the orbit by the superior orbital fissure, with the exception of one small sensory branch passing through the inferior orbital fissure. (The optic nerve has been already described, and is not included in this account.)

A. The **motor nerves** are the oculomotor, trochlear, and abducens.

1. The **oculomotor nerve** enters the orbit in two parts, an upper smaller, and a lower larger, division. The ***upper division*** [ramus superior] gives off two branches: one supplies the superior

rectus, entering its lower surface far back; the other branch goes to the levator palpebræ, entering its lower surface in its posterior third. The *lower division* [ramus inferior] divides into three branches, of which one supplies the inferior rectus, entering its upper surface far back, and another supplies the medial rectus, entering its medial surface a little behind its middle. The third branch of the lower division gives (1) the short root to the ciliary ganglion, and (2) one or more twigs to the inferior rectus, and the remainder of this branch then enters the lower surface of the inferior oblique muscle about its middle.

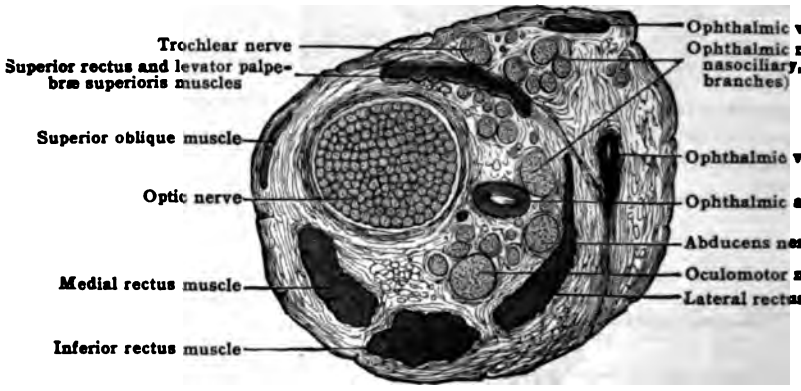
2. The **trochlear nerve** supplies the superior oblique muscle, entering its upper surface about midway in its course.

3. The **abducens nerve** supplies the lateral rectus, entering its medial surface about the junction of the posterior and middle thirds of the muscle.

As regards the manner of termination of these motor nerves, it is found that in all the ocular muscles the nerve on its entrance breaks up into numerous bundles of fibers, which form fine coarse and then fine plexuses, the latter ultimately sending off fine twigs supplying the muscle throughout with nerve-endings. The *posterior third* of these muscles is, however, comparatively poorly supplied with both kinds of plexuses and with nerve-endings.

B. The **sensory nerves** are supplied by the ophthalmic and maxillary divisions of the trigeminal cranial nerve. The ophthalmic division is chiefly orbital; while the maxillary sends only a small branch to the orbit.

FIG. 852.—CROSS-SECTION THROUGH RIGHT ORBIT 1–2 MM., IN FRONT OF THE OPTIC FORAMEN VIEWED FROM BEHIND. (After Lange.)



1. The **ophthalmic division** of the trigeminal nerve enters the orbit in three divisions, namely:—

(1) **Frontal**, splitting subsequently into *supratrochlear* and *supraorbital*, both passing out of the orbit. It is distributed to the corresponding upper eyelid, and the skin over the root of the nose, the forehead, and the hairy scalp as far back as the coronal suture on the same side. It also gives branches to the periosteum in this region, and to the frontal sinus.

(2) **Lacrimal**, supplying the lacrimal gland, anastomosing with a branch of the maxillary in the orbit, and finally piercing the upper eyelid. Outside the orbit it is distributed to the lateral part of the upper lid, the conjunctiva at the lateral angle, and the skin between this and the temporal region.

(3) **Nasociliary** giving off—(*a*) a branch to the ciliary ganglion, constituting its long root; (*b*) two or three *long ciliary nerves;* and (*c*) the *infratrochlear*, passing out of the orbit. The nerve then leaves the orbit as the anterior ethmoidal nerve, reentering the cranial cavity before being finally distributed to the nose. The infratrochlear branch [n. infratrochlearis], supplies the eyelids and skin of the side of the nose near the medial angle of the eye, the lacrimal sac, caruncle, and plica semilunaris. The anterior ethmoidal nerve, after its course in the cranial cavity, passes through an aperture in the front of the lamina cribrosa of the ethmoid bone, and is ultimately distributed to the nasal mucous membrane, and to the skin of the side and ridge of the nose near its tip.

2. The **maxillary division of the fifth nerve** gives a branch, called the **zygomatic nerve**, which passes into the orbit through the inferior orbital fissure, anastomoses with the lacrimal, and leaves the orbit in two divisions. These are distributed to the skin of the temple and of the prominent part of the cheek.

A few minute twigs from the sphenopalatine ganglion, and sometimes from the maxillary division of the fifth nerve, also pass through the inferior orbital fissure to supply the periorbita in this neighborhood.

C. The **sympathetic nerves of the orbit** are mainly derived from the plexus on the internal carotid artery. With the exception of branches accompanying the ophthalmic artery, and of the distinct sympathetic root of the ciliary ganglion, they enter the orbit in the substance of the other nerve-cords. The connections between the ocular nerves and the carotid plexus are recognizable as fibers going to the oculomotor, abducens, and ophthalmic nerves; as a rule, the comparatively large twigs going to the abducens join it furthest back, and those to the oculomotor furthest forward. Sympathetic connections with the trochlear nerve are very doubtful. The special courses of the motor fibers to the dilatator pupillæ muscle have already been described.

The **ciliary ganglion** is situated between the optic nerve and lateral rectus far back in the orbit. Its three roots—motor, sensory, and sympathetic—have been already mentioned Anteriorly, it gives off three to six small trunks, which subdivide to form the **short ciliary nerve.** nn. ciliares breves] about twenty in number, piercing the sclera around the optic nerve entrances.

The lymphatic system of the orbit.—Although there are no lymphatic *vessels* or *glands* in the orbit, the passage of lymph is nevertheless well provided for. We have already observed the lymph-channels within, between, and outside the sheaths of the optic nerve, and have seen how these communicate anteriorly with the lymph-channels of the eyeball, and posteriorly with the intracranial meningeal spaces.

The circulation of fluid in the anterior and posterior chambers was noted on p. 1101. In addition, there are lymph-spaces around the blood-vessels, situated between the outer coat and the loose investment furnished by the muscle-fascia. The nerves of the orbit (apart from the optic) are probably similarly surrounded by lymph-spaces. In the absence of lymphatic vessels it is difficult to trace the circulation thoroughly; much of the lymph from the orbital cavity is said to pass into the parotid nodes.

The Eyelids

The cutaneous and conjunctival surfaces of the eyelids [palpebræ] have already been examined (p. 1089), and the position of the tarsus has been indicated. We have now to ascertain the nature and relations of the tarsus, and describe the other tissues entering into the formation of the eyelids (fig. 853).

The skin here is thin, bearing fine hairs, and having small sebaceous and numerous small sweat-glands. Immediately beneath it is a loose subcutaneous tissue, destitute of fat, separating the skin from the palpebral part of the **orbicularis muscle.**

The lid-fibers of this muscle arise from the medial palpebral ligament, and course over the whole upper and lower eyelids in a succession of arches, so as to meet again beyond the lateral angle; there they in part join one another, in part are inserted into the lateral palpebral raphe. The muscular fibers are arranged in loose bundles, with spaces between them occupied by connective tissue; in the upper lid these connective tissue fibers may be traced upward and backward into the fibrous expansion of the tendon of the levator palpebræ superioris. One strong bundle of orbicularis fibers, called the **musculus ciliaris Riolani,** is found near the edge of the lid, in front of and behind the efferent ducts of the tarsal glands (fig. 853).

A connective tissue layer separates the orbicularis muscle from the tarsus in the tarsal division of the lids. In the upper lid this is to be regarded as mainly the anterior or fibrous expansion of the tendon of the levator palpebræ, which sends connective tissue septa between the bundles of the overlying orbicularis (as just mentioned) going to the skin. In the orbital part of this lid the central connective tissue includes also the palpebral fascia, lying here immediately beneath the orbicularis muscle; but this soon thins off and fades into the more deeply placed levator expansion. This latter is strengthened by an extension of the sheath of the superior rectus, by which this muscle is enabled to influence the elevation of the lid indirectly. In the lower lid the central connective tissue similarly consists of palpebral fascia, blended with a thin fibrous extension of the sheath of the inferior rectus. Immediately in front of each tarsus is a little loose connective tissue, which contains the large blood-vessels and nerves of the lids.

The **tarsus** of each lid is a stiff plate of dense fibrous connective tissue, with its surfaces directed anteriorly and posteriorly; in its substance the tarsal glands are embedded. One tarsal border is free, viz., toward the edge of the lid, the other is attached; the former is straight, while the latter is convex, especially in the upper lid.

The length of each tarsus is about 20 mm. Its breadth is greatest in the middle of the lid and becomes gradually smaller toward each angle, where the tarsi are joined to the lateral raphe and medial palpebral ligament. The breadth of the upper tarsus (10 mm.) is about twice that of the lower. The thickness of each is greatest, and its texture closest, at the middle of its length, thinning off toward the angles of the eye and toward both borders. Into the superior anterior border of the upper tarsus the lower layer of the levator expansion is attached, consisting of smooth muscle-fibers constituting the **superior tarsal muscle** of Müller. In like manner, at the inferior border of the lower tarsus, bundles of smooth muscle are inserted (the **inferior tarsal muscle** of Müller), developed in what has been regarded as part of the extension of the sheath of the inferior rectus.

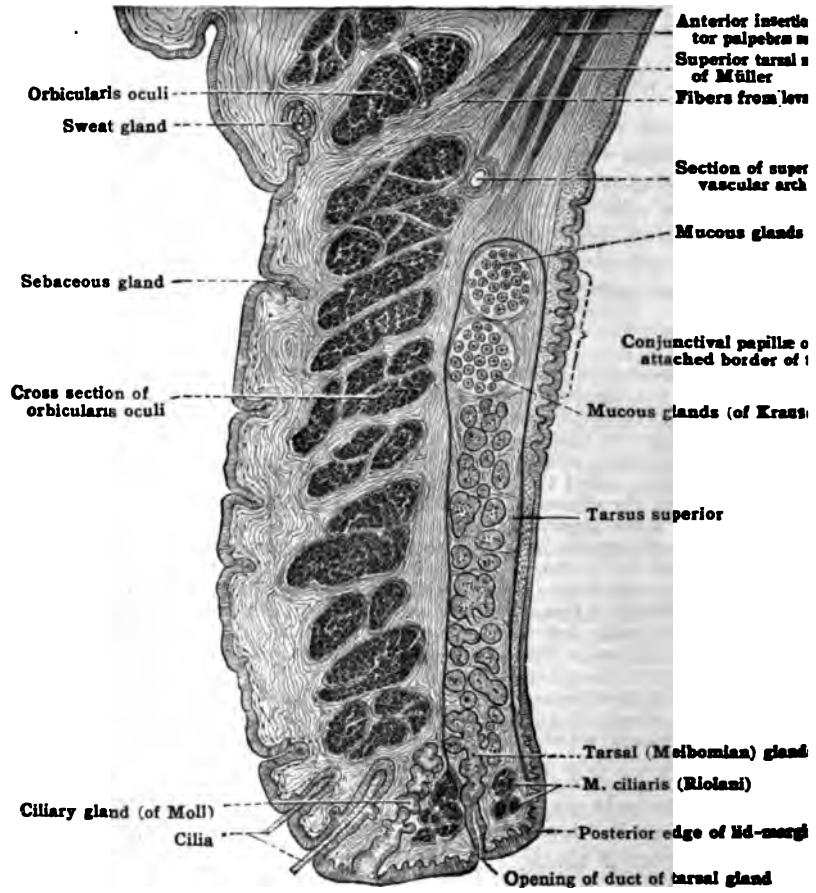
The **palpebral conjunctiva** is firmly adherent to the posterior aspect of the tarsus; but in the orbital part of the lid loose subconjunctival tissue intervenes between it and Müller's tarsal muscle.

Lymphoid tissue occurs in the substance of the conjunctiva, especially in its orbital division. Near the upper fornix, the conjunctiva receives expansions the tendon of the levator palpebræ and of the sheath of the superior rectus, and, at the lower fornix, of the sheath of the inferior

rectus. The surface of the tarsal conjunctiva shows small elevations or papillæ ever but these are particularly well marked over the attached border of the tarsus.

Glands of the eyelids.—From its manner of formation the eyelid m regarded as consisting of two layers of skin, the posterior having been d back upon the anterior at the edge of the lid; thus the epidermis and c of the skin proper are represented respectively by the conjunctival epit and tarsus of the inner layer. At the free border of the lid, accordingly, t glands corresponding to the sebaceous and sweat-glands of the skin, viz. sebaceous glands of the cilia (Zeiss's glands) and the ciliary glands of Moll, are modified sweat-glands. Again, in the inner skin-layer of the lid, the (Meibomian) glands are sebaceous.

FIG. 853.—SAGITTAL SECTION OF THE UPPER EYELID. (After Waldeyer and Fuchs.) surrounded by a red line.



Acinotubular mucous glands occur at the attached border of the tarsus (Krause' deyer's glands), and similar glands also occur at the fornix, and are especially abun the lateral angle of the upper lid, close to the efferent ducts of the lacrimal gland; t structure and the character of their secretion, these acinous or acinotubular glands termed by Henle 'accessory lacrimal glands.' Other simple tubular glands (Henl merely by the depressions between the papillæ, are best developed in the medial a fourths of the tarsal conjunctiva of both lids.

Blood-vessels.—The arteries run in the central connective tissue of the lids, the form of arches near the borders of the tarsus, from which twigs go to the diff pebral tissues. They are supplied by the lacrimal and palpebral branches of the op and by small branches derived from the temporal artery. The veins are more num larger than the arteries, and form a close plexus beneath each fornix. They empty t into the veins of the face at the medial, and into the orbital veins at the lateral angle

The lymphatic vessels of the lids are numerous, and are principally situated in junctiva. Lymph-spaces also surround the follicles of the tarsal glands. The lymphatic vessels from the lateral three-fourths of the lid pass through the anterior and parotid nodes; those from the medial fourth of the lower lid go to the facial and lary lymphatic nodes.

s.—(*a*) **Sensory.** The upper lid is chiefly supplied by branches of the supraorbital ıtrochlear nerves, the lower lid by one or two branches of the infraorbital. At the ıgle the infratrochlear nerve also aids in the supply, and, at the lateral angle, the (*b*) **Motor.** The palpebral part of the orbicularis is supplied by branches of the ve, which mainly enter it near the lateral angle. The tarsal muscles are supplied mpathetic nervous system.

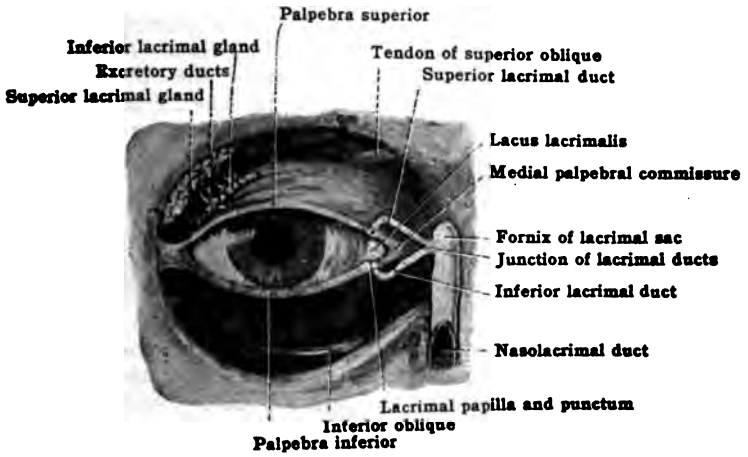
medial palpebral ligament has been referred to previously (p. 1106). from the frontal process of the maxilla, it extends laterally over the front he lacrimal sac, bends round the lateral wall of the sac, and then passes d to the posterior crest on the lacrimal bone.

hus U-shaped, having its limbs anterior and posterior, embracing the lacrimal sac; or limb lies immediately beneath the skin, and is visible in the living. The palpebral he orbicularis are inserted into the anterior surface of both limbs, those attached to rior limb constituting the pars lacrimalis of the orbicularis palpebrarum (Horner's The **lateral palpebral raphe** is merely a stronger development of connective tissue in ılaris. Both ligaments are connected with the tarsi as already mentioned.

THE LACRIMAL APPARATUS

tears are secreted by an acinous gland, and flow through fine ducts to the teral part of the conjunctival sac, whence they pass over the cornea and ıed off through the puncta, pass along the canaliculi into the lacrimal sac, mately down the nasolacrimal duct to the inferior meatus of the nose.

—DISSECTION OF THE EYE TO SHOW THE LACRIMAL APPARATUS, ANTERIOR VIEW.



lacrimal gland is situated near the front of the lateral part of the roof of ;, lying in a depression in the orbital plate of the frontal bone. It consists ery unequal parts, one placed above and the other beneath the tendinous ın of the levator palpebræ superioris, but small gaps in the expansion per- onnections between these two parts of the gland. The upper and larger ion (*superior lacrimal gland*) is a firm elongated body, about the size of almond; it has a grayish-red color, and is made up of closely aggregated The upper surface (next the orbital roof) is convex, and its lower surface y concave.

orly, the gland almost reaches the upper orbital margin, and it extends backward ximately one-fourth the depth of the orbit, measuring about 12 mm. in this direction. al border of the gland descends to near the insertion of the fascial expansion of the tus, while its medial border almost reaches the lateral edge of the superior rectus; its measurement is about 20 mm. It is enveloped in a capsule, which is slung by strong ınds passing to its medial border from the orbital margin (suspensory ligament of the

lower subdivision of the gland (*inferior lacrimal gland*) is composed of ıpplied lobules, and lies immediately over the lateral third of the upper ival fornix, reaching lateralward as far as the lateral angle.

ı subdivision of the gland possesses several **excretory ducts,** which all open lateral part of the upper fornix conjunctivæ, about 4 mm. above the ırder of the tarsus.

Those of the superior gland, three or four in number, pass between the lobules of the lower gland; the most lateral duct is the largest, and opens at the level of the lateral angle of the eye. The ducts of the inferior gland in part discharge themselves into those of the upper, but there are also several fine ducts from this subdivision that run an independent course.

Near the medial angle are the two **puncta lacrimalia**, upper and lower, each situated at the summit of its papilla. The top of each papilla curves backward toward the conjunctival sac, so that the puncta are well adapted for their function of draining off any fluid collecting there.

The **ductus lacrimales** (canaliculi) extend from the puncta to the lacrimal sac. The lumen at the punctum is horizontally oval, its lips being slightly compressed anteroposteriorly; the lumen of the lower punctum is somewhat larger than that of the upper. As the lower papilla is a little further from the medial angle of the eye than the upper, the corresponding duct is longer.

On tracing either ductus from its origin, we find that at first it runs nearly vertically for a short distance, then bends sharply toward the nose, and finally courses more or less horizontally, converging slightly toward its fellow, and not infrequently joining it before opening into the sac. The caliber varies considerably in this course, being narrowest a short distance from the punctum, and widest at the bend, from which point it again narrows very gradually as it nears the sac.

The wall of the ductus consists mainly of elastic and white fibrous tissue, lined internally by epithelium, and covered externally by striated muscle (part of the orbicularis). The muscle-fibers run parallel with the ductus in the horizontal part of its course; but they are placed, some in front and some behind, around the vertical part, acting here as a kind of sphincter. Just before their termination, the ducts pierce the periosteal thickening that constitutes the posterior limb of the medial palpebral ligament.

The **lacrimal sac** [saccus lacrimalis] lies in a depression (the lacrimal fossa) in the anterior part of the medial wall of the orbit. The sac is vertically elongated, and narrows at its upper and lower ends; the upper extremity or *fundus* is closed, while the lower is continuous with the nasolacrimal duct. Laterally, the sac is somewhat compressed, so that its anteroposterior is greater than its transverse diameter. The ducts, either separately or by a short common tube, open into a bulging on the lateral surface of the sac near the fundus.

As has previously been mentioned, the sac is surrounded by periosteum, but between this and the mucous membrane forming the true sac-wall there is a loose connective tissue, so that the cavity is capable of considerable distention. The relations of the medial palpebral ligament have already been described; it is to be noted that the fundus of the sac extends above this ligament.

The **nasolacrimal duct** [ductus nasolacrimalis] reaches from the lower end of the sac to the top of the inferior meatus of the nose, opening into the latter just beneath the adherent border of the inferior nasal concha. Traced from above, its main direction is downward, but it has also a slight inclination backward and laterally. It lies in a bony canal, whose periosteum forms its outer covering. Between this and the mucous membrane of the duct there is a little intermediate tissue, in which run veins of considerable size connected with the plexus of the inferior concha. The duct does not usually open directly into the nasal cavity at the lower end of the bony canal, but pierces the nasal mucous membrane very obliquely, so that a *flap* [plica lacrimalis (Hasneri)] of mucous membrane covers the lower border of the opening in the bone, upon which flap the tears first trickle after escaping from the duct proper.

The sac and nasolacrimal duct together constitute the **lacrimal canal**, lined throughout by a continuous mucous membrane. This membrane presents *folds* in some situations, especially near the opening of the ducts above, at the junction of the sac and duct, and at the lower end of the duct. That at the junction of sac and duct is the most important, as it sometimes interferes with the proper flow of tears out of the sac. The total length of the lacrimal canal is roughly 24 mm., half of this being sac, and half nasolacrimal duct. If, however, we reckon as duct the oblique passage through the nasal mucous membrane, this measurement may occasionally be increased by 8 or 10 mm. The lacrimal sac, when distended, measures about 6 mm. from before backward, by 4 mm. transversely. The nasolacrimal duct is practically cylindrical, and has a diameter of about 3 mm., rather less at its junction with the sac, where we find the narrowest part of the whole lacrimal canal.

Development of the Eye

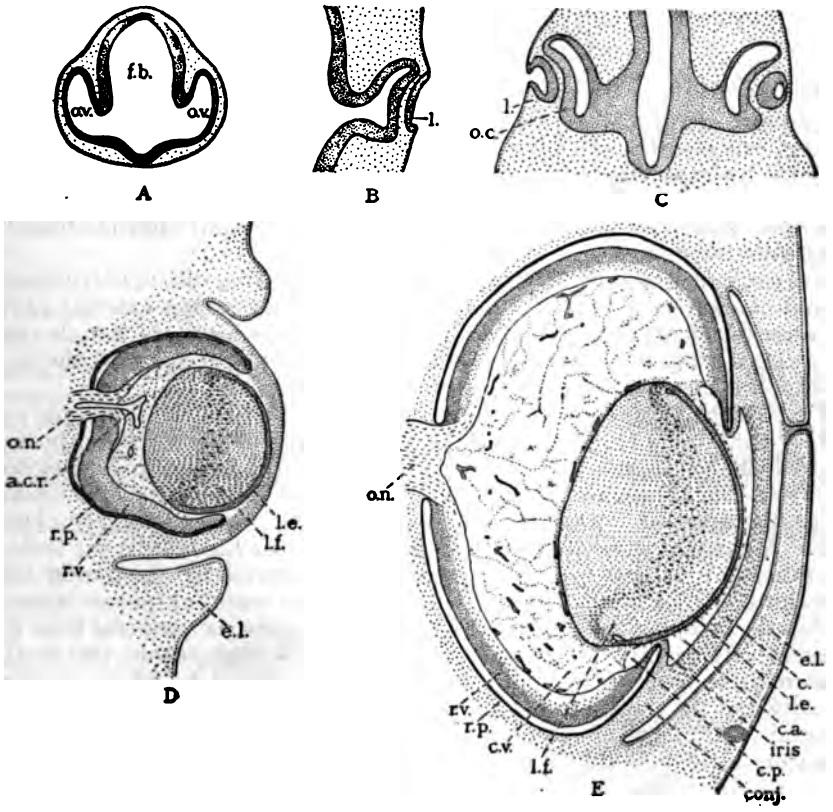
The eye is developed partly from the ectoderm and partly from mesoderm—the retina from a portion of the ectodermal wall of the forebrain on each side; the lens from the superficial ectoderm which surrounds the other structures, and the sclera, cornea (except epithelium) and choroidal coat from the mesoderm.

The process of development is, briefly, as follows (fig. 855): An outgrowth occurs from the ventrolateral aspect on each side of the forebrain, in the form of a hollow vesicle, the *primary optic vesicle* [vesicula ophthalmica]. The lateral surface of the vesicle comes into contact with the surface ectoderm of the head and this epithelium becomes thickened at the area of contact. The superficial portion of the vesicle expands, while its connection with the brain remains slender; becoming depressed on the surface, it forms a cup-shaped hollow, the *secondary optic vesicle* or *optic cup* [caliculus ophthalmicus] the wall of which is formed by two layers, an outer investing layer and an inner inverted one.

The *choroidal fissure* is present almost from the first stages as a cleft on the ventral aspect of both the distal portion of the vesicle, or cup, and of the stalk; it is formed by a longitudinal infolding of the wall of the vesicle. In this cleft is found vascular mesoderm passing to the interior of the hollow of the optic cup. The margins of the cleft meet and fuse, and enclose the vessels to

FIG. 855.—SECTIONS SHOWING THE DEVELOPMENT OF THE EYE IN RABBIT EMBRYOS. (Lewis and Stöhr.)

a.c.r., arteria centralis retinæ; c., cornea; c.a., anterior chamber; conj., conjunctiva; c.p. posterior chamber; c. v., corpus vitreum; e. i., eyelid; f. b., forebrain; l., lens; l. c., lens epithelium; l.f., lens fibers; o.c., optic cup; o.v., optic vesicle; r.p., pigmented layer of the retina; r.v., retinal layer of the retina.



the interior—hence the enclosure of the a. centralis retinæ within the optic nerve, and of the hyaloid artery in the interior of the vitreous. Should the margins of the cleft remain separate, the condition known as *coloboma* results.

From the optic cup is formed the whole of the retinal or nervous tunic. This tunic is composed of two layers, with a narrow slit-like interval between them, but the layers are continuous with each other at the margin of the cup. This margin is afterward found, in the fully developed eye, at the pupillary edge of the iris. The outer investing layer forms the pigment layer, and the inner inverted layer gives rise to the other parts of the retina, viz., the pars optica, over the bottom of the cup, the pars ciliaris, in the ciliary region, and the pars iridica, near the margin of the original cup.

The *lens* is formed as a hollow invagination from the surface ectoderm, opposite to the hollow of the optic cup. The margins meet and fuse, enclosing a cavity, and the lens-mass, sinking in more deeply, loses its connection with the surface, and a layer of mesoderm passes in between. At first the lens and the primitive retina are in contact with each other. They gradually draw apart, and the intervening space is filled by the *vitreous body*. The origin of the vitreous is uncertain, but it appears to be developed from the adjacent ectoderm of the optic cup, and in part from the surrounding mesoderm.

The optic cup and the lens are surrounded by mesoderm and from it are formed the structures of the tunica vasculosa in its different parts, viz., choroid, ciliary body and iris, and also the sclera and cornea (excepting the epithelium).

The anterior and posterior chambers are formed by cleavage of the mesoderm, spaces appearing which become filled with fluid. The mesoderm also forms a vascular covering for the [illegible] of the lens, termed the *capsula vasculosa lentis* (pupillary membrane), which disappears from the surface of the lens in the later months of development.

The *eyelids* and *conjunctiva* are formed from the integumentary covering of the eye. The former are mostly skin-folds, which, at first separate, meet and fuse with one another along their margin. Subsequently they become undermined by the ingrowth of epithelium from a central horizontal slit, the rima palpebrarum; the central part of the invading epithelium breaks down, and the free folds are formed.

The *lacrimal gland* is developed from a series of tubular outgrowths from the conjunctival sac.

The lacrimal ducts, sac and nasolacrimal duct are formed by the growth of an ectodermal band which extends into the mesoderm along the nasolacrimal groove. This band loses its primitive connection with the groove, and is reunited to the lid margins by secondary epithelial buds which grow from the primitive band to the lid margin. Similarly a secondary connection is later made with the nasal cavity at the lower end of the duct. The position of the nasolacrimal duct corresponds to the line of union of the nasal and maxillary processes; but the duct does not represent a portion of the cleft between these processes, and is formed secondarily between them.

THE EAR

Under the name of the **ear** [organon auditus] is included not only the structures fashioned to respond to such waves of the air as excite in us a consciousness of hearing, but also the semicircular ducts and their connections, which are the instruments for enabling the effects of gravity and the movements of the head or body as a whole so to influence the functions of the nervous system as to regulate posture and maintain equilibrium, both consciously and unconsciously, i. e., automatically.

The organ consists of three main parts, each possessing distinct structural and functional characters. The first portion, often known as the *external* ear, consists of a receptive organ placed upon the surface of the head, the auricle (pinna), and of a short tube, the external auditory meatus, which leads into the interior and is closed at its deep end by the tympanic membrane.

The second portion, known as the *middle* ear, consists of the tympanic cavity, a small air-containing chamber in the petrous portion of the temporal bone, connected with the nasal part of the pharynx by a tube, the auditory (or Eustachian) tube. From the tympanic chamber a recess passes posteriorly and leads to a cavity in the mastoid portion of the temporal bone, the mastoid or tympanic antrum. A chain of three small bones transmits across the middle ear the effects of the vibrations of the tympanic membrane produced by the sound waves.

The third part, or *internal* ear, which contains the essential sensory apparatus, lies within the complex cavities in the interior of the petrous temporal bone known as the osseous labyrinth. It consists of (1) the utricle and saccule, two small vesicular structures lying in the bony vestibule, and (2) the membranous semicircular ducts and (3) the membranous cochlea, which lie within the corresponding bony canals. Of these the semicircular ducts are concerned with the static or equilibratory sense and the cochlea with hearing.

These structures are filled with fluid, the endolymph, and communicate with one another. They are largely separated from the bony walls by fluid, perilymph, and they are lined by sensory epithelium. Closely related to the epithelial sensory cells are found the terminal branches of the cochlear and vestibular nerves. The to-and-fro movement of the stapes is converted into a wave movement of the endolymph which stimulates the nerve endings.

The description of the three divisions of the ear is taken up in order from the surface inward.

1. THE EXTERNAL EAR

The **external ear** consists of the auricle attached to the side of the head, and the external auditory meatus leading from it to the middle ear (fig. 858).

THE AURICLE

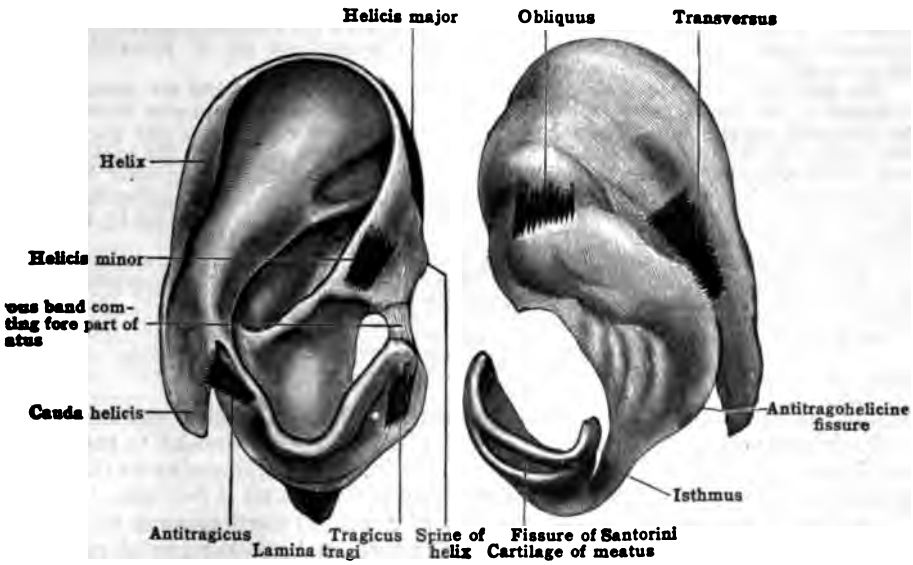
The **auricle** [auricula], or pinna, is an irregular oval plate-like structure which lies upon the lateral surface of the head. It presents a lateral and a medial surface. The lateral surface is irregularly concave (fig. 856). The deepest part of its concavity, situated near the center, is termed the **concha**, and it is partially divided by a prominent oblique ridge, the **crus of the helix**, into a superior part.

ymba conchæ, and a large inferior part, the **cavum conchæ.** The cavum hæ leads into the external auditory meatus, and is bounded anteriorly by a inent process, the **tragus,** which projects posteriorly over the entrance to the us. The tragus is separated from the crus of the helix by a well-marked ession, the **anterior incisure,** and has a small tubercle on it superiorly, the

FIG. 856.—LATERAL SURFACE OF THE LEFT AURICLE.

atragic tubercle. Bounding the cavum conchæ posteriorly and inferiorly is a ction, the **antitragus,** lying opposite, but inferior, to the tragus, and between wo is a deep notch, the **intertragic notch** [incisura intertragica]. A prominent circular ridge, the **anthelix,** bounds the concha posteriorly and supe- y. Inferiorly it is separated from the antitragus by a slight depression,

857.—LATERAL AND MEDIAL SURFACES OF THE CARTILAGE OF THE RIGHT AURICLE AND ITS MUSCLES, ETC.



posterior auricular sulcus. Superiorly the anthelix divides into two ridges, **crura of the anthelix,** and between these is a shallow depression, the **triangular a.** The superior and dorsal margin of the auricle is inverted and forms a ninent rim, the **helix,** which is continued anteriorly into the crus of the helix,

and inferiorly into the **lobule.** An elongated depression, partly overlapped by the helix, termed the **scapha** (scaphoid fossa), separates the helix and the anthelix. Superiorly and posteriorly the free margin of the helix frequently presents a slight projection, the **auricular tubercle** (tubercle of Darwin).

Upon the medial surface of the auricle the depressions of the lateral surface are represented by elevations, viz., the **eminence of the concha,** the **eminence of the scapha,** and the eminence **of the triangular fossa,** respectively; and the elevations by depressed areas, viz., the fossa of the **anthelix, transverse sulcus of the anthelix,** and the **sulcus of the crus of the helix.** The attachment of approximately one-third of the medial surface covers up the two latter depressions. The **cephaloauricular angle,** between the posterior free part of the auricle and the side of the head, averages 20 to 30 degrees.

Structure of the Auricle

The features of the auricle just described are mainly produced by a plate of yellow elastic cartilage, the **auricular cartilage.** In addition to the elevations and depressions already noted, it presents the following additional features. Projecting anteriorly from the helix near the crus is a small tubercle, **spine of the helix** (fig. 857); while the posterior margin of the helix terminates in a pointed tail-like process, the **cauda helicis,** which is separated inferiorly from the antitragus by the deep **antitragohelicine fissure.** Another deep fissure, the **terminal notch** [incisura terminalis auris], separates the cartilage of the auricle from that of the meatus, leaving only a narrow strip, the **isthmus,** connecting the two. The cartilage of the tragus, the **lamina tragi,** is separated from that of the auricle and is attached to the lateral margin of the cartilage of the meatus.

The auricle is covered on both its medial and lateral aspects by skin which closely follows the irregularities of the cartilage. Thus it is tightly bound to the perichondrium of the lateral surface by the subcutaneous areolar tissue, but much more loosely attached to the medial surface, and in the subcutaneous tissue there is little fat except in the lobule, which is made up almost entirely of fat and tough fibrous tissue. **Hairs** are abundant but rudimentary, except in the region of the tragus and antitragus, where they may be large and long, particularly in males and in the aged. **Sebaceous glands** are found on both surfaces, and are especially well developed in the concha and triangular fossa, but **sudoriferous glands** are few and scattered.

Ligaments and muscles.—The auricle is attached to the side of the head by the skin, by the continuity of its cartilage with that of the acoustic meatus, and by certain extrinsic ligaments and muscles. Three ligaments may be distinguished in the connective tissue: **The anterior ligament,** stretching from the zygoma to the helix and tragus; the **superior ligament,** from the superior margin of the bony external acoustic meatus to the spine of the helix; and the **posterior ligament,** from the mastoid process to the eminence of the concha. There are also three extrinsic muscles, the anterior, superior, and posterior auricular (see fig. 372). Six intrinsic muscles are distinguished. These are poorly marked in man and vary much in development. Upon the lateral surface (fig. 857) the **helicis major** stretches from the spine of the helix to the ventral superior margin of the helix; the **helicis minor** overlies the crus helicis: the **tragicus** runs vertically upon the tragus; and the **antitragicus** stretches from the antitragus to the cauda helicis. Upon the medial surface (fig. 857) the **transversus auriculæ** stretches between the eminences of concha and scapha, and the **obliquus** between the eminences of the concha and the triangular fossa. Two small muscles occasionally present are the m. **pyramidalis auriculæ** (Jungi) and the m. incisuræ helicis (Santorini).

The **arteries** are the auricular branch of the posterior auricular and the anterior auricular branches of the superficial temporal arteries. The **veins** are the anterior auricular vein of the posterior facial (temporal) and the auricular branches of the posterior auricular veins. The latter vessels sometimes join the transverse (lateral) sinus through the mastoid emissary vein. The **lymphatics** empty into the anterior, posterior and inferior auricular lymph-nodes. The sensory **nerves** of the auricle are the branches of the great auricular, small occipital (p. 1010, fig. 784), and auriculotemporal (p. 974, fig. 770). The muscles are supplied by the posterior auricular branch of the facial (p. 977, fig. 770).

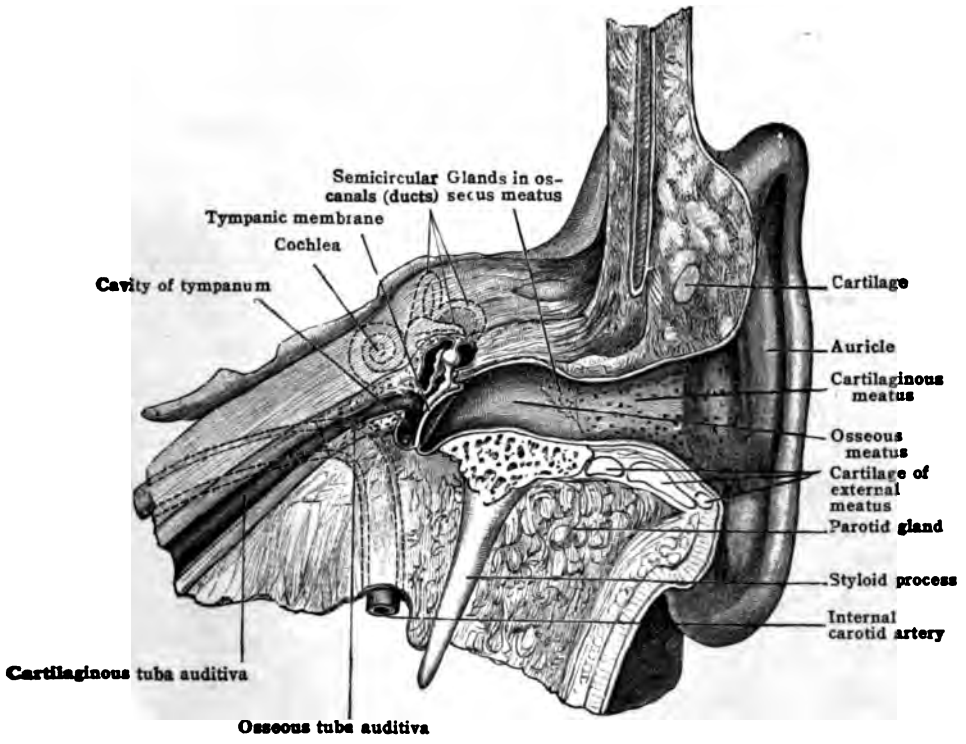
Variations.—There are many variations in the size, shape, and conformation of the auricle and in the cephaloauricular angle. These are associated not only with differences in sex, age, and race, but are also found in individuals of the same family.

THE EXTERNAL ACOUSTIC MEATUS

The **external acoustic (auditory) meatus** [meatus acusticus externus] extends medially and somewhat anteriorly and inferiorly from the concha to the tympanic membrane (fig. 858). It is about 25 mm. (1 in.) long, and, owing to the obliquity of the tympanic membrane, its anterior and inferior wall is 5–6 mm. longer than the posterior and superior. It consists of a lateral **cartilaginous** and a medial **osseous portion.** The canal is slightly curved in both horizontal and vertical directions. Near the auricular end it is convex anteriorly and inferiorly, while at the tympanic end the curve is reversed, and is concave in the same direction. The lumen is irregularly elliptical in outline, the longer axis being vertical at the auricular, but nearly horizontal at its tympanic end. The meatus is constricted at about its center, and also near the tympanum.

Relations.—The *anterior wall* is in relation with the condyle of the mandible medially, and the parotid gland laterally; the *inferior wall* is closely bound to the parotid gland; and *posterior wall* of the bony part is separated by only a thin plate of bone from the mastoid The *superior wall* is separated at its medial end by a thin plate of bone from the epipanic recess, and laterally a thicker layer of bone separates it from the cranial cavity. **Structure of the meatus.**—The walls of the meatus are formed laterally of fibrocartilage medially of bone, lined internally by skin. The cartilage is folded upon itself to form a ove, deficient in its dorsal part, where the edges of the cartilage are united by dense connective tissue. The cartilaginous groove is thus converted into a canal. Medially, the cartilage about one-third of the circumference; laterally, two-thirds. Two fissures (*incisures of torini*) usually occur in its anterior wall (fig. 857). Laterally the cartilage is directly tinuous with the cartilage of the auricle and medially it is firmly connected with the lateral

FIG. 858.—VERTICAL SECTION OF THE MIDDLE AND EXTERNAL EAR.



lip of the osseous portion. The osseous portion, which forms slightly more than half the canal, is formed by the tympanic portion of the temporal bone; it is described in connection with that bone.

The skin of the meatus forms a continuous covering for the canal and tympanic membrane. It is thick in the cartilaginous, but very thin in the bony, part of the meatus, especially near the tympanic end, where it is tightly bound to the periosteum. In the cartilaginous meatus it contains numerous fine hairs and sebaceous glands, but neither hairs nor sebaceous glands are found in the bony meatus. Tubular ceruminous glands, which secrete the cerumen (ear wax), form a nearly continuous layer throughout the cartilaginous, but occur on only a small part of the posterior and superior wall of the bony, meatus. The openings of their ducts appear as dark points to the naked eye (fig. 858).

The arteries are branches from the posterior auricular, superficial temporal, and deep auricular arteries (q. v.). The veins and lymphatics connect with those of the auricle and empty similarly. The nerves are branches from the auriculotemporal and the auricular ramus of the vagus.

2. THE MIDDLE EAR

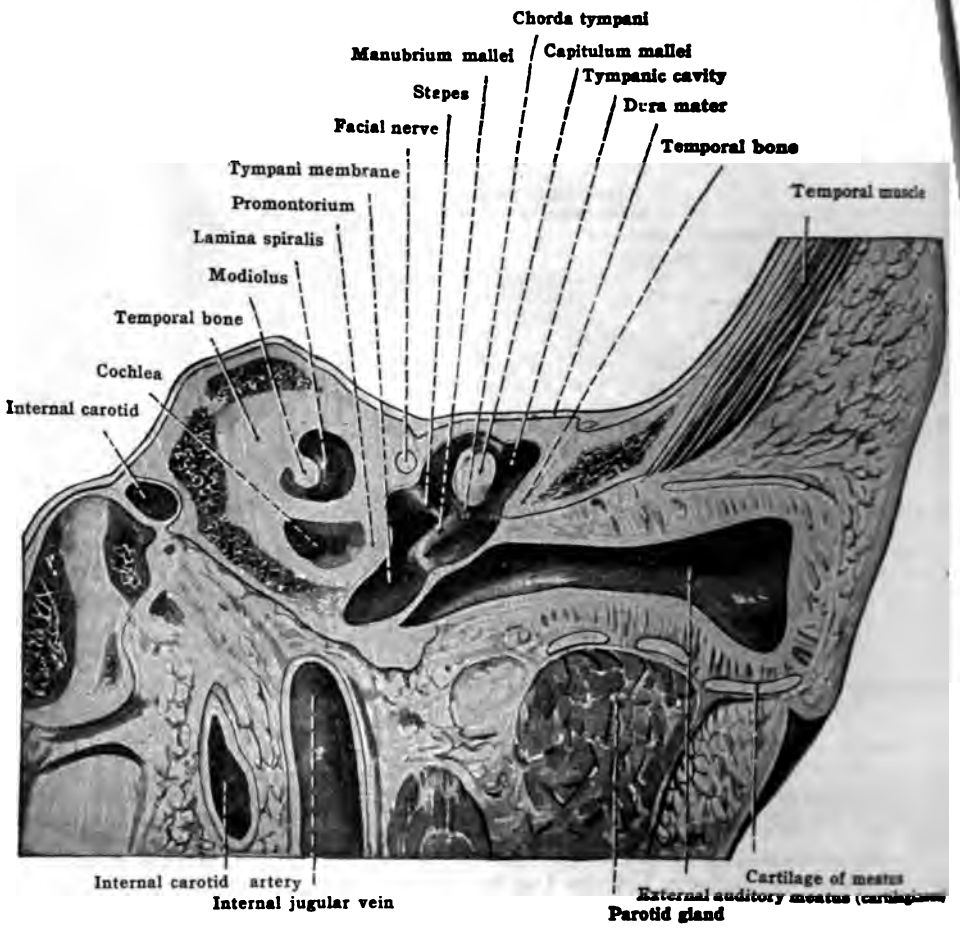
Under the term middle ear there are included the tympanic cavity (tympanum), the tympanic antrum and the auditory (Eustachian) tube. These form a continuous irregular passage, filled with air, and located, for the most part, within the temporal bone. The tympanum is shut off from the external ear by the tympanic membrane; and from the chamber which forms the internal ear by the structures which fill in the cochlear and vestibular fenestræ. It commu-

nicates with the pharynx by the auditory (Eustachian) tube. The structures of the middle ear are of importance, and the study is somewhat difficult, on account of the small size of the structures, the depth at which they lie, and the hard character of the surrounding bone.

The illustrations (figs. 858–860, 862, 863) will help to explain the text and should be constantly referred to. Figs. 859 and 860 are taken from sections traversing the right ear in the coronal planes; while figs. 862, 863 represent dissections.

The parts to be considered in order are the tympanic membrane, the tympanic cavity, the tympanic antrum and the auditory (Eustachian) tube.

FIG. 859.—CORONAL SECTION OF THE RIGHT EAR. (Somewhat enlarged.)



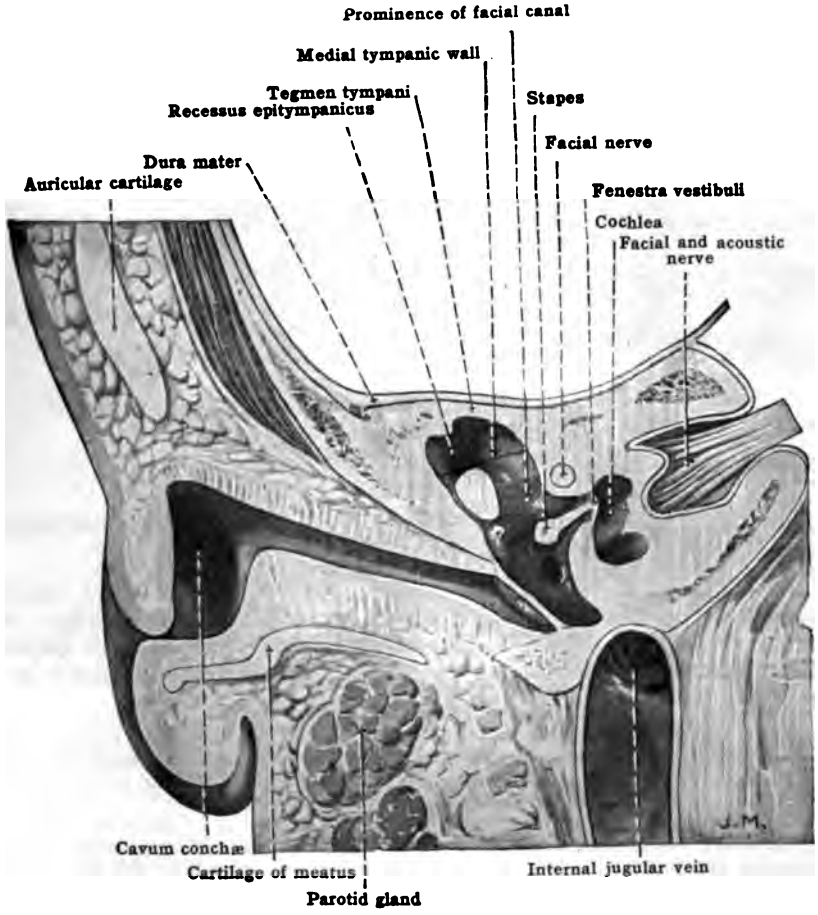
THE TYMPANIC MEMBRANE

The **tympanic membrane** [membrana tympani] (figs. 861, 864) is elliptical in shape, its long axis nearly vertical, measuring 9 to 10 mm., its short axis, 8 to 9 mm. It slopes medially from the superior and posterior to the inferior and anterior wall of the meatus, forming, as a rule, with the superior wall, an angle of 140 degrees. It varies, however, greatly in form, size, and obliquity. Viewed from the meatus, it appears as a semitransparent membrane, which sometimes has a reddish tinge. It is drawn medially by the manubrium of the malleus (fig. 863). The most depressed point at its center, the **umbo, is slightly inferior and posterior** to the center of the membrane, and corresponds to the tip of the manubrium (fig. 861). From it a whitish streak, the **malleolar stria, caused by the manubrium** shining through, passes superiorly toward the circumference. At the superior end of the stria is a slight projection, the **malleolar prominence,** formed by the lateral process of the malleus. From it two folds, **the anterior and posterior**

ce, stretch to the extremities of the tympanic sulcus (fig. 861). The small ngular area of the membrane bounded by the plicæ, is termed the **pars flaccida** rapnell's membrane). It is thin and flaccid, and is attached directly to the trous bone in the tympanic notch (notch of Rivinus). The larger part of the mpanic membrane, the **pars tensa,** is inferior to the plicæ and is tightly stretched. thickened margin, the **limbus,** is attached by a **fibrocartilaginous annulus** the tympanic sulcus, and at the spines of the tympanic ring is continuous with e plicæ.

Structure of the tympanic membrane.—The tympanic membrane is about .1 mm. thick, d consists of four layers. The lateral **cutaneous layer,** relatively thick, is a continuation the skin lining the external auditory meatus. Next to it is a **radiate fibrous layer,** composed

FIG. 860.—CORONAL SECTION OF THE RIGHT EAR. (Somewhat enlarged.)



of connective tissue, the fibers of which are attached to the manubrium of the malleus and radiate from it. Medial to it is the **circular fibrous layer,** which has its fibers arranged concentrically and is especially thick at the circumference. It is closely bound to the radiate layer. **The mucous layer,** which is a continuation of the mucosa of the tympanic cavity, covers the medial surface of the membrane smoothly, except where the manubrium of the malleus causes a projection. The fibrous layers are attached to the fibrocartilaginous ring and are not present in the pars flaccida.

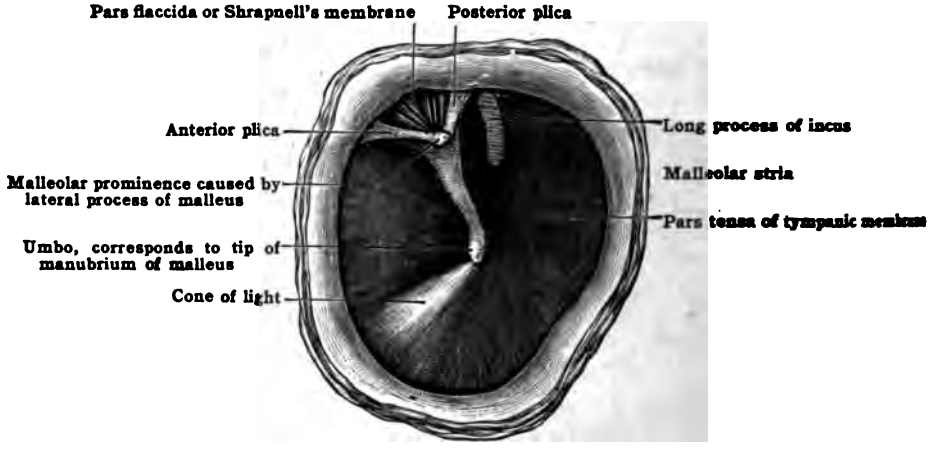
THE TYMPANIC CAVITY

The **tympanic cavity** [cavum tympani], as has been stated, is an air-space, lined with mucous membrane, situated between the external and the internal ear, It is of irregular outline, but, roughly, it is a slit-like cavity, lying in an oblique anteroposterior plane. Its transverse diameter measures only from 2–4 mm., while the vertical and anteroposterior diameters measure about 15 mm. (fig. 863).

It is narrowest at the center, and wider superiorly than inferiorly. The bony walls have already been partly described with the temporal bone, and hence the description given here will refer to the appearance found in the fresh, or macerated condition.

It will be noticed (see fig. 858) that the *floor* of the space is on very much the same horizontal plane as the floor of the external meatus, and the lower margin of the tympanic membrane. The *roof*, on the other hand, lies at a much higher level than the upper margin of that membrane. Hence the cavity may be divided into two regions, a *lower* part, corresponding in extent to the tympanic membrane, and an *upper*, above the upper border of the membrane, known as the *epitympanic recess*. This division forms a definite chamber, and contains the head of the malleus and the body and short process of the incus. It is on the posterior part of this chamber that the communication with the tympanic antrum is found (fig. 1075).

FIG. 861.—LATERAL SURFACE OF THE LEFT MEMBRANA TYMPANI. (Enlarged from life.)


Pars flaccida or Shrapnell's membrane
Posterior plica
Anterior plica
Long process of incus
Malleolar prominence caused by lateral process of malleus
Malleolar stria
Pars tensa of tympanic membrane
Umbo, corresponds to tip of manubrium of malleus
Cone of light

As the shape of the tympanum is irregular, its walls are not everywhere clearly marked off from one another, but there may be recognized (figs. 858 and 864) a **roof**, or **tegmental** wall, a **floor or jugular** wall, a **medial or labyrinthine** wall and a **lateral or membranous** wall, an **anterior or carotid**, and a **posterior or mastoid** boundary or wall.

The roof, or **tegmental wall** (figs. 864, 1075), is formed by a portion of the tegmen tympani, a thin plate of bone which is continued backward to form the roof of the tympanic antrum. This plate is formed by the petrous part of the temporal bone, and at its lateral margin is the petrosquamous suture, where a slight deficiency in the roof may occur.

The floor, or **jugular wall** is very narrow transversely, and is in intimate relation to the internal jugular vein (fig. 860). As shown in fig. 862, the surface is frequently very irregular from stalactite-like projections between which are the tympanic cellulæ (air-cells), while near the back there is occasionally a marked projection corresponding externally to the root of the styloid process.

The posterior or **mastoid wall** presents at its lower part, many additional tympanic cellulæ, and higher up, an elevation, the *pyramidal eminence*, on whose apex is an aperture transmitting the tendon of the stapedius muscle. The fleshy belly of that muscle is contained in a cavity in the interior of the bony pyramid of the posterior wall. Lateral to this is an aperture, the *apertura tympanica canaliculæ chordæ*, through which the chorda tympani nerve enters the tympanum, covered by a reflection of the mucous membrane. Between this opening and the pyramid is a slight elevation; and above it is a fossa, termed the *sinus posterior*. Above this again is a recess, where the posterior ligament of the incus is attached, known as the *fossa incudis*. This portion of the posterior wall forms the boundary of the epitympanic recess. Here the cavity of the tympanum is continued with that of the antrum tympanicum, or mastoid antrum, a large irregular space into which open the mastoid cells (see p. 1125). The boundaries of the orifice are formed above by the tegmen tympani, medially by the prominences of the lateral semicircular canal and facial nerve, and laterally by a plate of bone termed the *scutum*.

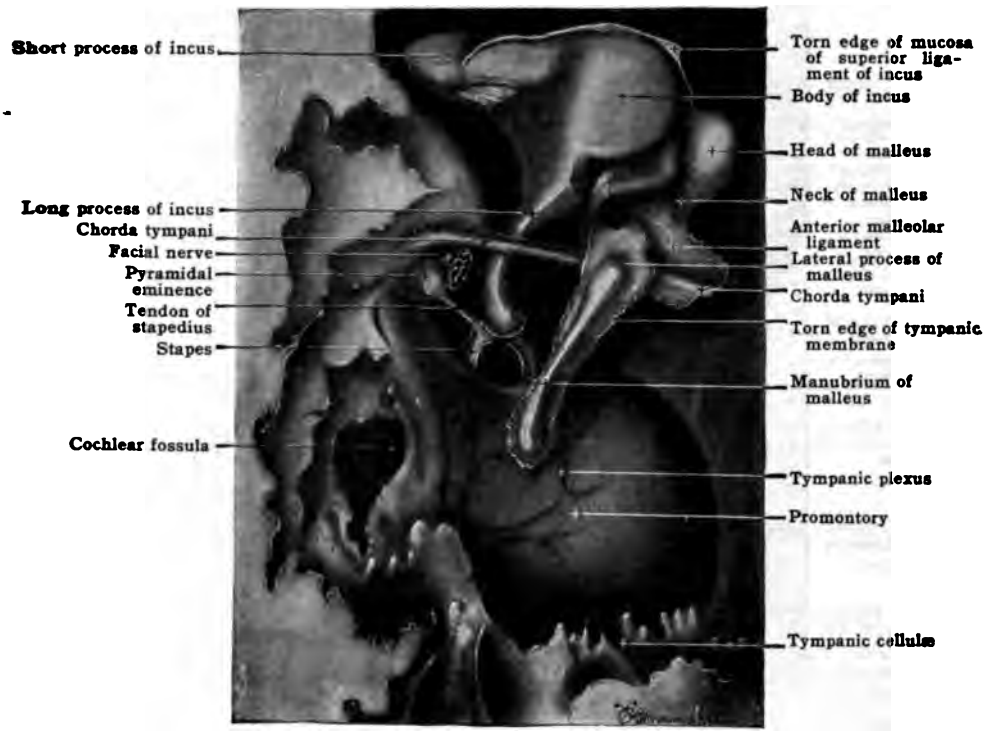
The **carotid (anterior) wall** presents superiorly the *tensor tympani muscle* in its canal, and at a lower level the opening of the *tuba auditiva* (Eustachian tube) (fig. 864) by means of which a direct communication is established into the nasopharynx. Inferiorly, a thin, bony wall, covered with tympanic cellulæ and pierced by the caroticotympanic nerves separates the tympanic cavity from the carotid canal.

The membranous (lateral) wall (fig. 864) is formed mainly by the tympanic membrane, with a small rim of bone to which it is attached, but superiorly the lateral wall of the epitympanic recess is formed by a plate of bone termed the scutum.

The labyrinth (medial) wall (fig. 862) presents inferiorly the *promontory*, produced by the first turn of the cochlea with the *tympanic plexus* (Jacobson's nerve) lodged in grooves upon its surface. Inferior and posterior to the promontory is a depression or fossula at the bottom of which is the *cochlear fenestra* (fenestra rotunda), closed by the *secondary tympanic membrane*, and posterior to the promontory is a smooth projection, the *subiculum of the promontory*, which forms the inferior border of a rather deep depression known as the *tympanic sinus*. Anteriorly and superiorly is the *cochleariform process*, and superiorly and posteriorly are a depression or fossula leading to the *vestibular fenestra* (*fenestra ovalis*), which is closed by the base of the stapes, the prominence of the facial (Fallopian) canal, and the prominence of the lateral semicircular canal, the two latter being formed in the medial wall of the entrance to the mastoid antrum.

The tympanic mucous membrane forms a complete covering for the walls and contents of the tympanic cavity. It is continuous anteriorly with the mucosa of the tuba auditiva (Eustachian tube) and posteriorly with that of the tympanic (mastoid) antrum and mastoid cells.

FIG. 862.—THE LABYRINTH (MEDIAL) WALL OF THE RIGHT TYMPANUM WITH THE TYMPANIC OSSICLES IN POSITION.



It is a thin, transparent, vascular membrane intimately united to the periosteum. As it passes from the walls to the contents of the tympanic cavity, besides covering the ligaments of the malleus and the incus and the tendons of the tensor tympani and stapedius muscles, it forms a number of special folds and pouches.

The **anterior malleolar fold** is reflected from the tympanic membrane over the anterior process and ligament of the malleus and the adjacent part of the chorda tympani, and the **posterior malleolar fold** stretching between the manubrium and the posterior tympanic wall, surrounds the lateral ligament of the malleus and the posterior part of the chorda tympani. Each of these folds presents inferiorly a concave free border, and between them and the tympanic membrane are two blind pouches, the **anterior and posterior malleolar recesses** or pouches of Tröltsch. Connected with the posterior recess is a third cul-de-sac, the **superior recess** of the tympanic membrane, or pouch of Prussak, situated between the pars flaccida of the tympanic membrane and the neck of the malleus. The floor of this recess is formed by the lateral process of the malleus, and is lower than its outlet; therefore, the recess may serve as a pocket in which pus or other fluid may accumulate. A somewhat variable fold of mucosa, the **plica incudis**, passes from the roof of the tympanic cavity to the body and short process of the incus. The body and short process of the incus, the head of the malleus, and this fold incompletely separate off a lateral **cupular portion** of the epitympanic recess, and a **stapedial fold** stretches from the posterior wall of the tympanic cavity and surrounds the stapes, including the oburator membrane, which stretches between its crura. Other inconstant folds have been described. The mucosa of the typanic cavity, except over the tympanic membrane, promontory, and ossicles, is covered by a columnar ciliated epithelium.

Bones.—The tympanic cavity contains three small movable bones, joined together and to the walls of the cavity, and having attached to them special muscles and ligaments. These auditory ossicles form a chain across the tympanic cavity connecting the tympanic membrane and the vestibular (oval) fenestra. They are the **malleus,** the **incus,** and the **stapes,** and are described in the section on OSTEOLOGY. (See p. 148.)

Articulations of the ossicles.—The manubrium and lateral process of the malleus are imbedded in the tympanic membrane. The margin of the irregularly elliptical articular surface on the posterior side of the head of the malleus is bound to the body of the incus by a thin capsular ligament, forming a diarthrodial joint, the **incudomalleolar articulation.** From the inner surface of the capsular ligament, a wedge-shaped rim projects into the joint cavity and incompletely divides it. The long crus of the incus lies parallel to the manubrium of the malleus and on its superior and medial aspect (figs. 862 and 864). It ends in the lenticular

FIG. 863.—THE TYMPANIC CAVITY, ANTERIOR WALL REMOVED.

process. The convex extremity of this fits into the concavity on the head of the stapes, to form a diarthrodial joint, the **incudostapedial articulation.** From its articulation with the incus, the stapes passes almost horizontally across the tympanic cavity to its junction with the medial wall. The cartilage-covered edge of the base is bound to the cartilage-covered rim of the vestibular (oval) fenestra by the annular ligament of the base of the stapes, thus forming the **tympanostapedial syndesmosis.**

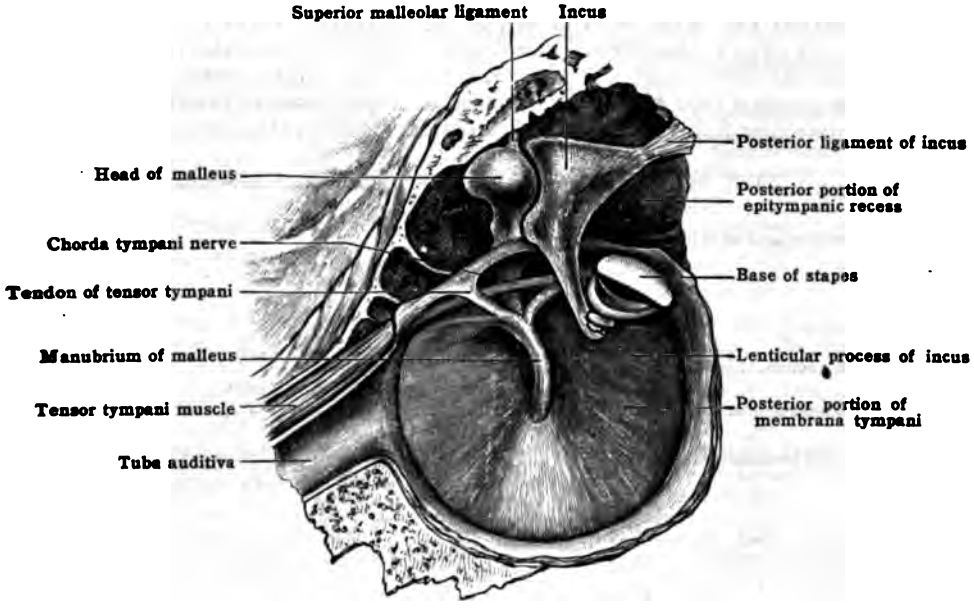
Ligaments of the ossicles.—In addition to the attachment of the manubrium of the malleus and the base of the stapes to the walls of the tympanic cavity, the bones have additional ligamentous attachments. The **superior malleolar ligament** runs almost vertically from the superior wall of the epitympanic recess to the head of the malleus (fig. 863). The **anterior malleolar ligament** extends from the angular spine of the sphenoid bone through the petrotympanic (Glaserian) fissure to the anterior or long process of the malleus, which it surrounds, and is inserted with it into the neck of the malleus. The **lateral malleolar ligament** is short and thick, and runs from the margins of the tympanic notch (notch of Rivinus) to the neck of the malleus (fig. 863). The **posterior ligament of the incus** passes from the fossa on the posterior tympanic wall to the crus brevis of the incus (fig. 864). The **superior ligament** of the incus is little more than mucous membrane; it runs from the tympanic roof to the body of the incus.

Muscles of the ossicles.—Each of the muscles of the ossicles is contained in a bony canal. The **tensor tympani** (fig. 864) is a pinniform muscle about 2 cm. long. It arises from the cartilaginous part of the tuba auditiva (Eustachian tube), from the adjacent part of the great wing of the sphenoid, and from the bony walls of the semicanal which encloses it. It ends in a round tendon which turns almost

right angles over the cochleariform process and passes laterally across the tympanic cavity to be attached to the manubrium of the malleus near the neck. It draws the manubrium medially and tightens the tympanic membrane, and is supplied by the motor division of the trigeminal cranial nerve, through the tensor tympani branch from the otic ganglion. The **stapedius** arises in the interior of the hollow pyramidal eminence. The tendon (fig. 862) escapes through the apex and then turns inferiorly and is inserted on the posterior surface of the neck of the stapes. It draws laterally the ventral border of the base of the stapes and is supplied by the facial nerve.

Vessels and nerves.—The **arteries of the tympanic cavity** are the anterior tympanic from the internal maxillary artery (fig. 495), the stylomastoid from the posterior auricular artery, the superficial petrosal from the middle meningeal artery, the inferior tympanic from the ascending pharyngeal (fig. 490), and the tympanic branch from the internal carotid. The

FIG. 864.—MEDIAL SURFACE OF RIGHT MEMBRANA TYMPANI. (Enlarged.)



veins empty into the superior petrosal sinus, the pterygoid plexus of veins and into the posterior facial (temporomaxillary vein). The **nerves** are the tympanic plexus formed by the tympanic branch of the glossopharyngeal (p. 984), and the inferior and superior caroticotympanic nerves which join the internal carotid plexus of the sympathetic (p. 1065). The small superficial petrosal nerve takes its origin from the tympanic plexus, and the chorda tympani crosses the tympanic cavity from the posterior to the anterior wall (p. 981, figs. 786, 864).

Antrum tympanicum and mastoid cells.—The aperture (*aditus*) in the upper part of the posterior wall of the tympanum leads into the chamber termed the **antrum tympanicum.** This is a comparatively large cavity, of irregular form, lying mainly behind but also somewhat above and lateral to the tympanum, and extends to the medial end of the external acoustic meatus. It is lined by mucous membrane, continuous with that of the tympanic cavity, and into it open the **mastoid cells** (cellulæ mastoideæ). These cells are small, irregular cavities in the interior of the mastoid process and they communicate with one another freely. They vary exceedingly in their size and arrangement. For further details concerning the topography of the middle ear and mastoid region, see pp. 147, 1336).

THE AUDITORY (EUSTACHIAN) TUBE

The **auditory tube** [tuba auditiva] (Eustachian tube) (fig. 858) extends from the carotid (anterior) wall of the tympanic cavity inferiorly, medially, and anteriorly to the pharynx. It is about 37 mm. (1.5 in.)long. In the lateral one-third of its length it has a bony wall, while in the medial two-thirds this wall is cartilaginous. The **osseous part** (see p. 144) begins a tthe **tympanic ostium** on the anterior wall of the tympanic cavity. It is in relation medially adn inferiorly with the carotid canal, and gradually contracts to its irregular medial extremity, which is the narrowest point in the tube, and is termed the **isthmus.**

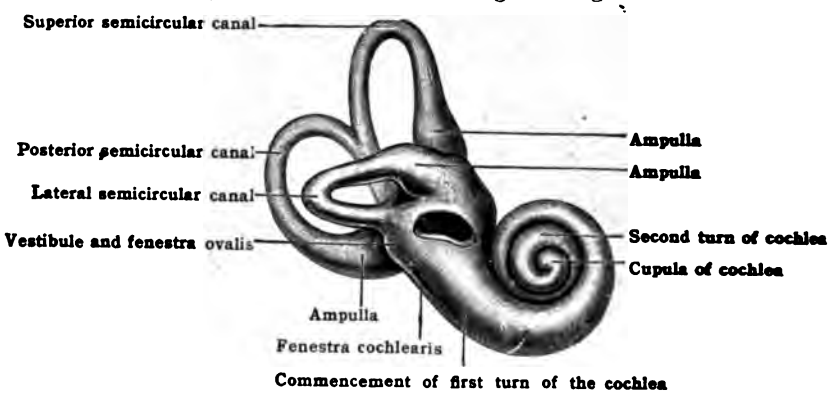
The **cartilaginous part** is firmly attached to the osseous and lies in a sulcus at the base of the angular spiue of the sphenoid bone. It gradually dilates in its passage to the lateral wall of the pharynx, where its opening, **pharyngeal ostium**, is just posterior to the inferior nasal concha and in front of the lateral pharyngeal recess (fossa of Rosenmiller). The walls of the cartilaginous part are formed by a cartilaginous plate which is folded so as to form a trough-like structure, consisting of a medial and a lateral **lamina**, completed inferiorly by a **membranous lamina** formed of connective tissue.

A small portion of the lumen in the superior part of the cartilaginous tube remains permanently open; elsewhere the walls are in contact, except during deglutition, where they are opened by the tensor veli palatini mucles. The mucosa of the osseous part is thin, and firmly attached to the bony wall, but in the cartilaginous part it becomes thicker, looser, and folded, and contains mucous glands, especially near the pharynx, where there is also some adenoid tissue.

3. THE INTERNAL EAR

The **internal ear** [auris interna] is the essential part of the organ of hearing. It consists of a cavity, the osseous labyrinth, contained within the petrous portion of the temporal bone, and enclosing a membranous labyrinth. The **osseous labyrinth** is divided into **cochlea, vestibule,** and **semicircular canals** (see p. 149). The accompanying figures (858, 865, 869) show their position and relations.

FIG. 865.—THE OSSEOUS LABYRINTH OF THE RIGHT SIDE.
(Modified from Soemmerring. Enlarged.)



It will be noticed that the vestibule forms a central chamber, from which the semicircular canals and the cochlea branch off; the former from the superior and dorsal portion, and the latter from the ventral and inferior.

It will further be noticed that the bony wall of this vestibule shows depressions and ridges on its interior, which are associated with parts of the membranous labyrinth, viz., an upper recess for the utricle (fovea hemielliptica) and a lower recess for the saccule (fovea hemispherica). There are openings in the bony wall for the entrance of nerves to the different parts of the membranous labyrinth, and for the transmission of the ductus endolymphaticus, as well as the small openings of the semicircular canals (ducts) and the opening of the cochlear canal (or duct).

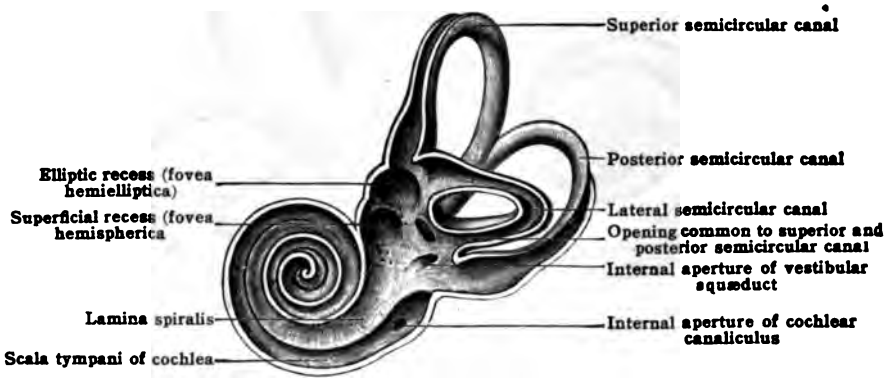
The **membranous labyrinth** (figs. 772, 868, 869), in which the cochlear and vestibular nerves end, lies within the osseous labyrinth, the form of which it more or less closely resembles. Thus the membranous semicircular ducts lie within the bony semicircular canals, the membranous cochlear duct within the bony cochlea; while the vestibule contains two small membranous sacs, the utricle and saccule, with their connections. The membranous structures are much smaller in diameter than the osseous, and are partially separated from the bone by an endothelial-lined space which is filled with a fluid, the **perilymph.** The membranes are in contact, however, with the bony wall along their convex margin, and the utricle, saccule and cochlear canals are in contact with the bony walls over the areas where the nerves enter them. The fluid which fills the membranous labyrinth is termed the **endolymph.**

The **utricle** is an oval tubular sac, whose rounded end lies in the superior and dorsal portion of the vestibule. It is here tightly bound to the elliptic recess (fovea hemielliptica) by con-

nective tissue and by the entrance of the filaments of the utricular division of the vestibular nerve as they pass from the superior macula cribrosa to the wall of the utricle. In the anterior part of the interior of the utricle, an oval, whitish, thickened area, **macula acustica utriculi**, marks the terminal distribution of the nerve, and posteriorly the utricle is joined by the orifices of the semicircular ducts.

The **saccule** is a flattened, oval sac, smaller than the utricle, and situated in the anterior and inferior part of the vestibule. It is bound to the spherical recess (fovea hemispherica) by connective tissue and by the saccular division of the vestibular nerve, filaments of which extend from the middle macula cribrosa to the anterior and medial wall of the saccule, to be distributed over a thickened area, **macula acustica sacculi**. Anteriorly and inferiorly the saccule gradually passes into a short canal, the **ductus reuniens**, which connects it with the cochlear duct, and

FIG. 866.—INTERIOR OF THE OSSEOUS LABYRINTH OF THE LEFT SIDE. (Modified from Soemmerring. Enlarged.)


Superior semicircular canal
Posterior semicircular canal
Elliptic recess (fovea hemielliptica)
Lateral semicircular canal
Superficial recess (fovea hemispherica)
Opening common to superior and posterior semicircular canal
Internal aperture of vestibular aqueduct
Lamina spiralis
Internal aperture of cochlear canaliculus
Scala tympani of cochlea

posteriorly the very small **endolymphatic duct** is attached (fig. 868). This extends through the aqueductus vestibuli to the posterior surface of the petrous portion of the temporal bone, where it ends in a dilated blind pouch, the **endolymphatic sac**, situated just beneath the dura. Just beyond the saccule, the endolymphatic duct is joined at an acute angle by a short canal of minute caliber, the **utriculosaccular duct**, which opens into the utricle through its anterior medial wall and, with the endolymphatic duct, connects it with the saccule.

The **semicircular ducts** (membranous semicircular canals) are situated within the osseous semicircular canals and are, therefore, known as the lateral, superior, and posterior semicircular ducts. They connect with the utricle by five openings, and posterior and superior ducts uniting to form a common crus before their termination. Each duct is less than a third of the diameter of the bony canal, from which it is separated by a large **perilymphatic space**, except along the greater curvature, where it is attached. The ducts are dilated in the bony ampullæ, producing the **lateral, superior,** and **posterior membranous ampullæ**, and on the attached surface of each of these there is a transverse groove, the **ampullary sulcus**, for the ampullary division of the vestibular nerve, and corresponding to the sulcus a ridge, the **ampullary crista**, projects into the

FIG. 867.—INTERIOR OF THE OSSEOUS COCHLEA. (Enlarged.)

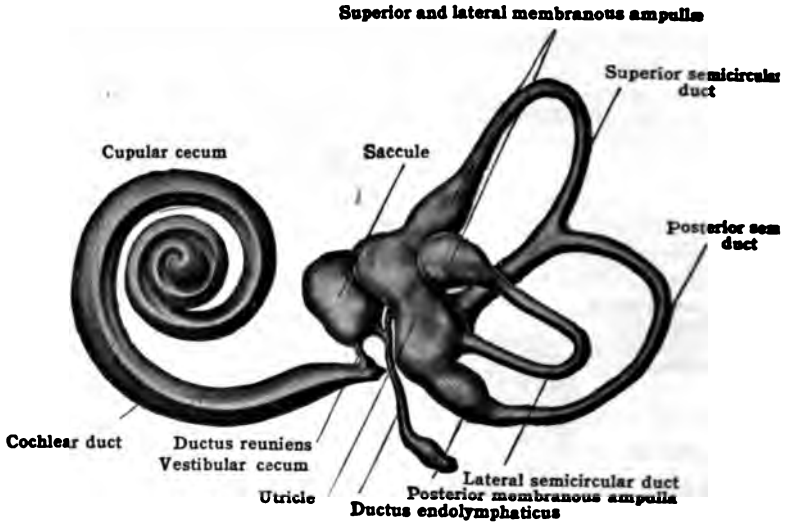
interior. The cristæ in the ampullæ of the membranous semicircular ducts and the maculæ in the saccule and utricle are superficially covered with fine crystals of calcium carbonate, **otoconia** (otoliths).

The **cochlear duct** (membranous cochlea or scala media) begins within the cochlear recess of the vestibule in a blind pouch, the **vestibular cecum**, and traversing the spiral canal of the cochlea, ends just beyond the hamulus of the lamina spiralis in a second blind pouch, the **cupular cecum**. Close to the vestibular cecum it is joined to the saccule by the **ductus reuniens**. It is lined throughout by epithelium and is somewhat triangular in cross-section. Its floor is formed by thickened periosteum over part of the osseous lamina spiralis and by a fibrous membrane, the **lamina basilaris**, which stretches from the free border of the lamina spiralis to a thickening of the periosteum, the **spiral ligament** of the cochlea, on the peripheral wall.

The epithelium of this floor is greatly modified, forming the **spiral organ (organ of Corti)** (fig. 872) in which the fibers of the cochlear nerve terminate. The peripheral wall is formed by the thickened periosteum upon the peripheral wall of the cochlear canal, while the third wall is

formed by a thin **vestibular membrane (membrane of Reissner)** which passes from t ipheral wall to the osseous lamina spiralis near its free margin, forming with the lamina an angle of 45 degrees. The cochlear duct and the osseous spiral lamina divide the spiral canal into two parts, one next to the basilar membrane, the **scala tympani**, and one the vestibular membrane, the **scala vestibuli**. The scala tympani unites with the scala

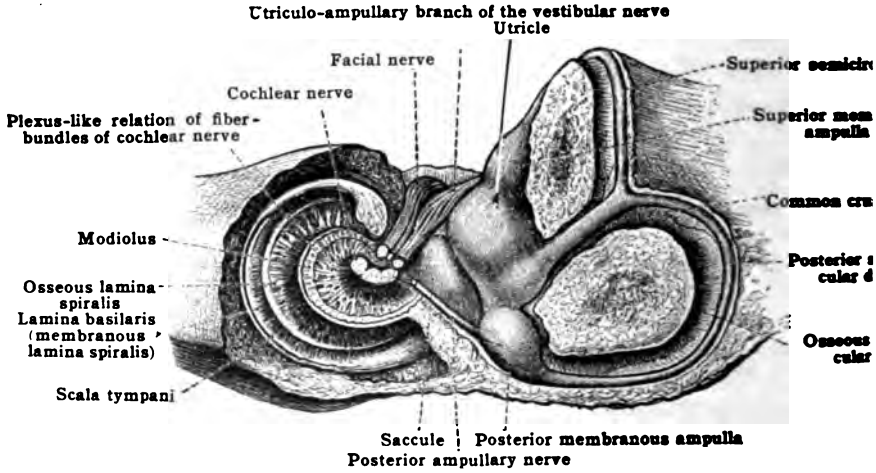
FIG. 868.—DIAGRAM OF THE LEFT MEMBRANOUS LABYRINTH. (Deaver.)



at the helicotrema, and from the scala tympani a minute canal, the **perilymphatic du** through the cochlear canaliculus and connects with the subarachnoid space. A thi ayer, the **secondary tympanic membrane,** closes the cochlear fenestra (fenestra and thus separates the scala tympani from the tympanic cavity, and the vestibular phatic space (scala vestibuli) is separated from the tympanic cavity by the base of t in the vestibular fenestra (fenestra ovalis).

Vessels and nerves.—The internal auditory artery, (fig. 555), a branch of the basil accompanies the cochlear and vestibular nerve. It supplies the vestibule, semicircul

FIG. 869.—RIGHT MEMBRANOUS LABYRINTH OF A NEWBORN CHILD. EXPOSED BY REMOVAL OF THE BONY LABYRINTH. VIEWED FROM BEHIND. (Toldt, 'Atlas of Anatomy,' Rebman, London and New York.)

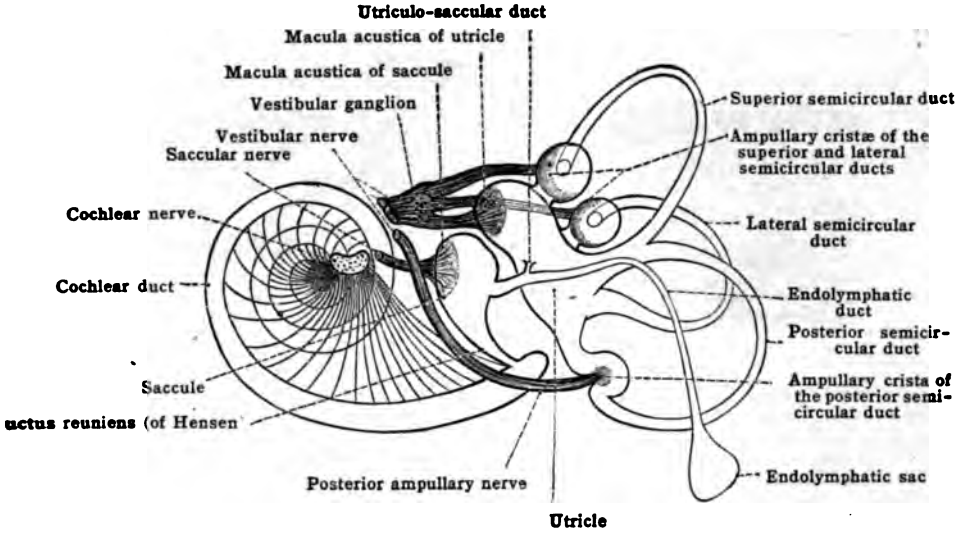


and cochlea, and their membranous contents. The blood is returned by the internal j vein into the inferior petrosal sinus, and by small veins which pass through the cochl vestibular aqueducts to the inferior and superior petrosal sinuses. **The acoustic nerve** figs. 870–872) consists of a vestibular and a cochlear division. **The membranou** ullæ of the semicircular ducts and the acoustic maculæ of the utricle and saccule plied by the vestibular nerve. The spiral organ (organ of Corti) in the cochlear supplied by the cochlear nerve.

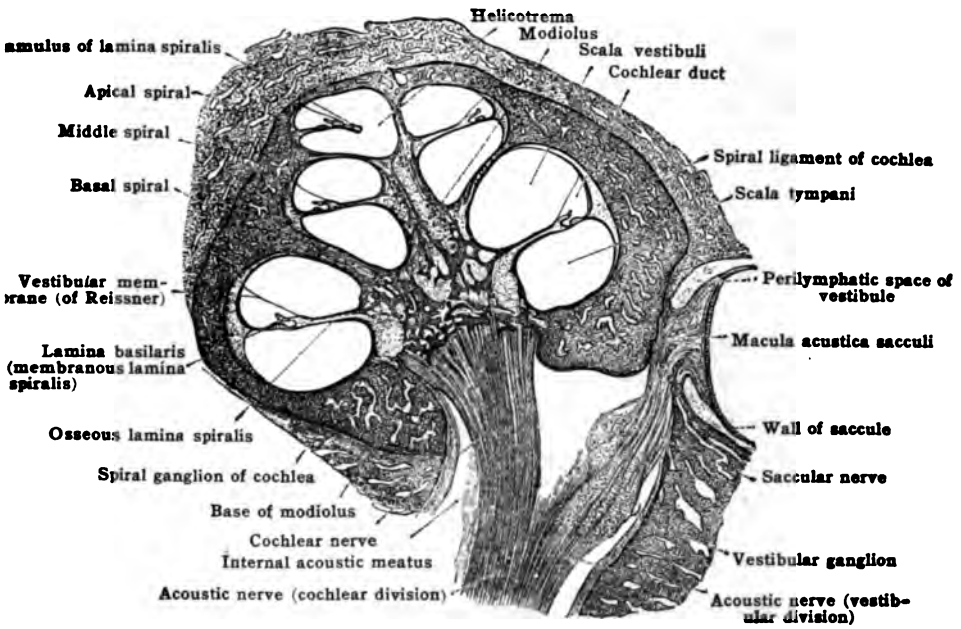
Development of the Ear

The external and middle ears have an origin quite distinct from that of the internal ear, and are to be regarded as portions of the branchial arch apparatus secondarily adapted to auditory purposes. The sensory epithelium lining the internal ear is derived from the otic vesicle, a structure formed from the surface epithelium of the head, while the membrane and bones surrounding it are formed from the mesoderm around the vesicle.

G. 870.—Schematic Representation of the Right Membranous Labyrinth and the Divisions of the Acoustic Nerve. Viewed From behind. (Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)



IG. 871.—Axial Section Through the Decalcified Cochlea of a Newborn Child (Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

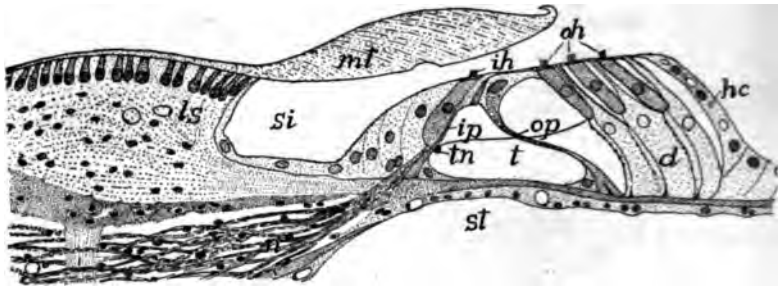


Internal ear.—The process of development is as follows:—

By invagination from the surface, an ectodermal vesicle, termed the primitive otocyst r otic vesicle, is formed dorsal to the extremity of the second branchial cleft (fig. 820). It is at rst merely a pit on the surface, but eventually it loses its connection with the surface epitheum and sinks into the interior. It then undergoes the alterations in shape and form shown the accompanying fig. 873. The vesicle is at first oval, and at its upper end there is a small

hollow stalk, the recess of the labyrinth, which forms the *ductus endolymphaticus* of t
The ventral and dorsal portions of the cyst become enlarged. From the latter tw
plate-like projections arise, one placed vertically, the other horizontally, and along
margins of these plates are formed the semicircular ducts, the superior and poster
the vertical, and the lateral duct from the horizontal one. The walls of the central par
plate become adherent and the fused areas are then absorbed; when this happens the p
part of each plate assumes the characteristic loop form of the adult semicircular duc
portion of the vesicle lying between the dorsal and ventral enlargements forms the

FIG. 872.—ORGAN OF CORTI OF GUINEA PIG. (From Kingsley, after Schneid
d, Deiter's cells; *hc*, Hensen's cells; *ih*, inner haircells; *ip*, inner pillar cells; *ls*, limbu
mt, membrana tectoria; *n*, nerve fibers; *oh*, outer haircells; *op*, outer pillar cells; *si*, inn
st, scola tympani; *t*, tunnel; *tn*, tunnel nerve.

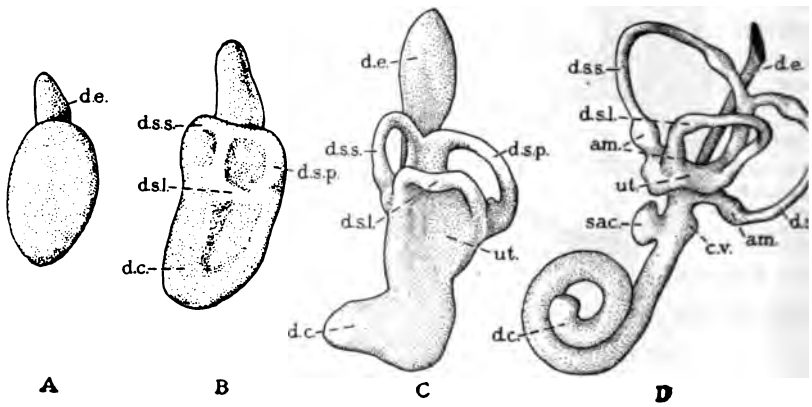


atrium. It becomes divided into two chambers, an upper dorsal connected with
circular ducts, forming the utricle, and an inferior ventral, the saccule, which is conne
that portion of the ventral expansion from which the cochlea is formed.

The endolymphatic duct retains its connection with the cavity of the vesicle at th
stalk connecting utricle and saccule. The cochlear duct is formed by an outgro
the saccule which becomes coiled in the way shown in fig. 873.

External and middle ear.—The *external auditory meatus* is formed from the o
of the first (external branchial) cleft, and the tympanic membrane from the membra
forms the floor of that pocket and separates it from the corresponding pharyngeal
pouch. Its outer surface is thus formed from ectoderm and the inner from endode
internal pouch gives origin to the tympanic cavity and tuba auditiva.

FIG. 873.—MODELS OF THE LEFT MEMBRANOUS LABYRINTH FROM HUMAN EMB
Lateral view; different enlargements. (After His, Jr.) *A*, from embryo of
B, 10.2 mm.; *C*, 13.5 mm.; *D*, 22 mm. *am*, ampulla; *c.v.*, vestibular cecum; *d.c.*, cochl
d.e., endolymphatic duct; *d.s.l.*, *d.s.p.*, and *d.s.s.*, lateral, posterior and superior sem
ducts; *sac.*, sacculus; *ut.*, utriculus.



The *auricle* is formed from nodular thickenings of the tissue bounding the outer e
first branchial cleft. Three nodules are formed on the first (mandibular) and thre
second (hyoid) arch. Behind the latter, the free margin of the auricle is formed by a f
of the integument. Later an additional tubercle is formed dorsally between the tw
nodules. From the mandibular nodules are formed mainly the tragus and the crus of th
from the hyoid tubercles the antitragus, the crus of the anthelix and the lobule.

The *auditory ossicles*, and their muscles are formed from the neighboring arches, th
and incus, together with the tensor tympani, being derived from the first arch, while t
and stapedius probably are derived from the second arch.

The *tympanic cavity* is at first quite small, but later increases greatly, partly by the condensation of the loose areolar tissue which underlies its mucous membrane, the auditory ossicles and their muscles being thus apparently brought within the cavity, and partly by the absorption of the neighboring bone. By this latter process the *antrum* and the *tympanic* and *mastoid cells* are formed, all these depressions or cavities being lined by mucous membrane continuous with that of the tympanic cavity.

The ear in the child differs from that of the adult in several important respects, as explained on p. 38.

References for the special sense-organs.—For the *development* of the various sense-organs, see article by Keibel in Keibel and Mall's Human Embryology, vol. 2. For the *anatomy* of all the sense-organs see Quain's Elements of Anatomy, 11th ed. vol. 2, part 2, 1909, and Poirier-Charpy, Traité d'anatomie humaine. A. **Visual.** Graefe-Saemisch, Handbuch d. ges. Augenheilkunde; Salzmann, Anat. u. Histol. d. Augapfels, 1912; various papers in Archiv f. Ophthalmologie; (*Anterior chamber, etc.*) Henderson, Ophthalmic Review, 1910-11; (*Optic disk*) Johnson, Phil. Trans. Royal Soc. B. vol. 194. Sutton, Anat. Rec. 1920, (*Fascia of Orbit*). B **Auditory.** Streeter, Amer. Jour. Anat, vol. 6, 1906. Gray, Labyrinth of Mammals, 1910) (*Tectorial membrane, etc.*) Hardesty, Amer. Jour. Anat., vol. 8; (*Auditory nerve, comparativer.* Holmes, Trans. Royal Irish Acad.,vol. 32, ser. B; (*Experimental embryology*) Lewis, Amer, Jour. Anat., vols. 3, 7; C. **Olfactory.** Read, Amer. Jour. Anat., vol. 8. D. **Taste.** Von Ebne.; in Koelliker's Handbuch d. Gewebelehre; Graberg, Anat. Hefte, Bd. 12.

SECTION X

DIGESTIVE SYSTEM

REVISED FOR THE SIXTH EDITION

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IN order to furnish the living protoplasm with the materials necessary for energy, growth and repair, a constant supply of food must be provided. Most foods must be rendered soluble, and must undergo certain preliminary chemical changes, in order to render them suitable for absorption and assimilation by the cells of the body. For this preparation of the food-supply, the *digestive system* [apparatus digestorius] is provided, which includes the alimentary canal and certain accessory glands (salivary glands, liver and pancreas). The alimentary canal is divided into a number of successive segments varying in size and structure according to their function. These segments (fig. 874) include the mouth, pharynx, esophagus, stomach, small and large intestines.

Typical structure.—The most important layer of the tubular alimentary canal is the inner *mucous membrane* [tunica mucosa]. From its epithelial lining, the various digestive glands are derived, and through it the process of absorption takes place. The epithelium is supported by a fibrous tunic [lamina propria mucosæ] beneath which is a thin layer of smooth muscle [lamina muscularis mucosæ]. The layer next in importance is the *muscular* coat [tunica muscularis] which propels the contents along the canal. It is typically composed of two layers of smooth (involuntary) muscle, the inner circular and the outer longitudinal in arrangement. Between the mucosa and the muscularis is a loose, fibrous *submucous* layer [tela submucosa], which allows the folds in the mucosa to spread out when the canal is distended. Finally, there is an outer *fibrous* coat [tunica fibrosa], which in the abdominal cavity becomes the smooth *serous* coat [tunica serosa], or visceral layer of the peritoneum, which eliminates friction during movements. The variations in the structure of the alimentary canal in different regions are due chiefly to differences in the mucosa.

Glands.—Since the glands form an important part of the digestive system, the classification of glands in general will be discussed briefly. A gland may be somewhat loosely defined as an organ which elaborates a definite substance which is either a waste product to be eliminated (excreted), or a secretion to be further utilized by the organism. Glands may be divided into (a) *ductless glands* (e. g. spleen, thyroid gland), which pour their secretions directly into the blood or lymph; and (b) *glands with ducts*, which open upon an epithelial surface. Some organs, however, belong in *both* classes (e. g., liver, pancreas).

The glands with ducts (the so-called 'true' glands) are derived from an epithelial surface and may be further subdivided upon the basis of either (1) form or (2) cell-structure of the terminal secretory portions. According to **form**, glands are classified as either *tubular* or *saccular* (alveolar, acinous). Each of these may be either *simple* or *compound* (branched). The compound saccular form is often called *racemose*. Moreover, intermediate forms (tubulo-racemose) occur.

According to **cell-structure** and character of secretion, glands are divided into mucous and serous types. In the *mucous* type, the cells appear larger and lighter when swollen with mucus which is secreted for purposes of lubrication. The goblet-cells of the intestine represent unicellular glands of this type. In the *serous* (or albuminous) type of glands, the cells usually appear somewhat smaller and more deeply stained, with numerous zymogen granules. The secretion is a watery, albuminous fluid, which contains the digestive enzymes. There occurs also a *mixed* type, with separate mucous and serous saccules, or both types of cells may occur in the same saccule (the serous cells as 'demilunes' or 'crescents'). The term *cytogenic* glands is applied to those which produce cells (e.g., gonads and lymphoid organs). In all cases, the epithelial gland cells are supported by a fibrous connective-tissue stroma, which provides a rich vascular and nerve-supply, and forms also an external fibrous sheath or capsule surrounding the entire gland.

Morphology.—The alimentary canal in comparative anatomy is divided into the *headgut* (mouth and pharynx), *foregut* (esophagus and stomach), *midgut* (small intestine), and *hindgut* (large intestine). Embryologically, the midgut corresponds roughly to the portion of the archenteron attached to the yolk-sac, the portions of the archenteron anterior and posterior to the yolk-sac being designated as foregut and hindgut respectively. (See Section I, p. 38).

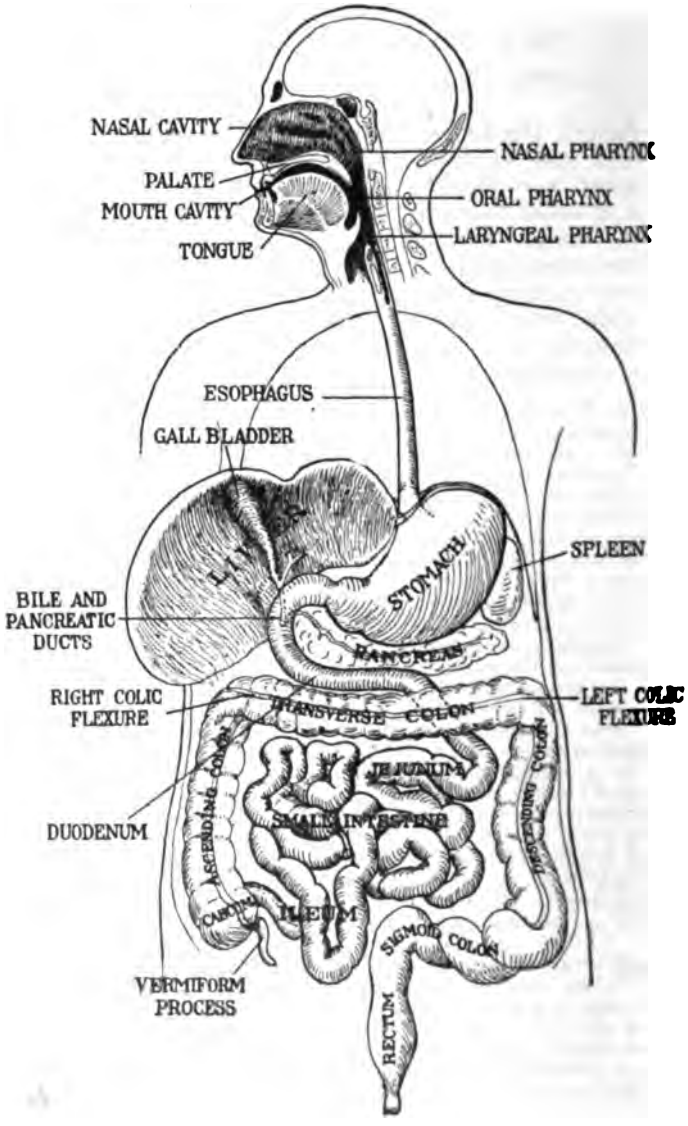
The lining epithelium of the alimentary tract is endodermal, excepting the anal canal and the mouth cavity, which are lined by invaginations of the ectoderm.

In the region of the mouth and pharynx, the digestive and respiratory systems are closely related in position, structure, function and origin. Morphologically, the headgut represents a primitive alimentary-respiratory apparatus.

THE MOUTH

The **oral cavity** [cavum oris] represents the first segment of the alimentary canal. Its walls are exceedingly specialized in structure, corresponding to its manifold functions (mastication, insalivation, taste, speech, etc.).

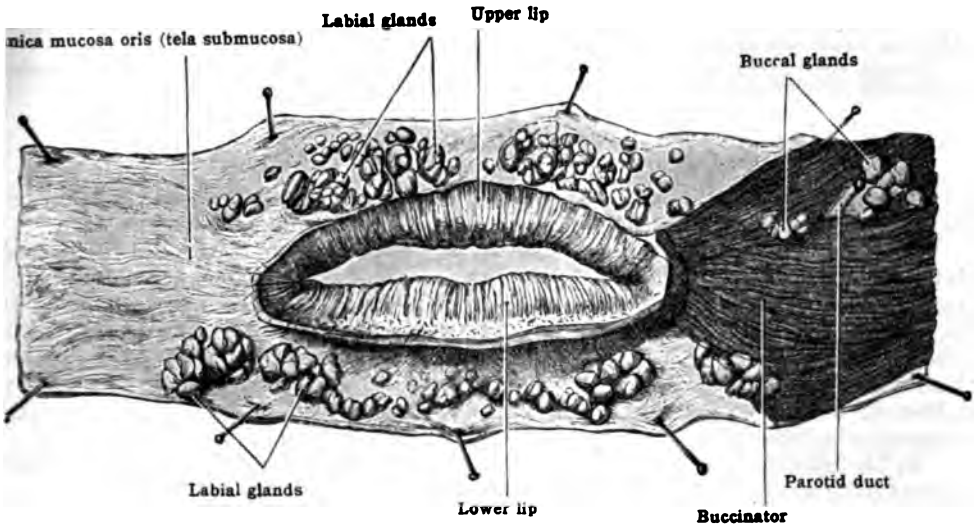
FIG. 874.—DIAGRAM OF THE ALIMENTARY CANAL.



Boundaries.—The oral cavity communicates anteriorly with the exterior through the transverse *oral fissure* [rima oris], and posteriorly with the pharynx through the *isthmus of the fauces* [isthmus faucium]. The *anterolateral walls* are formed by the flexible lips and cheeks. The *roof* is chiefly immovable and is formed by the upper jaw with the hard and soft palate. The movable *floor* is formed by the lower jaw, the tongue and the sublingual region.

Glands.—The *skin* of the lips and cheeks is well supplied with the usual sudoriparous and baceous glands. The mucosa likewise presents two kinds of glands, the sebaceous and the ucous glands. The *sebaceous* glands are relatively few in number and variable, being present about 30 per cent. of cases in the adult (Stieda). They are similar in structure to those of e skin (though not associated with hair-follicles), and when present are visible as small yellow- h bodies in the mucosa. They occur chiefly near the free margins of the lips and along the eek opposite the teeth.

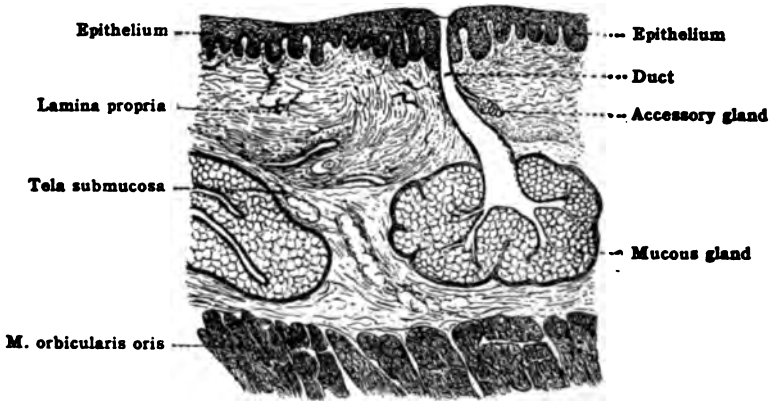
IG. 878.—LABIAL AND BUCCAL GLANDS EXPOSED BY DISSECTION OF THE SKIN FROM IN FRONT. (From Toldt's Atlas.)



The *mucous glands* are much more numerous and constantly present (figs. 878, 879). They .re all of the racemose type. They are variable but small in size, and closely packed together n the submucosa of the lips [glandulæ labiales], where they may easily be felt. Those of the heeks [gl. buccales] are less numerous. A few of them especially in the region of the molar eeth [gl. molares], are placed outside the buccinator. The ducts of the molar glands pierce his muscle near the parotid duct to open on the surface of the mucosa.

Vessels and nerves.—The mucosa of the lips and cheeks has a characteristic reddish hue, on ıccount of the numerous blood-vessels which are visible through the thick but transparent

?IG. 879.—SECTION OF LABIAL MUCOSA, SHOWING GLANDS. × 16. (From Toldt's Atlas.



stratified squamous epithelium (figs. 877, 879). The numerous papillæ of the lamina propria are highly vascular. The *blood-supply* of the lips and cheeks is derived chiefly from the labial (coronary) and buccal arteries. The rich *nerve-supply* (sensory) is from the infraorbital, mental and buccal branches of the trigeminus. The lips are especially sensitive near the rima oris.

Development.—During the second month in the human embryo, ledges of epithelium grow into the substance of the mandibular and the fused frontonasal and maxillary processes. These ledges develop into grooves which separate the upper and the lower lips from the upper and the lower jaws, the grooves forming the oral vestibule.

The philtrum and labial tubercle are said to correspond to the lower part of the frontonasal process. A failure of union between the medial nasal and the maxillary processes presents an arrest of development resulting in the malformation known as 'harelip.'

In the late fetus and newborn, the red portion of the lips consists of an external smooth *pars glabra*, and an inner zone, *pars villosa*, which is covered with numerous villus-like projections. The largest of these reach a length of 1 mm. They also extend backward in an irregular band along the mucosa of the cheek. They disappear during the first few weeks of postnatal life. In the infant, the *corpus adiposum* is especially well developed. On account of its supposed aid as a support for the buccinator in sucking, it has been called the 'sucking pad.'

The sebaceous glands of the mucosa are said not to appear until about the age of puberty.

Variations.—As is well known, the lips and cheeks are exceedingly variable in shape, size and structure in different individuals. There are also characteristic differences according to race and sex in the form and structure of the lips, rima oris, beard, etc. The 'harelip' malformation was mentioned above.

Comparative.—Typical lips are found only in mammals, and are probably organs phylogenetically developed in connection with the process of suckling.

THE PALATE

The **palate** forms the roof of the mouth cavity proper, and consists of two portions, the anterior or hard palate and the posterior or soft palate.

The **hard palate** [palatum durum] (figs. 876, 880) is continuous in front and laterally with the alveolar processes of the maxilla, and gives attachment posteriorly to the soft palate. It separates the mouth from the nasal cavity. It is supported by the palatine process of the maxilla and the horizontal part of the palate bone. The *oral surface* is concave from side to side, and also from before backward. It is covered by a thick, somewhat pale mucosa, which is firmly adherent to the periosteum through the submucosa. The submucosa contains numerous mucous *glands* [gl. palatinæ] (fig. 880), similar to those of the lips.

In the median line of the hard palate is a line or ridge, the *raphe* (fig. 880), terminating anteriorly in the small *incisive papilla*, which corresponds in position to the bony incisive foramen. Anteriorly there occur four to six more or less distinct *transverse ridges* [plicæ palatinæ transversæ]. Near the posterior margin of the hard palate there is on each side of the raphe a small pit (fig. 880), the *foveola palatina*, which is variable and inconstant.

The **soft palate** [palatum molle] (figs. 876, 910) separates the posterior portion of the mouth cavity from the nasal part of the pharynx. It is attached to the hard palate anteriorly and to the pharyngeal wall laterally. The posterior portion or *velum* projects backward and downward into the pharynx. Its free margin presents a median conical projection, the *uvula*, and splits laterally on each side to form two folds, the palatine arches, between which is located the palatine tonsil (fig. 880). The palatine arches and tonsil will be described later in connection with the pharynx.

Structure.—The soft palate is a fold of mucous membrane enclosing a fibrous aponeurosis, muscles, vessels, and nerves. It is marked in the middle line by a raphe indicating the line of junction of the two halves from which it was formed.

The posterior layer of the mucous fold, which is directed toward the cavity of the pharynx, is continuous with the nasal mucous membrane; the anterior layer lies in the posterior boundary of the mouth and is continuous with the mucous membrane of the hard palate. The structure of the mucosa is very similar to that of the lips (fig. 877). Mucous glands are numerous in both layers, but more especially in the anterior, and make up a large portion of the mucosa and submucosa (figs. 879, 880).

The aponeurosis is attached above to the posterior margin of the hard palate; laterally it is continuous with the aponeurotic layer of the pharyngeal wall; below, toward the lower margin of the velum, it gradually disappears. It gives attachment to fibers of the levator veli palatini and the pharyngopalatinus (palatopharyngeus) and to the tendon of the tensor veli palatini.

Muscles.—The muscles of the soft palate are described later (p. 1164) with those of the pharynx, with which they are closely associated.

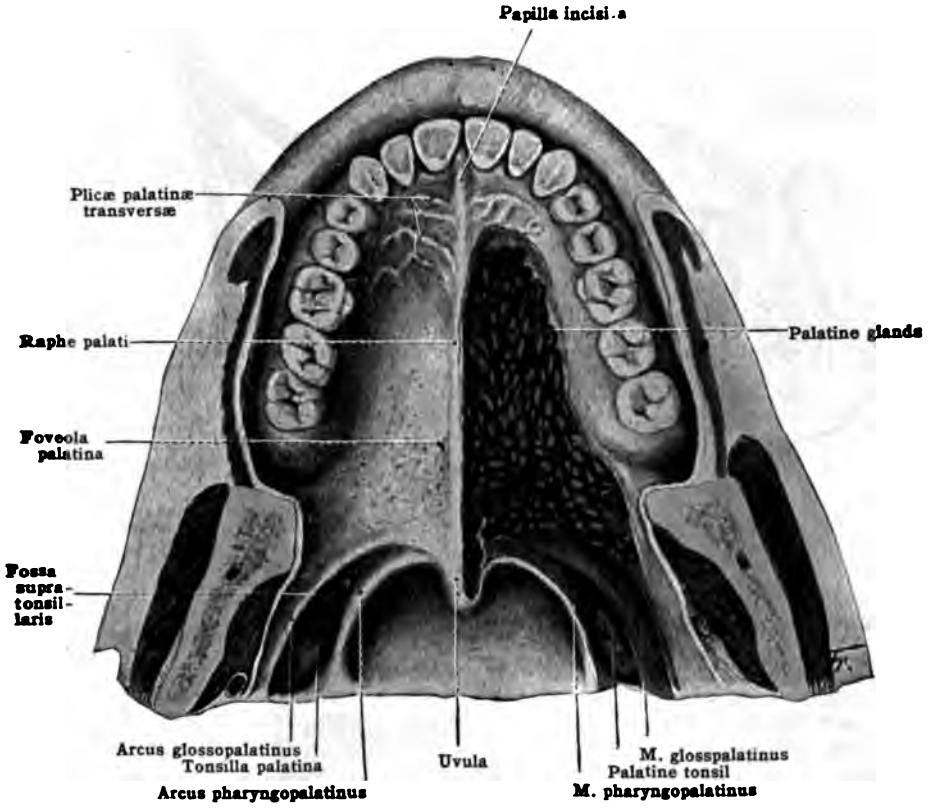
Vessels and nerves.—The arterial supply of the *hard palate* is derived chiefly from the major palatine branches of the internal maxillary. The arteries of the *soft palate* include: (1) Ascending palatine of external maxillary (facial); (2) pharyngeal branches of ascending pharyngeal; (3) twigs from descending palatine of internal maxillary, which enter the smaller palatine canals, are distributed to the soft palate and tonsils, and communicate with the ascending palatine of the external maxillary (facial) artery; (4) lingual artery, by twigs from the dorsal branch.

The *sensory nerves* to the palate are derived chiefly from the trigeminus through the sphenopalatine ganglion. The hard palate is supplied by the nasopalatine and anterior palatine branches; the soft palate chiefly by the middle and posterior palatine branches. The *motor* nerves will be mentioned later in connection with the muscles.

The development of the palate.—The development of the *palatine shelves* is described on p. 38. The incisive foramen indicates the place of meeting of the premaxilla and palate shelves, which closes the primitive communication between the oral and the nasal cavity. A lack of union of the palate shelves presents an arrest of development known as cleft palate. The *uvula* is similarly formed by the union of the posterior ends of the palatine shelves, and a failure to unite may produce a bifid uvula. The transverse *palatine ridges* are better developed in the infant than in the adult, and may assist in holding the nipple in sucking.

Variations.—*Cleft palate* and *bifid uvula* were mentioned above. The transverse *palatine ridges* are quite variable in number and prominence. On each side of the *incisive papilla* there is often found a small pit or shallow tube, a vestige of the embryonal incisive canal (Merkel). Sometimes there is instead a single median pit, representing the lower end of the incisive (Stenson's) canal. These pits are remnants of the primitive embryonic communication between mouth and nasal cavities.

FIG. 880.—ROOF OF MOUTH, SHOWING HARD AND SOFT PALATE DISSECTED ON ONE SIDE (Rauber-Kopsch.)



Comparative.—The palate is absent in fishes. In amphibia, the nasal cavities open directly into the primitive mouth cavity. In some birds, the palate shelves fail to unite, leaving a normal cleft palate. The incisive (Stenson's) canal remains open permanently in some mammals (e.g., ruminants), bifurcating above and thus placing the mouth cavity in communication with the nasal cavity on each side in the vicinity of Jacobson's organ. The transverse palatine ridges are much better developed among many mammals, especially the carnivora.

THE TONGUE

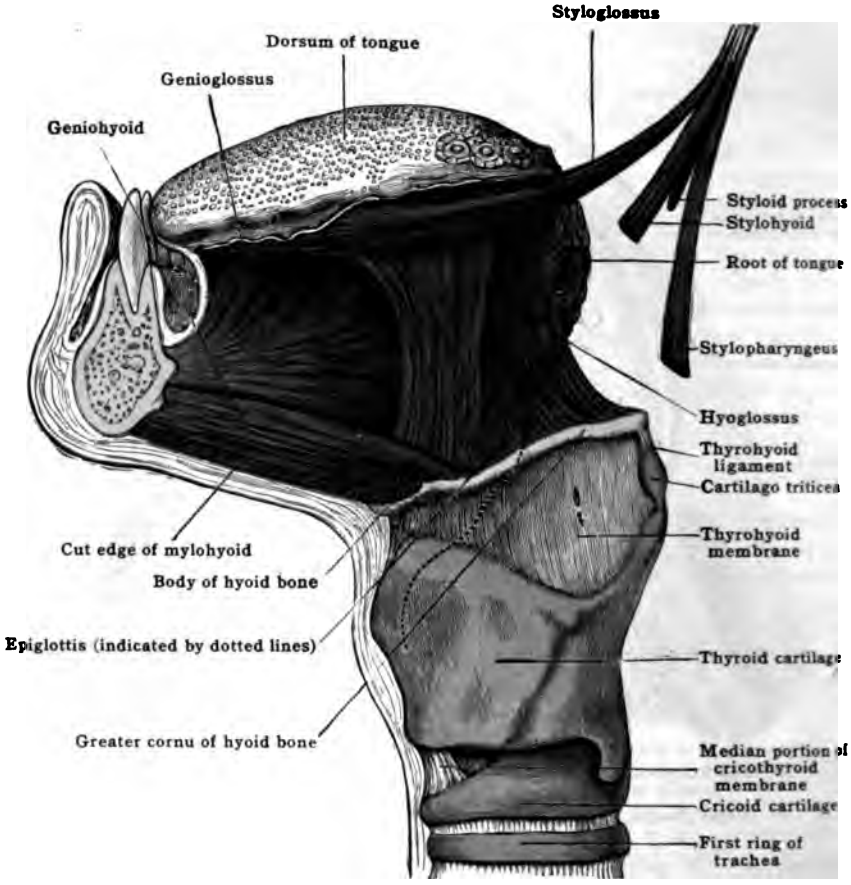
The **tongue** [lingua] is a muscular organ covered with mucous membrane and located in the floor of the mouth. It is an important organ of mastication, deglutition, taste and speech. Upon its upper surface (fig. 889) is a V-shaped groove (sulcus terminalis) indicating the division of the tongue into two parts. The larger anterior part, or *body* [corpus linguæ] belongs to the floor of the mouth, while the smaller posterior part, or *root* [radix linguæ], forms the anterior wall of the oral pharynx. The *inferior* surface [facies inferior] of the tongue is chiefly attached to the muscles of the floor of the mouth, from the hyoid bone to the mandible (fig. 884). Anteriorly and laterally, however, the inferior surface of the body is free and covered with mucosa. The superior surface of the body is called

the *dorsum*. It is separated from the inferior surface by the *lateral margins*, which meet anteriorly at the *tip* [apex linguæ].

The dorsum of the tongue usually presents a slight *median groove* [sulcus medianus linguæ]. Its posterior end corresponds to a small pit of variable depth, the *foramen cecum*, which is placed at the apex of the V-shaped *terminal sulcus*. The dorsum of the body has a characteristic rough appearance due to numerous small projections, the *lingual papillæ*.

Lingual papillæ.—Five or six varieties of papillæ are distinguished, between which intermediate forms occur. The *conical* [papillæ conices] and *thread-like* [papillæ filiformes] are most numerous, and are arranged more or less distinctly in rows parallel with the terminal

FIG. 881.—LEFT SIDE OF THE TONGUE, WITH ITS MUSCLES, ETC.



sulcus (fig. 882). They are best developed toward the midline of the dorsum in its posterior part. As shown in vertical section (fig. 882), each papilla consists of an axial core of vascular fibrous tissue (from the lamina propria) often beset with smaller secondary papillæ. The stratified squamous epithelial covering often presents numerous thread-like prolongations from the apex of the papilla. The papillæ vary from 1 to 3 mm. in length.

The **fungiform** ('toadstool-shaped') papillæ are somewhat similar to the conical in structure, but larger and more prominent, with an expanded free portion and a slightly constricted stalk of attachment. They are relatively few in number and are scattered irregularly over the dorsum, being most numerous near the margins (fig. 889). They are easily distinguished in life by their larger size and reddish color. A smaller, flattened variety of the fungiform is sometimes called the *lenticular* ('lens-shaped') papillæ. (This term, however, is applied by Toldt to certain small rounded elevations with underlying lymphatic nodules in the mucosa of the root of the tongue.)

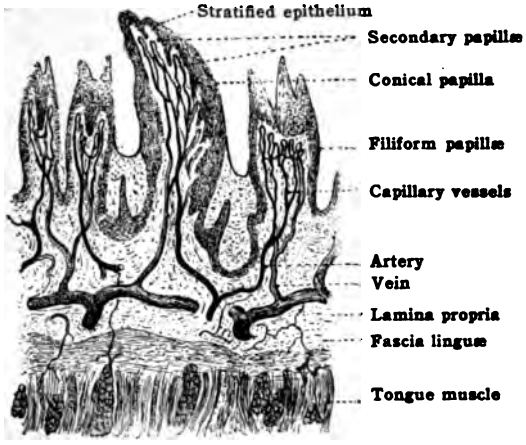
The **vallate** (circumvallate) papillæ [papillæ vallatæ], usually seven to eleven in number, are conspicuous and arranged in a V-shaped line parallel with and slightly anterior to the sulcus terminalis, (fig. 889). They are, as a rule, shaped like short cylinders, 1 to 2 mm. in width, and somewhat less in height. As is shown in section (fig. 883), each is surrounded by a trench or fossa, into the bottom of which open ducts of the serous glands of von Ebner. On the sides of the fossæ are the *taste-buds*, as described in the section on SENSE ORGANS.

The **foliate** papillæ are represented by a few (five to eight) parallel transverse or vertical folds of mucosa, along the margins of the tongue just anterior to the glossopalatine arch on each side (fig. 889). They are variable in size and sometimes rudimentary. In structure they somewhat resemble the vallate papillæ (though of different form), their walls being studded with taste-buds.

The free **inferior surface** of the tongue (fig. 884) is covered by a thin smooth mucosa. In the median line is a prominent fold, the *frenulum*, which connects the tongue with the mandible and the floor of the mouth. On each side of the inferior surface, an irregular, variable, fringed fold, the *plica fimbriata*, extends from near the apex backward approximately parallel with the lateral margin of the tongue (fig. 884). Between the frenulum and the plicæ fimbriatæ, the lingual (ranine) veins are visible on each side beneath the mucosa.

The **root** (or base) of the tongue [radix linguæ] belongs to the pharynx, but is here included with the mouth for convenience of description. Its free surface is directed posteriorly, and represents the continuation of the dorsum linguæ (fig. 881). Laterally it is continuous with the region of the palatine tonsils. Inferiorly it extends to the epiglottis, with which it is connected by a median and two lateral folds, between which are the depressions known as the *valleculæ*. The

FIG. 882.—SECTION OF LINGUAL PAPILLÆ. × 20. (From Toldt's Atlas.)



mucosa over the root of the tongue is irregular and warty in appearance due to the projections of the underlying nodular masses of lymphoid tissue, the *lingual follicles*. A *crypt* or tubular pocket of surface epithelium usually dips down into each of these follicles, as seen in surface view, and shown in section (fig. 885). The follicles vary from 34 to 102 in number, the average being 66 (Ostman), and are somewhat irregular in size and form. They are often arranged in more or less distinct longitudinal rows, with corresponding folds of the mucosa (Jurisch). The lingual follicles are collectively designated as the **lingual tonsil** [tonsilla lingualis]. Between the lingual follicles and around the periphery of the lingual tonsil there are found smaller ordinary lymphoid nodules (without crypts) and indefinite masses of lymphoid tissue. The sulcus terminalis forms a fairly sharp boundary between the lymphoid mucosa of the root and the papillated mucosa of the body of the tongue (fig. 889).

Glands.—The glands of the tongue are of three types—mucous, serous and mixed. The most numerous are those of the **mucous** type, which are typical for the mouth cavity in general and resemble those already described in the lips, cheeks and palate. They are spread over the entire surface of the root of the tongue, in the spaces between the lingual follicles, usually opening upon the surface but in many cases into the crypts. Anteriorly, they extend a short distance along the posterior portion of the lateral margin of the tongue, and also occupy small areas in and near the midline in front of the vallate papillæ.

In the immediate region of the vallate papillæ, and in the small lateral areas corresponding to the foliate papillæ (i. e., in the regions of the taste-buds), the mucous glands are displaced by the **serous** glands (of von Ebner), which have a watery secretion (fig. 883). Finally, on the inferior surface of the tongue, on either side of the frenulum near the apex, are the **anterior lingual glands** (glands of Nuhn or Blandin). Each is about 15 mm. in length, and is composed of a group of racemose glands with three or four very small ducts opening on the surface of the

tongue near the plica fimbriata. The anterior lingual glands are deeply placed and are covered not only by the mucosa, but also by some of the longitudinal muscle-fibers (inferior longitudinal and styloglossus). This gland is of the mixed type, though chiefly mucous.

FIG. 883.—VERTICAL SECTION OF A HUMAN VALLATE PAPILLA WITH LINGUAL GLANDS. × 25. (Lewis and Stöhr.)

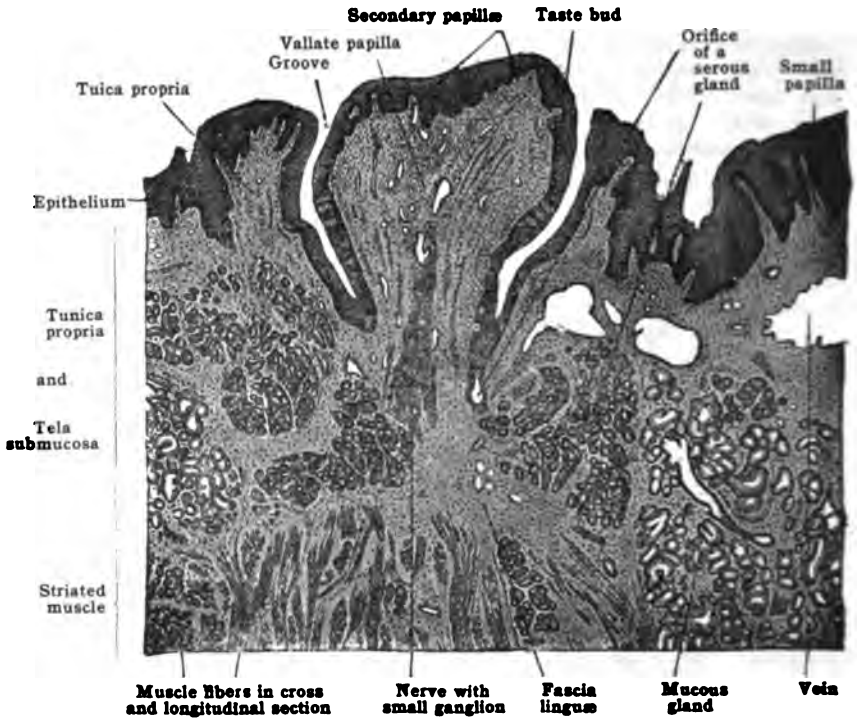
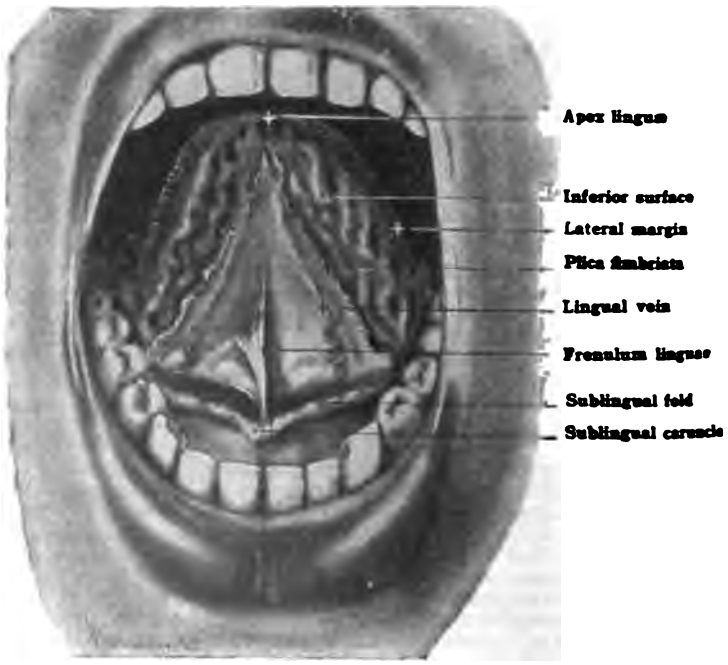


FIG. 884.—INFERIOR SURFACE OF THE TONGUE. (Modified from Spalteholz.)

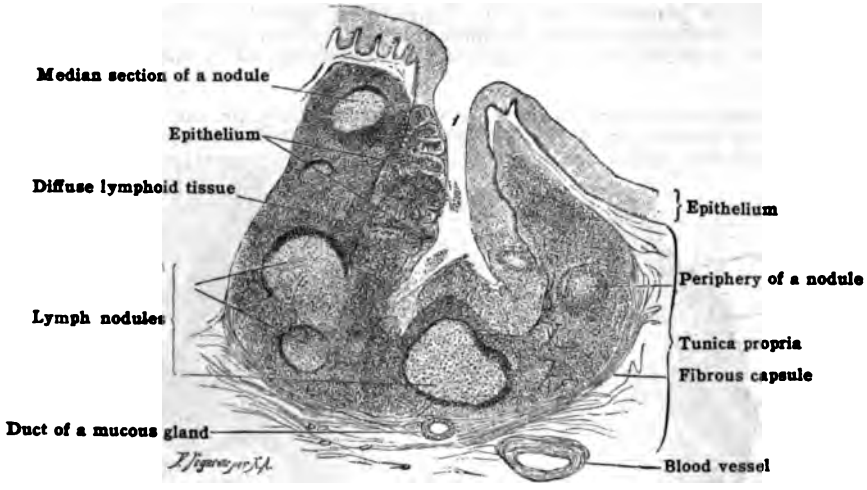


Muscles of the tongue.—A layer of fibrous connective tissue, the **lingual septum**, separates the halves of the tongue, extending in the median plane from the apex to the root, where it is attached below to the hyoid bone. The muscles of the tongue are classified as extrinsic and

insic. The **extrinsic muscles** (fig. 881) extend into the tongue from without. They are hyoglossus, chondroglossus, genioglossus, styloglossus, and glossopalatinus (palatoglossus), of which are described elsewhere (see Section V).

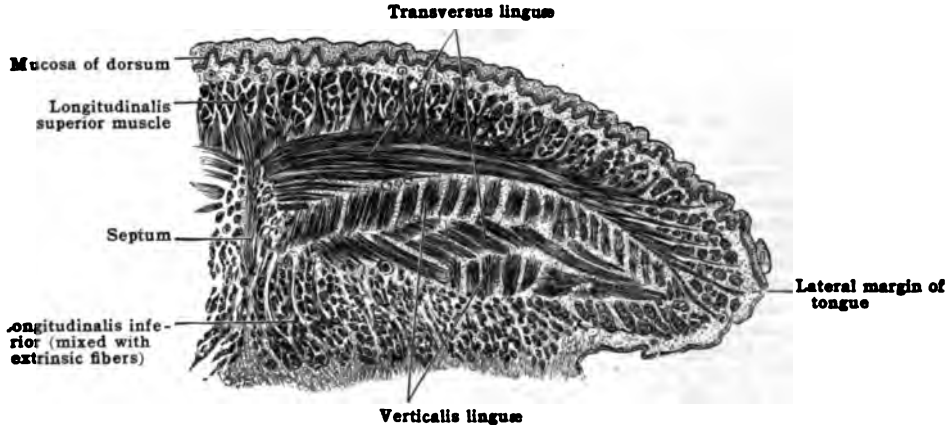
The intrinsic muscles.—The **longitudinalis superior** (fig. 886) is a superficial longitudinal atum extending from the base to the apex of the tongue, immediately beneath the mucosa the dorsum, to which many of its fibers are attached. The **longitudinalis inferior** (fig. 886) composed of two muscle-bands extending from base to apex on the inferior surface of the

FIG. 885.—FROM A SECTION OF THE LINGUAL TONSIL OF AN ADULT MAN. × 20. 1. Pit crypt) containing leucocytes which have infiltrated its epithelium on the left side; that on the ght is almost intact. (Lewis and Stöhr.)



ıgue, and is situated between the hyoglossus and the genioglossus, some of its fibers near e apex mixing with the styloglossus, while posteriorly some are attached to the hyoid bone. The **ınsversus linguæ** (fig. 886) consists of fibers which pass transversely, and is situated between e superior and inferior longitudinal muscles. The fibers arise from, or pass through, the sep- m linguæ, and are attached to the mucosa of the dorsum and lateral margins of the tongue. ıe **verticalis linguæ** (fig. 886) is composed of fibers which pass from the mucosa of the dorsum the mucosa of the inferior surface of the tongue, interlacing with those of the other intrinsic d extrinsic muscles.

G. 886.—TRANSVERSE SECTION THROUGH THE LEFT HALF OF THE TONGUE. (Magnified.) (From a preparation by Mr. J. Pollard, Middlesex Hospital Museum.)



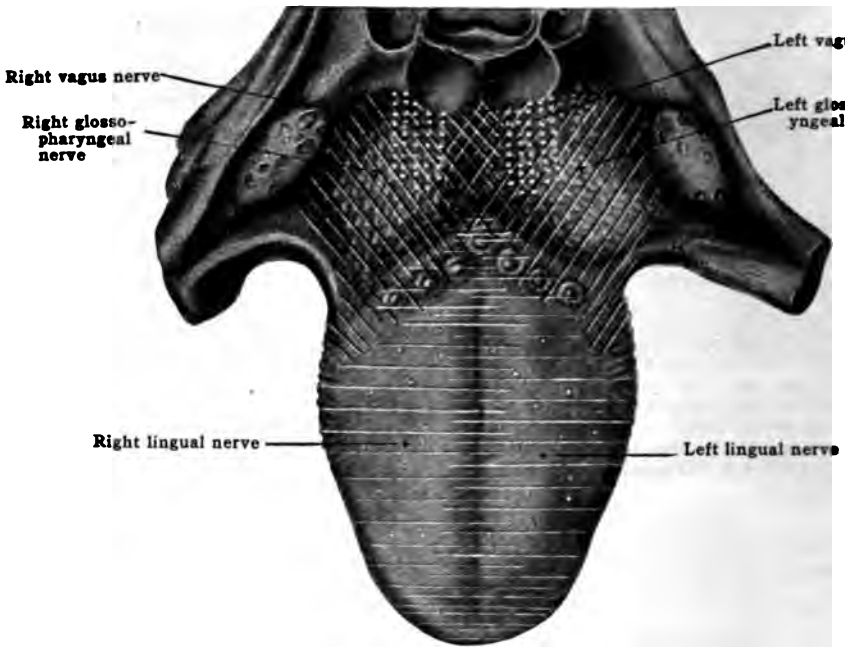
Vessels and nerves.—The **lingual arteries** furnish the principal blood-supply. The **lingual ins** carry the blood from the tongue to the internal jugular. The **lymphatics** form a network the lamina propria, connected with a deeper network in the submucosa. The latter network rms plexuses around the lingual follicles. The efferent lymph-vessels from the tongue empty iefly into the superior deep cervical lymph-nodes. (For details concerning the blood- and mph-vessels, see Sections VI and VII.) **The nerves** are motor and sensory. The **hypoglossal rve** supplies the intrinsic and all the extrinsic muscles of the tongue except the glossopalatinus alatoglossus), which is supplied from the pharyngeal plexus. The sensory nerves (fig. 887)

are:—the **lingual nerve**, a branch of the mandibular division of the trigeminus, which, after joining with the chorda tympani from the facial, is distributed to the anterior two-thirds of the tongue and represents the nerve of touch; the **lingual branches of the glossopharyngeal** (nerve of taste), which are distributed to the root of the tongue, including also the vallate and foliate papillæ; and **the superior laryngeal branch of the vagus**, which supplies a small area near the epiglottis.

Development.—The body of the tongue (anterior to the sulcus terminalis) is derived from the ventral region of the mandibular arch, and its epithelium is derived from the ectoderm of the oral sinus. The root of the tongue is covered with entodermal epithelium of the oral pharynx. For details concerning the development of the tongue, see p. 41.

Variations.—Of the manifold variations in the structure of the tongue, some have already been mentioned. Additional mucous glands sometimes occur along the margin of the tongue (completing Oppel's 'glandular ring'). In 'tongue-tied' individuals, the frenulum is abnormally short. A *forked* tongue (normal in some animals) is a rare congenital anomaly. Another rare variation is the so-called *'hairy'* tongue, due to hypertrophy of the filiform papillæ. While

FIG. 887.—SCHEMATIC REPRESENTATION OF THE DISTRIBUTION OF THE SENSORY NERVES IN THE MUCOUS MEMBRANE OF THE TONGUE. Areas of distribution according to R. Zander. When dotted area indicates vagus; oblique lines, glossopharyngeal; horizontal lines lingual.



the V-shaped arrangement of the vallate papillæ is typical, the Y-form (two to four papillæ in the median line forming the stem of the Y) is nearly as frequent. Indeed, in some of the colored races the latter type seems to predominate. The sulcus terminalis and foramen cecum are often indistinct and sometimes absent.

Comparative.—The tongue of fishes and lower amphibia contains neither glands nor intrinsic musculature. Among higher vertebrates, the tongue varies exceedingly in form and structure, but always contains intrinsic musculature and mucous glands. The latter primitively form a ring around the margin and root of the tongue (Oppel). The serous glands occur only in mammals, and are associated closely with the papillæ bearing taste-buds.

The plica fimbriata in man is homologous with the 'sublingua' of lower mammals. According to Gegenbaur, the 'sublingua' represents the entire primitive vertebrate tongue, but this view is opposed by Oppel. Among various mammals, the number of vallate papillæ varies from one to thirty, but the V- or Y-arrangement is typical. The region of the foliate papillæ ('marginal organ') is typical for mammals, and is much better developed in some (e. g., rabbit) than in man. The mucosa of the root of the tongue is always different from that of the body. The lingual papillæ are especially well developed in the tongue of carnivora.

THE SALIVARY GLANDS

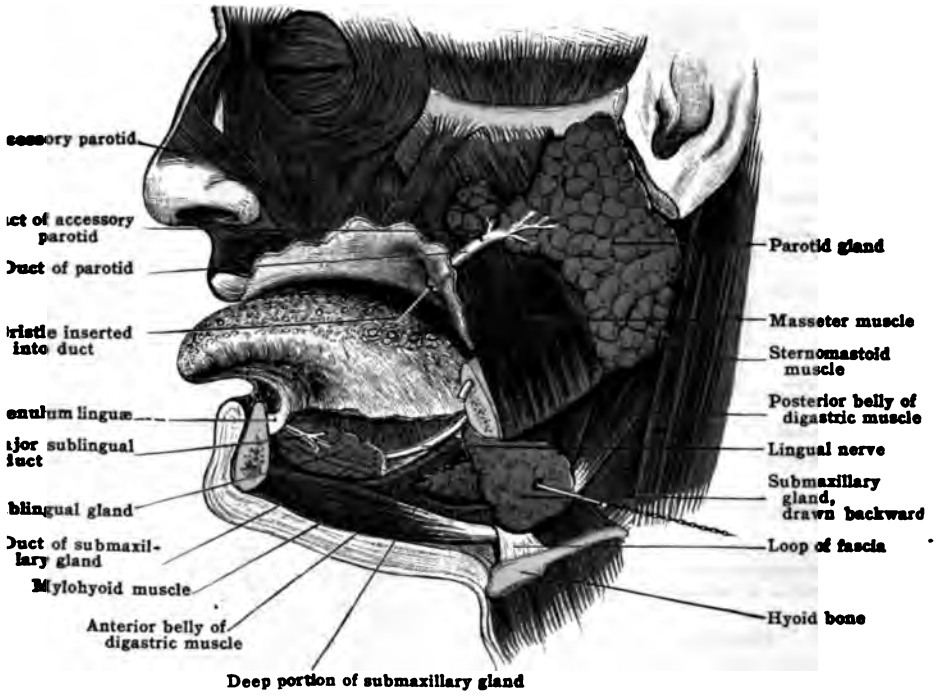
Numerous glands—labial, buccal, palatine and lingual—have already been mentioned, which pour their secretions into the mouth cavity. In addition to these there are three larger pairs, the salivary glands proper. They include the parotid, the submaxillary, and the sublingual (the latter really a group of glands).

THE PAROTID GLAND

The parotid gland [glandula parotis] is the largest of the salivary glands, ying from 15 to 30 gm. in weight. It is located below and in front of the ear the retromandibular fossa (fig. 888), extending from the zygomatic arch above the angle of the mandible below.

Form and relations.—The parotid is somewhat prismatic or wedge-shaped gs. 888, 889), with three surfaces and three borders or angles. The *lateral* sur- e is covered by skin and superficial fascia, and in its lower part by the platysma. e *anterior* (anteromedial) surface overlaps the masseter and extends medial- rd in contact with the posterior border of the mandibular ramus and with the sterior aspect of the internal pterygoid muscle. An irregular 'pterygoid lobe' y extend forward. The *posterior* (posteromedial) surface is in contact with

FIG. 888.—THE SALIVARY GLANDS.



sternomastoid muscle laterally, and with the styloid process and associated scles medially. Between the sternomastoid and styloid process it touches the sterior belly of the digastric, and is in relation with the internal carotid and gular vessels. The upper part of the posterior surface is in contact with the stoid process. The various structures in contact with the parotid gland often ke more or less distinct grooves upon its posterior and anterior surfaces.

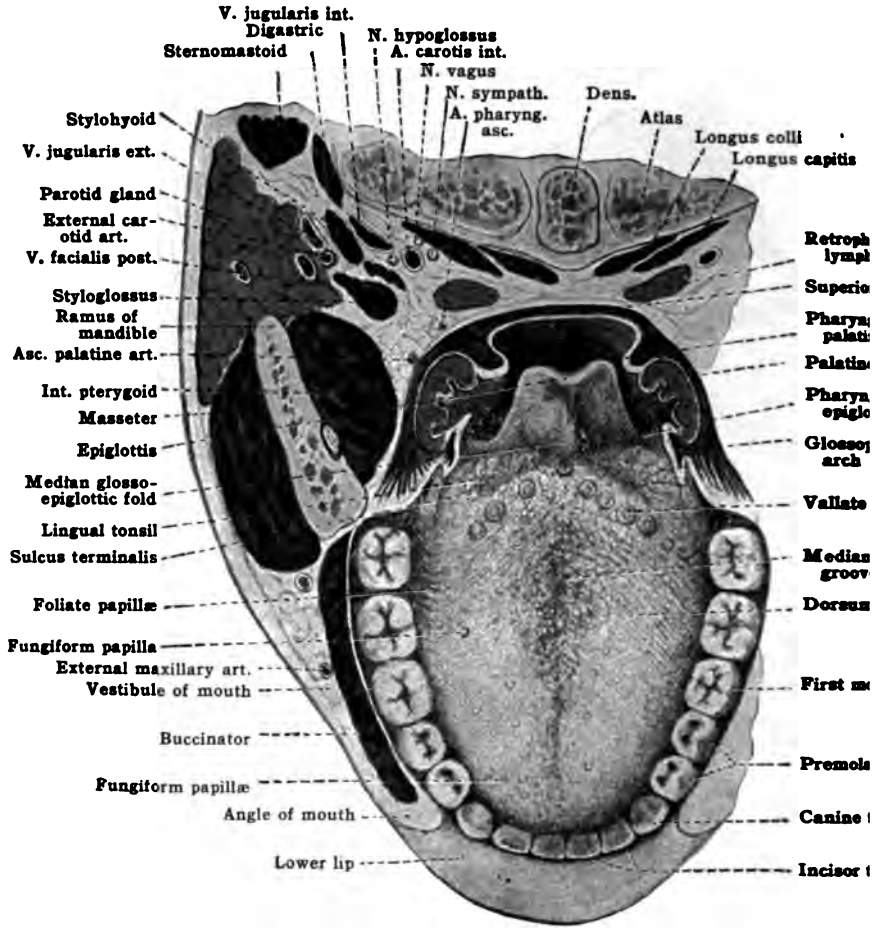
Borders.—The *anterior* border usually extends from below obliquely upward d forward so as to give the whole superficial surface a triangular appearance. ar the upper end of the anterior border, the parotid duct leaves the gland, and t above this there is usually a small separate *accessory lobe* [gl. parotis acces- ia], of variable form and size. The branches of the facial nerve also emerge m the anterior border. The *posterior* border extends along the anterior aspect the sternomastoid muscle up to the mastoid process. The *medial* border deeply placed (at the junction of the anterior and posterior surfaces), and proaches the wall of the pharynx. The medial border forms the apex of the dge-shaped parotid mass, and is termed the *processus retromandibularis*.

The *upper extremity* of the parotid sends a process into the posterior part of manibular fossa, behind the condyle of the mandible, and is related with the ernal auditory meatus. From the upper extremity emerge the superficial

temporal vessels and the auriculotemporal nerve. The *lower extremity* is rated by the stylomandibular ligament from the posterior end of the submax gland.

Fascia.—As shown in fig. 890, the parotid gland is enclosed in a sheath (called the fascia or aponeurosis) derived from the deep fascia of the neighborhood. The su layer of the sheath covers the lateral surface of the gland, while the deep layers cover the anterior and posterior surfaces of the gland. The sheath is very feeble or deficient medial angle. The superficial and the deep layers of the parotid sheath unite below to thick fascial band (stylomandibular ligament) extending from the angle of the mandible tip of the styloid process.

FIG. 889.—HORIZONTAL SECTION THROUGH HEAD AT LEVEL OF RIMA ORIS. (After modified.)



Contents.—Within the sheath, the parotid gland is in intimate relation with i important structures. Extending along the medial border, and partly embedded in t is the external carotid artery, dividing above into the superficial temporal and internal (including the origins of the deep auricular and transverse facial); and the poster (temporomaxillary) vein and branches. The auriculotemporal nerve passes through t part of the gland, while the facial nerve passes through it at a lower level, dividin temporofacial and cervicofacial divisions. Grégoire (Jour. de l'anat., etc. T. 48, 1 McWhorter (Anat. Rec., Vol. 12, 1917) have shown that the parotid is fundamentally into two lobes, superficial and deep, between which lie the principal branches of the fac Finally, there are embedded in the gland two or three deep lymphatic nodes, whic lymphatic vessels from the external auditory meatus, the soft palate and the posterio the nasal fossa; and several superficial nodes, which receive lymphatic vessels from th eyebrows and eyelids, cheek and auricle.

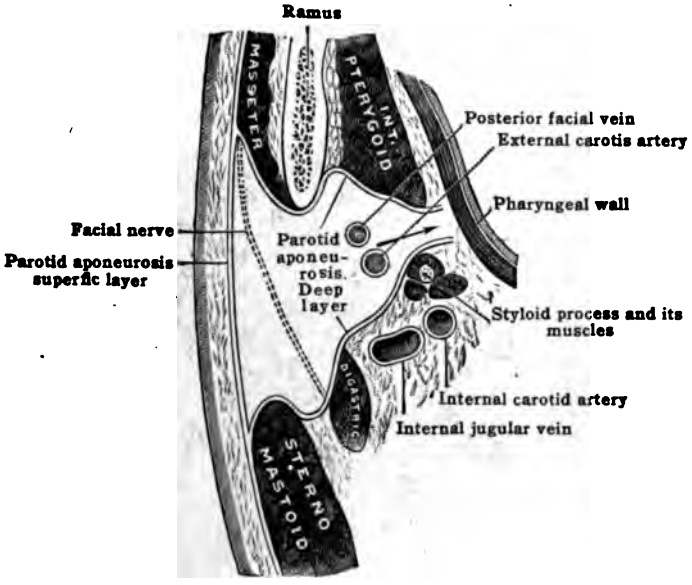
Structure.—The parotid is a racemose gland of the serous type.

Duct, vessels and nerves.—The parotid duct (Stenson's) issues from the anterio of the gland, crosses the masseter a finger's breadth below the zygoma, and turns medialward round the anterior border. It penetrates the fat of the cheek and t of the buccinator muscle, between which and the mucous membrane it ru

nce before it terminates, sometimes on the summit of a little papilla, by a minute
ıis opening is placed opposite the crown of the second upper molar tooth. The duct
: by numerous branches, which converge toward the anterior border of the gland,
's in its passage across the masseter the duct of the accessory parotid gland. The
ɔut the size of a crow-quill; length about 35 to 40 mm., diameter 3 mm. The wall
; is thick and tough, and consists of fibrous tissue intermixed with smooth muscle-

:eries are derived from those lying in the gland substance and from the posterior
rtery. The veins terminate in the posterior facial (temporomaxillary) trunk.
rves.—The parotid gland receives its secretory fibers from the otic ganglion, con-
ıulses from the glossopharyngeal via the lesser petrosal and the auriculotemporal;
supply through branches of the fifth nerve; and its sympathetic supply from the

-Diagram of Horizontal Section Showing the Parotid Compartment and
TIONS. Arrow indicates opening in sheath. (From Woolsey after Testut.)



xus. The **lymphatics** from the parotid gland terminate in the superficial and deep
nds, and especially in the deeper group of parotid nodes embedded in the substance
d.
ns.—The parotid is quite variable in size and in the form of its various processes,
of the accessory lobe, as already mentioned. The lobulations are less distinct in
Rarely the parotid is confined to the masseteric region, the retromandibular fossa
with a fatty tissue enclosing the vessels and nerves normally found with the gland.

THE SUBMAXILLARY GLAND

ıbmaxillary gland [glandula submaxillaris] weighs 7 to 10 grams, and is of
form and size of a flattened walnut. It consists of a chief or superficial
a smaller deep process. The chief portion is located in the digastric
ınd presents three surfaces—superficial, deep and lateral (figs. 875, 891).
:es.—The *superficial* (inferolateral) surface is covered by skin, superficial
ia, platysma and deep fascia (which forms an incomplete capsule around
). It is crossed by the anterior facial vein and by cervical branches of
nerve. Several lymphatic glands, which receive vessels from the ante-
l region, lie upon or embedded in this surface.
ıteral surface is the smallest of the three. It is in contact with the sub-
fossa of the medial surface of the mandible, and with the lower part of
nal pterygoid muscle. The posterior aspect of the gland is deeply
ɣ the external maxillary (facial) artery and is separated from the parotid
the stylomandibular ligament. The *deep* (mediosuperior) surface is
t with the lower surface of the mylohyoid, and behind this with the hyo-
ıtylohyoid and posterior belly of the digastric. Between this surface
mylohyoid muscle are the mylohyoid nerve and artery and the sub-
'tery.

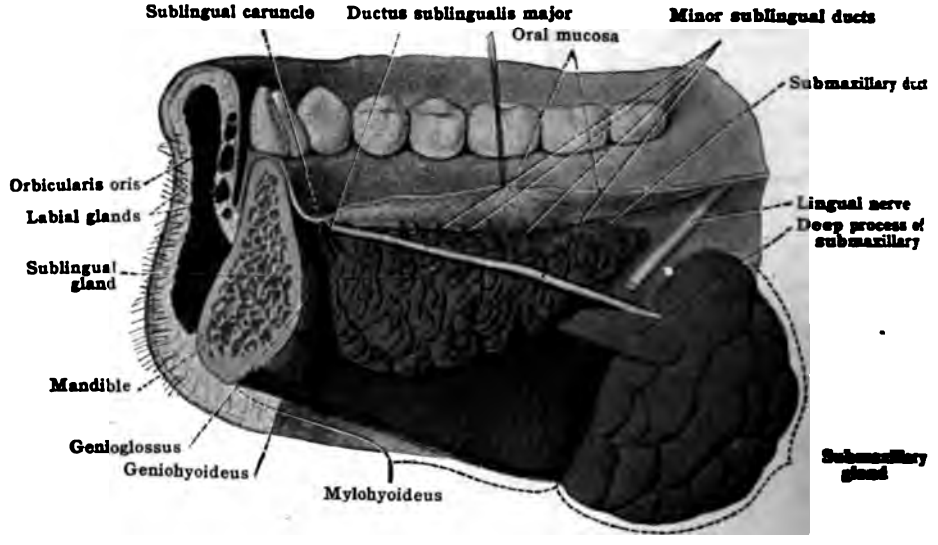
The **deep process** (fig. 891) is a tongue-like extension which passes from the deep surface of the submaxillary gland around the posterior border of the mylohyoid muscle, and extends forward in company with the duct, under cover of (above) the mylohyoid, and in relation with the hyoglossus and genioglossus muscles. At its commencement, the deep process lies just below the submaxillary ganglion.

Structure.—The submaxillary is a racemose gland belonging to the mixed type, some of the acini being serous, others mucous.

The **submaxillary (Wharton's) duct** springs from the deep surface of the superficial part of the gland associated with the deep process; it passes forward and inward and opens by a small orifice on the summit of a papilla [caruncula sublingualis] by the side of the frenulum of the tongue. It is crossed superficially by the lingual nerve. It lies at first between the mylohyoid and hyoglossus; next, between the mylohyoid and genioglossus; and lastly, under cover of the mucous membrane of the mouth, between the genioglossus and the sublingual gland. The duct is about 5 cm. in length, and has comparatively thin walls.

Vessels and nerves.—The **arteries** to the gland are derived from the external maxillary (facial) and lingual, and they are accompanied by *veins* joining the anterior facial.

FIG. 891.—MEDIAL VIEW OF THE SUBMAXILLARY AND SUBLINGUAL GLANDS. (Sobotta–McMurrich's Atlas.)



The **nerves.**—The submaxillary gland receives its secretory fibers from numerous small sympathetic ganglia situated on the submaxillary duct and in the hilus of the gland, these conveying impulses from the chorda tympani; its sensory branches probably come from the geniculate ganglion, and its sympathetic branches from the cervical sympathetic.

Variations.—Absence of the gland is a rare anomaly. A case is recorded (Turner) where the submaxillary was placed entirely under cover of the mylohyoid, being closely associated with the sublingual gland.

THE SUBLINGUAL GLAND

The **sublingual gland** [gl. sublingualis]—the smallest of the salivary glands (2 to 3 gm.) is in reality a group of glands forming an elongated mass in the floor of the mouth under the tongue (fig. 875). *Above*, it forms a distinct ridge, covered by a fold of mucosa (plica sublingualis) upon which its ducts open (fig. 891). It is flattened from side to side, its *lower* border resting upon the upper surface of the mylohyoid, its *lateral* surface in contact with the sublingual fossa of the mandible, and its *medial* surface with the geniohyoid, geniohyoglossus, lingual nerve, deep lingual artery and submaxillary duct (fig. 888). *Anteriorly* it touches its fellow of the opposite side, while *posteriorly* it is often related with the deep process of the submaxillary gland. It has no distinct capsule, thus differing from the submaxillary and parotid glands. In *structure*, it is a racemose mixed gland, but predominantly mucous.

Ducts. The *minor sublingual ducts* [ductus sublinguales minores], ducts of Rivinus, vary from five to fifteen or more in number, and open on minute papillæ along the crest of the plica sublingualis (fig. 884). The anterior portion of the gland often forms a *major* (*Bartholin's*) *duct* [ductus sublingualis major] which opens alongside the submaxillary duct on the *caruncula sublingualis* (figs. 884, 891).

Vessels and nerves.—The *arteries* are derived from the sublingual and submental, with corresponding *veins*. The *lymphatics* are tributaries of the superior deep cervical nodes.

Nerves.—The sublingual glands receive their secretory fibers from the submaxillary and associated sympathetic ganglia, conveying impulses from the chorda tympani; sympathetic branches come from the cervical sympathetic and sensory fibers probably from the geniculate ganglion, although this question needs further investigation.

Development of the salivary glands.—The salivary glands appear early as buds from the ectodermal epithelium of the oral sinus. For details, see p. 41.

Variations.—The duct of Bartholin is present in about half of the cases, and the corresponding anterior part of the gland may be more or less separate [gl. sublingualis major]. The number of ducts may reach thirty (Tillaux). Rarely processes from the gland may penetrate the mylohyoid, appearing on its lower surface in one or more places (Moustin). Most of the variations in this and the other salivary glands are due to developmental irregularities.

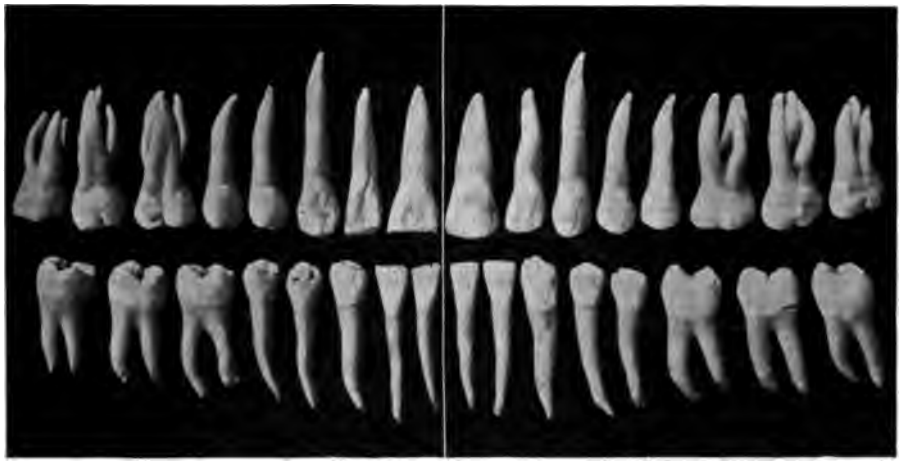
Comparative.—Oral glands are usually absent in the lower aquatic vertebrates. Mucous glands occur in all terrestrial vertebrates, but true salivary (digestive) glands appear only in mammals. Although great variations occur in the different species of mammals, those in man (excepting the anterior lingual) are typical for the order. The sublingual gland, however, often occurs as two separate glands, corresponding to the sublingualis major and minor. The parotid gland apparently has no representative in forms below mammals. In some mammals (e. g., monkey) it has two main lobes—a larger superficial and a smaller deeper lobe between which lies the facial nerve (Gregoire). Other oral glands (e. g., orbital, zygomatic) appear in some mammals.

THE TEETH

The **teeth** [dentes] are highly specialized structures developed in the oral mucosa as organs of mastication and also (in man) of speech. The adult individual with perfect dentition has thirty-two teeth, arranged arch-like in the sock-

FIG. 892.—TEETH OF ADULT, LINGUAL SURFACES. (Broomell and Fischelis.)

FIG. 893.—TEETH OF ADULT, LABIAL AND BUCCAL SURFACES. (Broomell and Fischelis.)



ets (alveoli) of the maxilla and the mandible. Sixteen belong to the upper or maxillary arch; and sixteen to the lower or mandibular. The four central teeth in each dental arch are the *incisors*, the tooth next to these on each side is the *canine* (cuspid); behind these are the two *premolars* (bicuspids); and lastly the three *molars*. This relation of teeth is expressed by the following dental formula:

$$i\frac{2}{2}, c\frac{1}{1}, pm\frac{2}{2}, m\frac{3}{3} = 32.$$

Forms.—Each tooth [dens] has a *crown* [corona dentis], the portion exposed beyond the gum, and covered with enamel (figs. 894, 895). The root [radix dentis] is the portion covered with cementum and embedded in the bony socket. At the line of union of crown and root is the slightly constricted *neck* [collum dentis]. The surface of the tooth directed toward the lip (or cheek) is termed the *labial* (or buccal) surface [facies labialis; f. buccalis]; while that toward the tongue is the *lingual* surface [f. lingualis]. The crowns of the opposite arches meet at the *masticating* or occlusal surface [f. masticatoria]. The surfaces in contact with the

adjacent teeth of the same arch [facies contactus] are, for the incisors and canines, termed *medial* and *lateral*, while those for the premolars and molars are termed *anterior* and *posterior*.

Structure.—As shown in longitudinal section (figs. 895, 896), each tooth has a central cavity [cavum dentis] or pulp cavity, which is filled with *pulp* [pulpa dentis]. The pulp is a soft fibrous tissue richly supplied with vessels and sensory nerves which enter the *root canal* through the apical *foramen* [foramen apicis dentis]. The body of the tooth, both crown and root, is composed of a dense modified variety of bone called *dentine* [substantia eburnea]. It is yellowish in color. The striated appearance of the dentine is due to numerous fine canals, the *dentinal tubules* [canaliculi dentales]. These contain 'Tomes' fibrils,' which are long protoplasmic branches of the *odontoblasts*, a layer of cells on the surface of the pulp. At the outer surface of the dentine in the root are numerous small, irregular *interglobular spaces*, corresponding to Tomes' 'granular sheath' (fig. 896). The dentine of the crown is covered with a layer of white *enamel* [substantia adamantina], which is the hardest substance in the body. It is composed of numerous minute hexagonal *prisms* [prismata adamantina] which are arranged perpendicular to the surface and are of epithelial origin. In adult teeth, the enamel is often worn through in places, exposing the yellowish dentine. The dentine of the root is covered by a thin layer of

FIG. 894.—CANINE TOOTH, LINGUAL SURFACE.

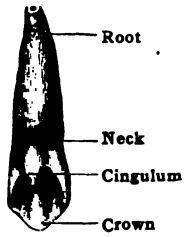
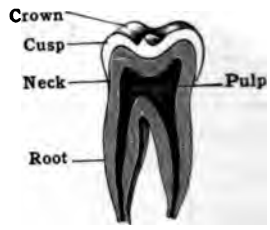


FIG. 895.—A MOLAR TOOTH IN SECTION



cementum [substantia ossea], a layer of modified bone which is very thin at the neck, but becomes thicker toward the root apex (fig. 896). Surrounding the root is the *alveolar periosteum* [peridental membrane), a fibrous membrane connecting the cementum firmly with the bony lining of the socket. For further details of the minute structure of teeth, works on histology may be consulted.

The relations of the teeth and alveoli are well shown by the X-rays (fig. 898).

Gums.—Covering the alveolar portions of the maxilla and mandible are the gums [gingivæ]. They are continuous with the mucosa of the oral vestibule externally and of the palate or floor of the mouth internally. Like the mucosa of the mouth elsewhere, they are covered with stratified squamous epithelium. The lamina propria is especially thick and strong, and is firmly attached to the subjacent bone. Around the neck of each tooth, the epithelium of the gum forms an overlapping collar and the lamina propria is continuous with the alveolar periosteum (peridental membrane) (fig. 896).

The incisors.—(Figs. 892, 893, 897.) The incisor teeth [dentes incisivi] are so named on account of their function in cutting the food. The *crown* has a characteristic chisel-shape. The *masticating* surface is narrow and chisel-edged. In recently erupted teeth, the cutting edge is elevated into three small cusps, which soon wear down, leaving a straight edge. These cusps correspond to three indistinct ridges on the labial surfaces. The lateral angle of the crown is usually more rounded than the medial. The *labial* surfaces are slightly convex, the *lingual* slightly concave. The *contact* surfaces are somewhat triangular. The *roots* of the incisors are single, though often longitudinally grooved, indicating traces of a division. They are somewhat conical, but flattened from side to side, especially the lower set, and are slightly curved lateralward.

The upper or maxillary incisors are much larger than the lower. They are lodged in the premaxilla, and are inclined downward and forward. They overlap the lower incisors in mastication, hence the masticating surface is worn off and rounded at its posterior edge, while the anterior edge becomes sharp and chisel-like. The lingual surfaces of the crowns terminate near the gum in a low, inverted V-shaped ridge, the basal ridge or *cingulum*. At the apex of the V, near the gum, there is often (especially on the lateral incisor) a small *lingual cusp*. The medial upper incisor is distinguished from the lateral by its such larger size.

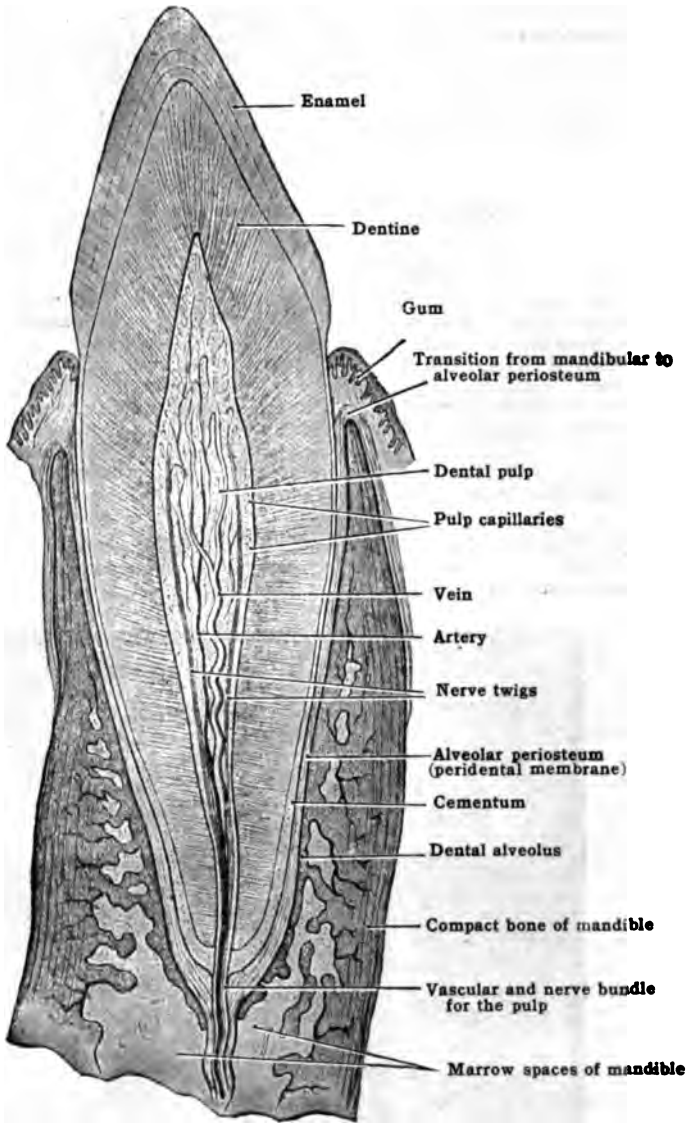
The lower or mandibular incisors are smaller than the upper, the cutting edges being only about half as wide. Being overlapped by the upper set, the lower incisors have the masticating surface worn off anteriorly, leaving a sharp cutting edge posteriorly. The lower incisors are vertically placed, and the crown becomes narrower toward the neck. A cingulum is rarely visible. The medial lower incisor, unlike the upper, is slightly smaller than the lateral.

The canines.—(Figs. 892–894.) The canine teeth [dentes canini] so-called from their prominence in the dog-tribe, are sometimes termed the 'cuspids.' They are the longest of all the teeth. The *crown* is thicker and more conical than in the incisors. The *masticating* surface forms a median angular point, on either side of which the cutting edge slopes to the lateral

[redacted]le. The medial limb of the cutting edge is usually somewhat shorter than the lateral, ren[redacted]g the crown asymmetrical. The *labial* surface is convex, the *lingual* somewhat concave. [redacted] *root* is single, long, flattened from side to side and grooved on the sides as in the incisors. [redacted] canine root is usually slightly curved lateralward. The bony alveolar protuberances [juga [redacted]olaria] are more prominent than those of any other teeth.

The **upper canine** slants forward and overlaps the lower, as in the incisors. The upper [redacted]ne also presents a well-marked *cingulum*, and usually a distinct *lingual cusp* (fig. 894) [redacted]ow which a slight median ridge extends along the lingual surface. On the **lower canine,**

FIG. 896.—VERTICAL SECTION OF AN INFERIOR CANINE TOOTH, IN SITU. × 4. (From Toldt's Atlas.)



these structures are poorly marked or absent. The lower canine is somewhat smaller than the upper, and its root is occasionally bifid.

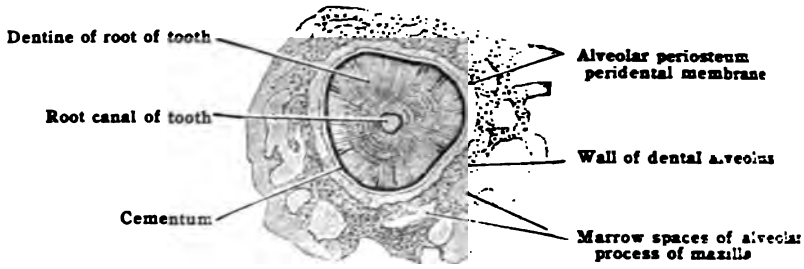
The premolars.—(Figs. 892, 893, 899, 900.) The premolars [dentes premolares] are so named on account of their position in front of the molars. The *crown* presents on the masticating surface two prominent cusps, on account of which the premolars are often called 'bicuspids.' The *buccal* and *lingual* surfaces are convex especially from side to side, so that the crown is somewhat cylindrical in form, with flattened, quadrilateral anterior and posterior *contact* surfaces. The *root* is (usually) single and more or less flattened anteroposteriorly, and usually somewhat curved backward.

The **upper premolars** are distinguished from the lower by a greater anteroposterior flattening of the crown and by a deep groove separating the cusps (excepting at their anterior and posterior margins) on the masticating surface. In the *first* upper premolar the lingual cusp

and surface are decidedly smaller than the buccal; and the root is frequently bifid or a (occasionally even triple). In the *second* upper premolar the lingual cusp and surface a large as the buccal; and the root, though deeply grooved, is rarely bifid.

In the **lower premolars,** the crowns are more cylindrical in form, and the cusps are u by a median ridge so that the masticating surface presents two small pits. The roots are rounded and tapering, and rarely grooved. In the *first* lower premolar (like the corresp upper) the lingual cusp and surface are much smaller than the buccal, the lingual cusp s times being rudimentary; while in the *second* they are more nearly equal. The second

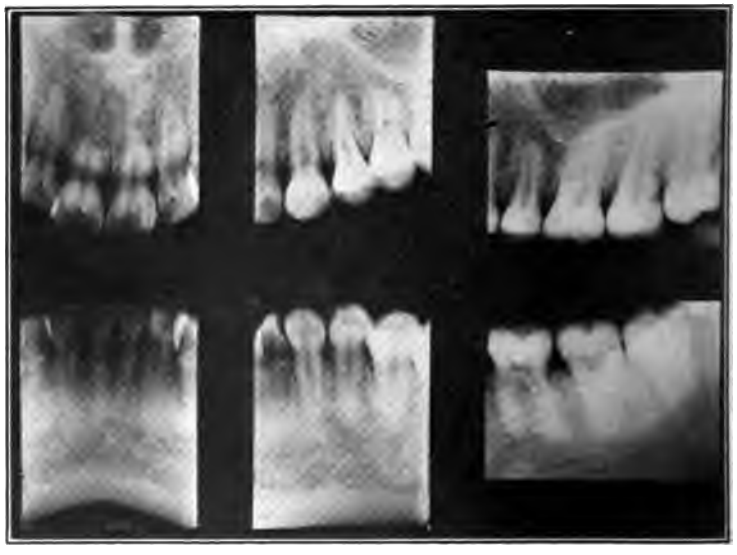
FIG. 897.—CROSS-SECTION OF THE MEDIAL UPPER INCISOR, IN SITU. × 4. (From T Atlas.)



premolar is often slightly larger than the first, while in the upper premolar the convers It should be noted, however, that the premolars are quite variable in all respects, s therefore often difficult to identify the individual isolated teeth.

The molars.—(Figs. 892, 893, 895, 899.) The molars (dentes molares) or 'grind characterized by their large size, and by the presence of three to five masticating cusp sometimes called 'multicuspids'). The *crowns* are massive, somewhat resembling cubes, and the lingual and buccal surfaces present vertical grooves continuous with the separating the cusps. The *pulp-cavity* (fig. 895) has slight extensions corresponding cusps, and also communicates with the canals of the *roots*, which are usually two or number, and more or less curved.

FIG. 898.—RADIOGRAPH OF THE TEETH. (DR. R. D. Carman, Mayo Clinic.) Up lower teeth of one side shown; incisors on the left, canine and premolars in the molars to the right.



The **upper molars** are most easily distinguished from the lower by the presence of root. The masticating surface is nearly square with rounded angles. They each have t four cusps, separated by grooves resembling a diagonally placed H (fig. 880). The cr the upper molars are obliquely placed so as to slant downward and slightly latera

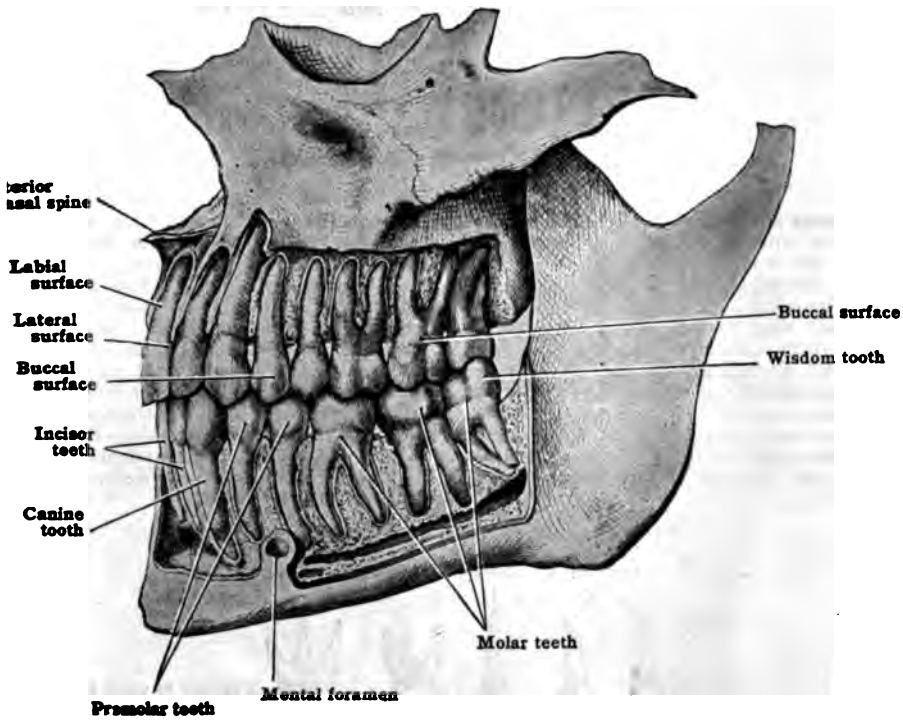
Each upper molar has three roots, two buccal and one lingual or palatal. They (especially the buccal) in more or less close relation with the floor of the maxillary ant Highmore) (fig. 899). The buccal roots are flattened anteroposteriorly, and longit grooved, and bent backward. The palatal root is more rounded, with a groove on th surface, and usually bent medialward. Either of the buccal roots may fuse with the or there may be an extra fourth root.

As to the *individual* upper molars, the *first* has almost invariably four typical cusps (rarely r three, or with an additional fifth rudimentary). The *second* upper molar has only three ps in about half of the cases (in Europeans), and four in the remainder. The *third*, or wisdom th [dens serotinus] is exceedingly variable in size and form. It has three cusps much more uently than four, and its three roots are often more or less fused into a conical mass. It sually much smaller than the other molars, and is absent in nearly one-fifth of all cases.

The lower molars have usually four or five cusps (two lingual, and two or three buccal) fissures separating them being cross-shaped or stellate (fig. 889). The crowns incline upd and slightly medialward. They have each two roots, anterior and posterior, flattened eroposteriorly, and usually somewhat curved backward. The roots, especially the anterior, y be longitudinally grooved. The anterior has two root-canals, the posterior usually only one. e apices of the roots of the lower molars, especially of the third, approach the mandibular ferior dental) canal (fig. 899).

Of the *individual* lower molars, the *first* is usually slightly the largest, and has five cusps the great majority of cases (variously estimated at from 60 to 95 per cent.), otherwise four. ie four main cusps (two buccal and two lingual) are separated by a cruciform fissure, which furcates posteriorly to embrace the small fifth cusp (which is placed slightly to the buccal

FIG. 899.—DISSECTION SHOWING THE ROOTS OF THE TEETH. Teeth in Occlusion. ×1. (From Toldt's Atlas.)



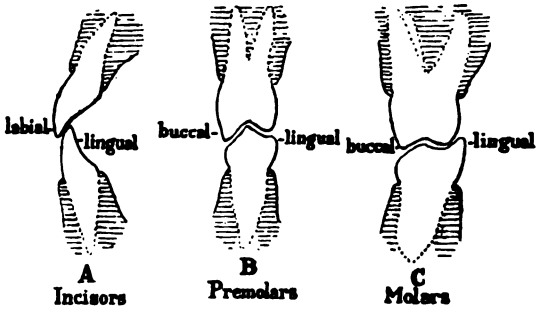
le) when present. The *second* lower molar has usually four cusps (75 to 85 per cent. of cases), nerwise five, the fifth usually small or rudimentary. The roots are sometimes confluent. ie lower *third* or wisdom tooth [dens serotinus], like the upper, is usually small and exceedgly variable. It has usually four or five cusps; but the number may be increased to six or ven, or reduced to three, two, or one. The roots are often short and fused into a conical ass, in which sometimes only a single canal is present.

The dental arches.—On comparing the upper and the lower dental arches, it is seen that e upper (fig. 880) forms an elliptical curve, while the lower (fig. 889) resembles a parabola. ie upper arch is slightly larger (due chiefly to the slant of the teeth, as previously explained) that it slightly overlaps the lower when the teeth are in occlusion. Thus, as shown in fig. 9, the upper incisors (and canines) overlap the lower. The buccal cusps of the lower preolars and molars fit into the groove between the upper buccal and lingual cusps; while the per lingual cusps correspond to the groove between lower buccal and lingual cusps. This rangement favors a more perfect mastication (see fig. 900).

Moreover, when viewed from the side (fig. 899), it is seen that in general, the corresponding eth of the upper and the lower arches are not opposite, but alternate with each other. This due chiefly to the great width of the upper central incisor. The lower molars, however, espeally the third, are wider (anteroposteriorly) than the upper, so that the two arches are arly equal in length. The interdental line between the two arches is not straight, but slightly nvex downward (fig. 899). In both arches, the crowns of the incisors and canines are taller an those of the premolars and molars.

Vessels and nerves.—The vessels and nerves of the teeth are distributed partly to the pulp and partly to the surrounding alveolar periosteum. The *arteries* are all derived from the internal maxillary. Those for the upper teeth are the posterior superior alveolar and the anterior superior alveolar (from the infraorbital). Similar branches to the lower jaw are given off by the inferior alveolar. They give off twigs to the gums (rami gingivales), the alveolar periosteum (rr. alveolares), and the pulp cavities (rr. dentales). A dental branch enters each root canal through the apical foramen, and breaks up into a rich peripheral capillary plexus under the odontoblast layer. From this plexus, the corresponding *veins* arise. There is a plexus of peridental *lymphatics*, which anastomose with those of the surrounding gums, and drain chiefly into the submaxillary nodes. Lymphatics have also been demonstrated in the pulp of the tooth (Schweitzer).

FIG. 900.—DIAGRAM SHOWING THE ARTICULATION OF THE TEETH. (Poirier-Charpy.)

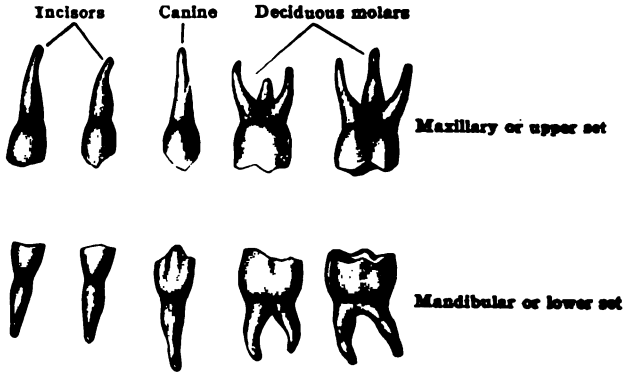


The **nerves** are sensory branches derived from the trigeminus. Those for the upper teeth are from the anterior, middle, and posterior superior alveolar (fig. 765); while those for the lower teeth are from the inferior alveolar (fig. 766). These nerves give numerous branches to the gums, alveolar periosteum (peridental membrane), and pulp cavities. The latter enter with the corresponding vessels, and their distribution within the tooth is a subject of controversy. They may be followed easily to a plexus under the odontoblasts; but whether they end freely, or in connection with the odontoblasts (which by some are considered as peripheral sensory cells), or send fine terminal branches out into the dentinal canals is still uncertain.

Development of the teeth.—The teeth represent calcified papillæ of the oral mucosa, the enamel being a derivative of the ectodermal epithelium, and the remainder of the tooth coming from the underlying mesenchyme. The early development of the teeth is described on p. 38.

Surrounding the entire developing tooth there is formed a strong, fibrous connective tissue membrane, the *tooth-sac*. The deeper part of this sac later becomes the *alveolar periosteum*

FIG. 901.—THE DECIDUOUS TEETH, EXTERNAL VIEW.



(peridental membrane) around which the bony alveoli are formed. This bone may entirely surround the tooth-sac, excepting at the summit, where a foramen persists through which a process of connective tissue (*gubernaculum dentis*) connects the tooth-sac with the overlying gum (see fig. 177.) Upon the inner surface of the tooth-sac, next to the root, the bony *cementum* is deposited upon the dentine. The root gradualy elongates, and is usually not completed until long after the eruption. The remaining superficial portion of the tooth-sac undergoes pressure atrophy and absorption. The remnants of the enamel organ, however, persist and form a thin tough cuticle [cuticula dentis], *Nasmyth's membrane*, which is soon worn off when the crown is exposed at the surface.

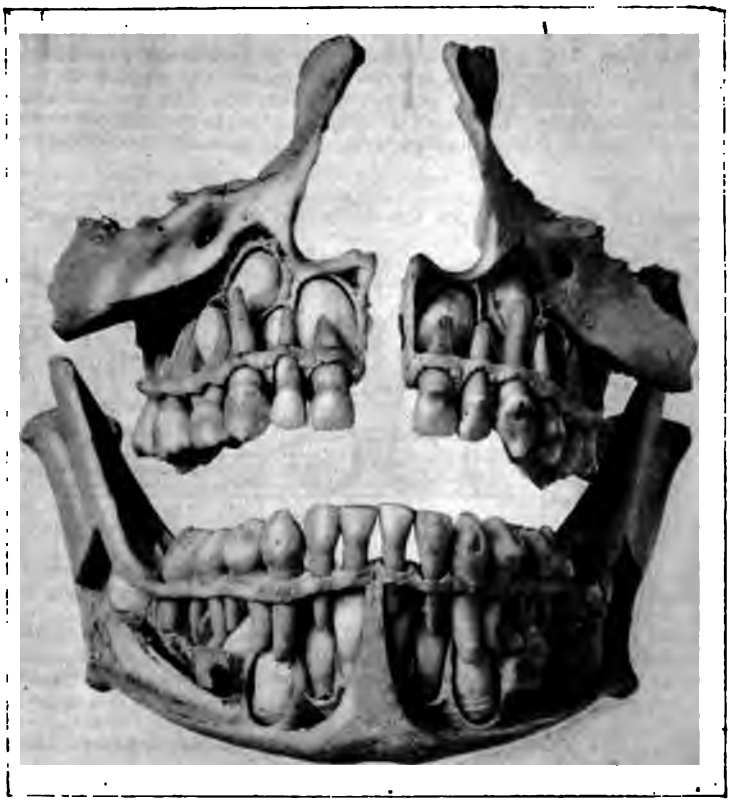
From the remainder of the dental ridge, which lies on the lingual side of the deciduous teeth (fig. 39), the *permanent teeth* are later derived in a very similar manner. (Rudimentary

indications of a *prelacteal* dental ridge have also been described.) The anlages of the permanent teeth therefore lie to the lingual side of the deciduous (fig. 902). From the posterior end of the dental ridge a process extends into the jaw behind the deciduous teeth, and from this process the permanent molars (which have no deciduous predecessors) are formed. At birth, although no teeth have yet been cut, there are present in the gums the anlages of not only all of the deciduous teeth, but also all of the permanent teeth, with two exceptions. Those of the second molars do not appear until six weeks after birth, and of the third molars not until the fifth year. The remnants of the dental ridges become broken up into small masses of epithelial cells, which persist for a variable time, forming the so-called 'glands' of Serres or Black.

The deciduous teeth.—The deciduous [dentes decidui], temporary or milk teeth are twenty in number, corresponding to the following formula:

$$\text{di}\,\frac{2}{2},\ \text{dc}\,\frac{1}{1},\ \text{dm}\,\frac{2}{2} = 20.$$

FIG. 902.—DISSECTION SHOWING BOTH DECIDUOUS AND PERMANENT TEETH AT ABOUT SIX YEARS. (Broomell and Fischelis.)



The deciduous teeth (figs. 901, 902) are much smaller in size than the permanent teeth, and their necks are more constricted. The enamel of the crown-cap is thicker. In general, their form and structure otherwise are very similar to that already described in the case of the permanent incisors and canines. The molars, however, are different. Their cusps on the masticating surface are very sharp and irregular. There are usually three cusps on the first upper molar and four on the second; four cusps on the first lower molar and five on the second. The roots correspond to those of the permanent molars (three above and two below), but they are much more divergent, to allow room for the development of the corresponding subjacent permanent premolar teeth. The first molar is always considerably smaller than the second.

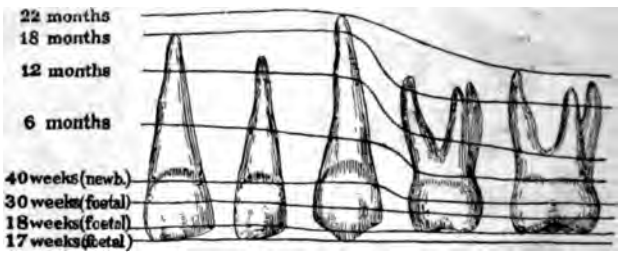
Calcification in the dentine and enamel of the teeth does not begin until the anlages of the crowns are well formed. The process of calcification follows that of the development of the tooth in general, beginning in the superficial portion of the crown and gradually spreading toward the root. Calcification in the *deciduous* teeth begins during the fifth fetal month, and at birth the crowns are nearly completed (fig. 904). Of the *permanent* set of teeth, only the first molar has begun to calcify at birth (fig. 905). Calcification of the other permanent teeth begins as follows: incisors, first year; canines, third year; premolars, fourth and fifth years; second molars, fifth year; third molars, eighth or ninth years. There are, however, great

variations in the time at which the calcification of the various teeth begins. As a rule, th calcification of the roots is not completed at the apices until some time after the crowns a exposed in eruption. As shown by fig. 905, calcification in most of the teeth is comple between the tenth and twelfth years; but in the second molars not until the sixteenth ye and in the third molars at eighteen years or later.

FIG. 903.—GROWTH OF THE ROOT AND PULP-CAVITY OF THE UPPER FIRST MOLAR, FROM TH FIFTH TO THE NINTH YEAR. (Broomell and Fischelis.)

Eruption of the teeth.—On account of pressure due to growth and expansion at the root the tooth (and probably other obscure factors), the crowns are pushed toward the surfa The overlying portion of the tooth-sac, together with corresponding portions of the tempor alveolar bone, are absorbed, and the crown is 'cut,' i. e., breaks through the surface of the g in eruption. In the case of the permanent teeth, this is normally preceded by a sheddin

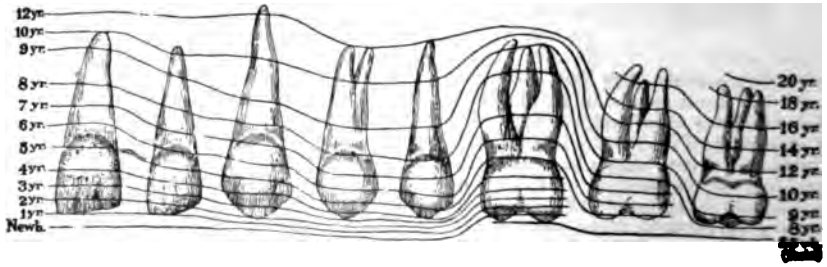
FIG. 904.—SHOWING THE EXTENT OF CALCIFICATION OF DECIDUOUS TEETH. (Peirce.



the deciduous teeth. The latter have been loosened by the absorption of their roots, whic perhaps due largely to the activity of certain *odontoclasts* (like the osteoclasts of bone) wh are found in the region of absorption.

Time and order of eruption.—The *time* of the eruption of the various teeth is subject great variation, so that no two investigators agree upon it. Aside from the wisdom teeth, time of eruption is most variable in the canines and premolars, and least variable in the f

FIG. 905.—SHOWING THE EXTENT OF CALCIFICATION OF THE PERMANENT TEETH. (Peir



permanent molars (Röse). According to Röse, the eruption averages four and one-half mon earlier in the male, and is also earlier in well-to-do and city children. But Boas and Bean f the eruption usually earlier in girls than in boys. The *order* in which the teeth appear is l variable. The average time at which the various deciduous and permanent teeth appear a are shed is indicated approximately in the following table. The lower teeth usually er before the corresponding upper teeth.

A. Deciduous Teeth

	Eruption Occurs	Shedding Begins
Medial incisors	7 (6–8) months	7th year
Lateral incisors	9 (7–12) months	8th year
First molars	14–15 months	10th year
Canine	18–19 months	10th year
Second molars	20–24 months	11th–12th year

B. Permanent Teeth

The approximate age (in years) at which the eruption of each of the permanent teeth has occurred in 50 per cent. of the individuals examined, which corresponds to the time of most rapid eruption, is given in the following table (observations of Bean upon 1445 school children at Ann Arbor, Michigan, and of James and Pitts on 4850 English children). The lower teeth, excepting the premolars, usually appear before the corresponding upper teeth.

	American		English
	Girls	Boys	
First molars	6.0	6.5	5.75– 6.25
Medial incisors	6.5	7.0	6.25– 7.50
Lateral incisors	8.0	8.5	7.50– 8.75
First premolars	10.0	11.0	9.75–10.50
Canines	10.5	11.5	10.25–11.75
Second premolars	10.0	11.5	10.75–12.00
Second molars	11.5	12.5	11.75–(12+)

The third molars (wisdom teeth) are extremely variable, usually erupting between the ages of 17 and 25, but sometimes later and occasionally failing to appear at all.

Variations.—The great variability of the teeth has already been emphasized, and numerous variations described in connection with the various individual teeth and their development. The observations of James and Pitts show a range of 4 or 5 years in the date at which eruption occurs. Bean has shown that there is marked racial variation in this respect. In *number*, the teeth may be reduced, due to absence (oftenest of the third molar) or incomplete development with failure of eruption. An *increase* in the normal number is less common. It may be only apparent, due to the retention of a deciduous tooth. There may rarely, however, be a true extra third incisor or premolar, or a fourth molar. Aberrant teeth may occur either on the labial or palatal side of the dental arch. A third dentition appears rarely in old age. In *form*, there is much greater variation as before mentioned. All intermediate forms between rudimentary and fully developed teeth may occur. Fusion between neighboring teeth is sometimes found, and deformities in the dental arches necessarily accompany palatal defects involving the alveolar arches.

Comparative.—As the oral mucosa represents an invagination of the integument, so the teeth are morphologically equivalent to modified dermal papillæ. The close relationship between the teeth and the dermal appendages is clearly shown among many of the lower vertebrates, but most clearly in the Selachians (which include sharks and allied forms). In fig. 906, which illustrates a sagittal section through the lower jaw of a young dogfish, it is clearly evident that the external placoid scales or 'dermal teeth' are continuous with the equivalent oral teeth at the oral margin of the jaw. Both the dermal teeth and the oral teeth are composed of dentine which presents an enlarged base and a somewhat conical apex. The base is embedded in the fibrous lamina propria (often in bony plates) while the apex projects through the epithelium and is covered with a thin cuticular layer the 'enamel membrane.' True enamel is usually rudimentary or absent in the primitive teeth of lower vertebrates, and represents a secondary acquisition. The dentine is in all cases derived from the connective tissue, and the enamel from the epithelium.

The process of development of the primitive oral teeth is also illustrated in fig. 906. Just within the oral margin there is a shelf-like downgrowth of the ectodermal epithelium, forming a primitive germinal ridge. Along this ridge may be seen the anlages of several rows of teeth in various stages of development. As fast as the mature teeth at the oral margin are worn off, new teeth pass up from below to replace them. Thus the primitive form of dentition is *polyphyodont*, with many sets of teeth developed successively throughout life. As we pass up the vertebrate scale there is a tendency to a reduction in the number of sets, although there is a wide variation among the various forms. In most mammals, as in man, the number of sets of teeth has been reduced to two, or *diphyodont* dentition, with only traces of an earlier (prelacteal) and also a later (post-permanent) set. In some mammals (nomotremes, cetacea) the dentition has been reduced to a single set, *monophyodont*, while in birds all except rudimentary traces of dentition have been lost.

As may be further observed in fig. 906, the primitive teeth are of a recurved conical form, and serve primarily for grasping and holding the food. The specialization of the teeth for purposes of mastication is in general a secondary acquisition amongst higher vertebrates.

It is also noteworthy that the primitive teeth, as found among nearly all forms below the mammals, are practically alike in form, i. e., *homodont*. Among mammals, however, there is a marked specialization of the teeth, or *heterodont* dentition. The mammalian teeth are usually differentiated into four distinct classes, incisors, canines, premolars and molars, similar to those found in man.

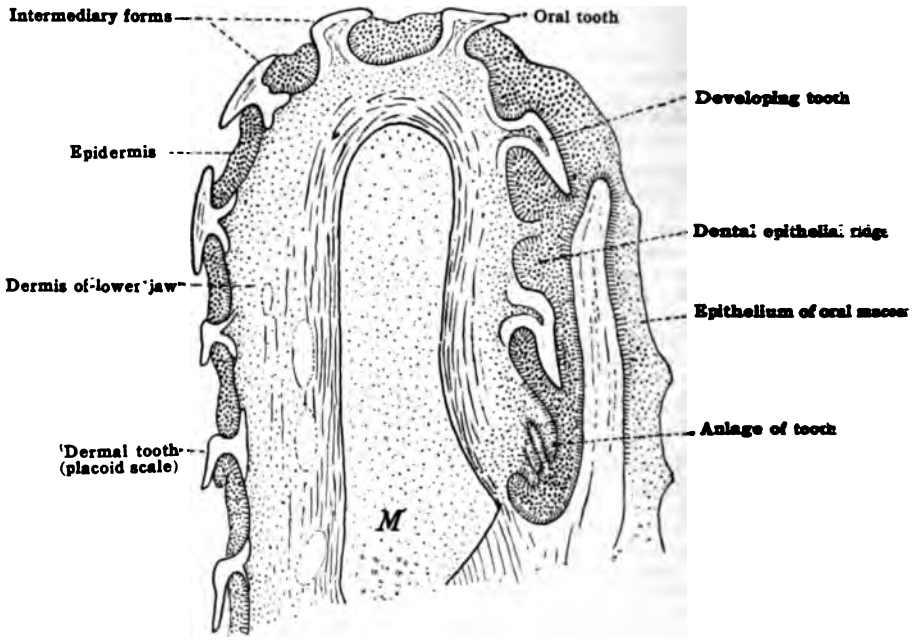
The typical or complete mammalian dentition (found in mole, pig and young horse), however, contains a larger number of teeth than found in man, and is represented by the formula:

$$i\ \frac{3}{3},\ c\ \frac{1}{1},\ pm\ \frac{4}{4},\ m\ \frac{3}{3} = 44.$$

Thus it is evident that there has been a reduction in the incisors and premolars in the human species, and there has been considerable discussion of the question as to which teeth of the primitive series have been lost. This reduction in the number of teeth is probably correlated with the general reduction in the jaws, which are relatively much larger and stronger in the savage races and lower animals. The third molar, or wisdom tooth, is probably now on the road to extinction, due to a continuation of the same evolutionary process.

Another interesting problem, concerning which there has been much speculation, is the origin of the multicuspidate mammalian molar. It has clearly been derived from the primitive conical type of the homodont dentition, but as to the method of evolution there is a difference of opinion. According to one view (the 'concrescence' theory), the molar has been derived by a process of fusion, each cusp representing a primitive conical tooth. Another view (the

FIG. 906.—SECTION THROUGH LOWER JAW OF DOG-FISH, SHOWING THE DEVELOPMENT OF THE ORAL TEETH, AND THE TRANSITION TO DERMAL TEETH. M, mandible. (After Gegenbaur.)



'differentiation' theory) is that the molar represents a single primitive tooth, upon the crown of which the various cusps have been differentiated. According to a third view, which is a compromise, the tritubercular (tricuspid) form of tooth, which is that found in the earliest fossil mammals, was derived by a process of concrescence of three primitive teeth, while from this tricuspid form the multicuspidate molar has been derived by a process of differentiation.

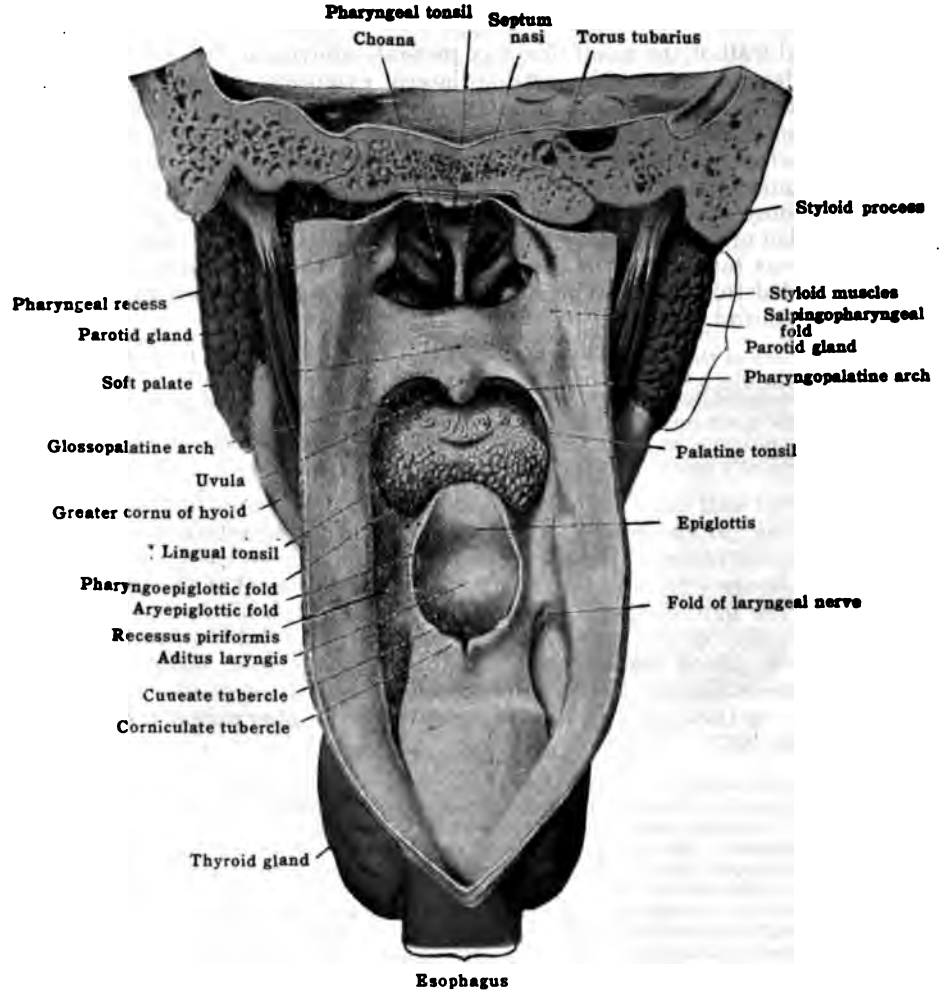
THE PHARYNX

The **pharynx** is a vertical, tubular passage, flattened anteroposteriorly, and extending from the base of the cranium *above* to the beginning of the esophagus below. *Posteriorly*, it is in contact with the bodies of the upper six cervical vertebræ. *Laterally*, it is in relation with the internal and common carotid arteries, the internal jugular vein, the sympathetic and the last four cranial nerves. *Anteriorly*, it communicates above with the nasal cavity, beneath this with the oral cavity, and below with the laryngeal cavity. The pharynx is correspondingly divided into three parts: the *nasal pharynx* [pars nasalis], which is exclusively respiratory in function; the *oral pharynx* [pars oralis], which is both respiratory and alimentary; and the *laryngeal pharynx* [pars laryngea], which is almost entirely alimentary.

Size and form.—The average length of the pharynx is about 12 cm. (5 inches). It is widest at the nasal pharynx, with a constriction (isthmus) at the junction

with the widened oral pharynx, and is again somewhat narrowed at the junction of oral and laryngeal pharynx (fig. 907). It is narrowest at the point where it joins the esophagus below. In sagittal section (fig. 876), it is evident that the anterior and posterior walls are closely approximated in the laryngeal pharynx, and have only a small space between them in the oral pharynx. The nasal pharynx, however, has a considerable anteroposterior depth, and by its bony walls is always kept open for respiratory purposes.

FIG. 907.—THE INTERIOR OF THE PHARYNX, VIEWED FROM BEHIND. (Sobotta-McMurrich.)



Structure.—The pharynx approaches the typical structure of the alimentary canal, yet differs from it in several important respects. The lining *mucosa* is continuous with that of the various cavities which open into the pharynx. Above, it is closely adherent to the base of the cranium, where it is thick and dark in color. It becomes thinner where it approaches the openings of the auditory tubes and choanæ; and below it is paler and thrown into longitudinal folds.

External to the mucosa, there is a characteristic fibrous membrane, the *pharyngeal aponeurosis* [fascia pharyngobasilaris], which is well marked above, but below it loses its density and gradually disappears as a definite structure. Above, it is attached to the basilar portion of the occipital bone in front of the pharyngeal tubercle. Its attachment may be traced to the apex of the petrous portion of the temporal bone, and thence to the auditory (Eustachian) tube and medial lamina of the pterygoid process. It descends along the pterygomandibular ligament to the posterior end of the mylohyoid ridge of the lower jaw, and passes thence along the side of the tongue to the stylohyoid ligament, the hyoid bone, and thyroid cartilage.

External to the pharyngeal aponeurosis is a thick *muscular* layer, made up of various cross-striated muscles, as will be described later. Outside of the muscular layer is a thin fibrous tunica adventitia, connected with the adjacent prevertebral fascia by a loose, areolar tissue. This loose tissue allows movement of the pharynx, and also favors the spreading of post-pharyngeal abscesses.

The **nasal pharynx** (figs. 876, 907) belongs, strictly speaking, with the nasal fossa as a part of the respiratory rather than the digestive system. . **Its anterior wall** is occupied by the two *choanæ* (posterior nares), with the nasal septum between them. The *floor* is formed by the upper surface of the soft palate and is a direct posterior continuation of the floor of the nasal fossæ. Posteriorly, however, the floor presents a more or less narrowed opening, the *pharyngeal isthmus*, which communicates with the oral pharynx below.

The isthmus is formed anteriorly by the uvula, laterally by the posterior (pharyngopalatine) arches. These slope backward and downward to the posterior wall of the pharynx, which forms the posterior boundary of the isthmus. The floor and isthmus change their form and position greatly during the action of the palatal muscles, as will be mentioned later.

The **lateral wall** of the nasal pharynx presents above and behind, corresponding to its widest point, a wide, slit-like lateral extension, the *pharyngeal recess* [recessus pharyngeus] or fossa of Rosenmueller (fig. 907). Below and in front of this recess, the greater part of the lateral wall is occupied by the aperture of the auditory (Eustachian) tube [ostium pharyngeum tubæ]. This is a somewhat triangular, funnel-shaped opening, with an inconspicuous *anterior lip* [labium anterius], a more distinct *posterior lip* [labium posterius], which presents posteriorly a rounded prominence (due to the projecting cartilage of the auditory tube), called the *torus tubarius*. On the lower aspect of the triangular aperture is a slightly rounded fold, the *levator cushion*, which is a prominence caused by the levator veli palatini muscle.

The prominence of the posterior lip facilitates the introduction of the Eustachian catheter, in connection with which the location of the aperture in the midlateral wall just above the level of the floor of the nasal fossa should be carefully noted. A fold of mucosa descending from the posterior lip of the aperture to the lateral pharyngeal wall is the *plica salpingopharyngea* (due to the m. salpingopharyngeus). An inconspicuous *plica salpingopalatina* descends from the anterior lip to the soft palate.

The **posterior wall** (fig. 876) of the nasal pharynx slopes from below upward and forward, passing (at the level of the anterior arch of the atlas) into the *roof* or *fornix* [fornix pharyngis]. The fornix is attached chiefly to the basioccipital and basisphenoid bones, extending laterally to the carotid canal of the pyramid, and anteriorly to the base of the nasal septum. The mucosa of the fornix and to a certain extent also of the posterior wall, especially in children, is thrown into numerous folds, which contain much lymphoid tissue, both diffuse and in the form of numerous characteristic lymphoid nodules, with crypt-like invaginations of the surface epithelium. This area constitutes the **pharyngeal tonsil** [tonsilla pharyngea] (fig. 907).

The pharyngeal tonsil is well developed in children (often abnormally enlarged, producing 'adenoids'), but usually, though not always, atrophied in the adult. According to Symington, the involution of the pharyngeal tonsil begins at 6 or 7 years, and is usually completed at 10 years. In the region of the pharyngeal tonsil and elsewhere, the mucosa presents numerous small racemose mucous glands, especially thick in the palatal floor of the nasal pharynx and similar to those of the oral cavity.

In the mucosa of this region, and closely associated with the pharyngeal tonsil, there is also found a small, inconstant blind sac, the *pharyngeal bursa*. A '*pharyngeal hypophysis*,' apparently derived from the lower end of Rathke's pouch, has also been described as constantly present (fig. 1070).

The **oral pharynx** (figs. 876, 889, 907) is continuous *above* through the pharyngeal isthmus with the nasal pharynx and *below* with the laryngeal pharynx. Its *posterior* wall presents no special features. The *anterior* wall is deficient above, where there is a communication with the mouth cavity through the *isthmus faucium*. The faucial isthmus is bounded above by the uvula, laterally by the anterior (glossopalatine) arches, and below by the dorsum of the tongue in the region of the sulcus terminalis. Below the faucial isthmus, the anterior wall of the oral pharynx is formed by the root of the tongue, which has been described previously. The *lateral* wall of the oral pharynx on each side presents the *palatine tonsil*, enclosed in a somewhat triangular *tonsillar fossa* [sinus tonsillaris] limited anteriorly and posteriorly by the anterior and posterior palatine arches, and below by the root of the tongue.

The **palatine arches** (pillars) are folds of the mucosa formed at the sides of the free posterior border of the soft palate, as already mentioned in connection with that organ. The *anterior arch* [arcus glossopalatinus] extends from the soft

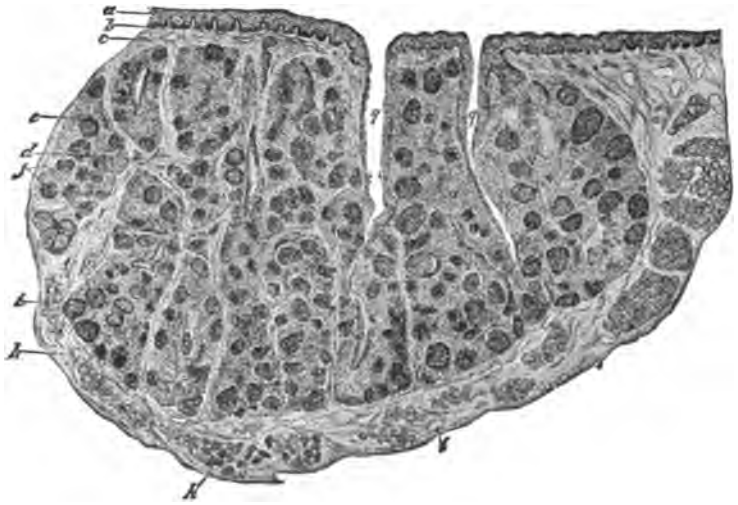
palate downward and forward to the lateral margin of the tongue, just behind the papillæ foliatæ. It is a fold of mucosa due to the underlying glossopalatine muscle, and inconspicuous except when this muscle is in action, or when the tongue is depressed. It forms the lateral boundary of the faucial isthmus. The *posterior arch* [arcus pharyngopalatinus] is a more prominent fold which extends from the soft palate in the region of the uvula downward and backward to join the posterolateral aspect of the pharyngeal wall. It forms the lateral boundary of the pharyngeal isthmus, and encloses the pharyngopalatine muscle, whose action will be explained later.

The Palatine Tonsil

The **palatine tonsil** [tonsilla palatina] (figs. 889, 908, 909) is a flattened ovoidal body, usually visible through the mouth cavity and faucial isthmus, and located on each side of the oral pharynx. The tonsil is extremely variable in size, but in the young adult averages 20 to 25 mm. in height, 15 to 20 mm. in width (anteroposteriorly) and about 12 mm. in thickness. The weight averages 1.4 grams (Gundobin).

The **lateral** or attached **surface** of the tonsil is covered by a thin but firm fibrous *capsule*, which is continuous with the pharyngeal aponeurosis, and in contact with the superior constrictor muscle of the pharynx (fig. 889).

Fig. 908.—Vertical Section of a Human Palatine Tonsil. *a*, Stratified epithelium; *b*, basement membrane; *c*, tunica propria; *d*, trabeculæ; *e*, diffuse lymphoid tissue; *f*, nodules; *h*, capsule; *i*, mucous glands; *k*, striated muscle; *l*, blood vessel; *g*, crypts. (From Radasch.



Just outside the constrictor, the tonsil is in relation with the ascending pharyngeal and ascending palatine arteries, but is separated by a considerable space from the external and internal carotids. Rarely, however, the lingual or external maxillary may extend up higher than usual, so as to be in close relation with the lower aspect of the tonsil. Further lateralward, the palatine tonsil is in relation with the internal pterygoid muscle, and on the surface corresponds to a point somewhat above and in front of the angle of the mandible. The posterior border of the tonsil is thicker than the anterior, and forms a somewhat flattened surface in contact with the pharyngopalatine muscle (fig. 909).

The **medial** or free **surface** of the tonsil is covered with mucosa and presents a variable number (12 to 30) small pits which are the openings into the tubular or slit-like *crypts* [fossulæ tonsillares]. These crypts are somewhat more numerous in the upper part of the tonsil, and are sometimes branched or irregular in form. Usually they end blindly in the substance of the tonsil, surrounded by lymphoid tissue in characteristic nodular masses (fig. 908).

The lymphocytes normally migrate through the stratified squamous epithelium lining the crypts (occasionally eroding passages of considerable size), and escape into the pharyngeal and mouth cavities, where they form the so-called *salivary corpuscles*. Around the periphery of the palatine tonsil, within the capsule, are many mucous glands (fig. 908), similar to those described in connection with the lingual and pharyngeal tonsils. The ducts of the mucous glands sometimes enter the crypts, but usually pass to the surface chiefly around the margins of the palatine tonsil.

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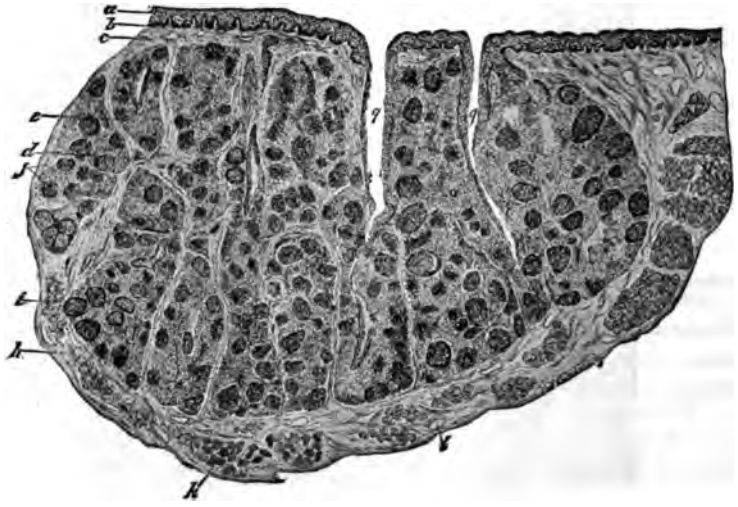
The **lateral** or attached **surface** of the tonsil is covered by a thin but firm fibrous *capsule*, which is continuous with the pharyngeal aponeurosis, and in contact with the superior constrictor muscle of the pharynx (fig. 889).

Fig. 908.—Vertical Section of a Human Palatine Tonsil. *a*, Stratified epithelium; *b*, basement membrane; *c*, tunica propria; *d*, trabeculæ; *e*, diffuse lymphoid tissue; *f*, nodules; *h*, capsule; *i*, mucous glands; *k*, striated muscle; *l*, blood vessel; *g*, crypts. (From Radasch.



Just outside the constrictor, the tonsil is in relation with the ascending pharyngeal and ascending palatine arteries, but is separated by a considerable space from the external and internal carotids. Rarely, however, the lingual or external maxillary may extend up higher than usual, so as to be in close relation with the lower aspect of the tonsil. Further lateralward, the palatine tonsil is in relation with the internal pterygoid muscle, and on the surface corresponds to a point somewhat above and in front of the angle of the mandible. The posterior border of the tonsil is thicker than the anterior, and forms a somewhat flattened surface in contact with the pharyngopalatine muscle (fig. 909).

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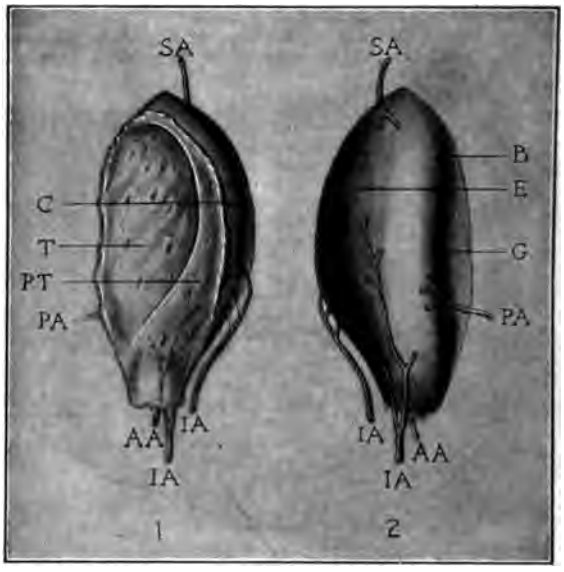
The lymphocytes normally migrate through the stratified squamous epithelium lining the crypts (occasionally eroding passages of considerable size), and escape into the pharyngeal and mouth cavities, where they form the so-called *salivary corpuscles*. Around the periphery of the palatine tonsil, within the capsule, are many mucous glands (fig. 908), similar to those described in connection with the lingual and pharyngeal tonsils. The ducts of the mucous glands sometimes enter the crypts, but usually pass to the surface chiefly around the margins of the palatine tonsil.

Tonsillar plicæ and fossæ.—Connected with the tonsil are certain important folds and fossæ. The *plica triangularis* (fig. 909) is a fold of variable extent and appearance, placed just behind the anterior arch, wider below and narrower above. According to Fetterolf, it is a prolongation of the tonsillar capsule, covered with mucosa. It may be adherent to the anterior part of the medial surface of the tonsil, or it may be free, in which case it covers a recess called the *anterior tonsillar fossa*. Occasionally there is a similar plica and fossa at the *posterior* border of the tonsil. Above the tonsil there is similarly a *supratonsillar fossa* [fossa supratonsillaris], which is also inconstant and exceedingly variable in size and shape. Killian found a supratonsillar fossa or canal in 41 of 105 cadavers.

Tonsillar vessels.—The *arteries* to the tonsil (figs. 492, 909) include the *anterior* tonsillar (from the dorsalis linguæ); the *inferior* tonsillar (from the external maxillary); the *posterior* tonsillar (from the ascending pharyngeal) and the *superior* tonsillar (from the descending palatine). These pierce the capsule and supply the gland. The *veins* form a plexus around the capsule and empty into the lingual vein and the pharyngeal plexus. The *lymphatic* relations of the palatine tonsil are important. *Afferent* vessels are received from adjacent areas of the mucosa in the pharynx, mouth and lower part of the nasal cavity (v. Lenart). These are connected with an extensive lymphatic plexus around the lymph follicles within the tonsil. *Efferent*

FIG. 909.—THE LEFT PALATINE TONSIL, SHOWING THE ARTERIAL SUPPLY.

1, Mesial aspect. 2, Posterolateral aspect. E, lateral surface. B, posterior surface. T, medial surface. G, groove for pharyngopalatine muscle. C, capsule. PT, plica triangularis. Arteries: AA, anterior tonsillar (from dorsal lingual); PA, posterior tonsillar (from ascending pharyngeal); SA, superior tonsillar (from descending palatine); IA, inferior tonsillar (anterior from dorsal lingual; posterior from tonsillar branch of internal maxillary). (Fetterolf: Amer. J. Med. Sc., 1912.)



lymphatic vessels pass chiefly to the upper deep cervical lymphatic nodes. One of these, located just behind the angle of the mandible, is so closely connected with the tonsil, and so constantly enlarged following tonsillar infection, that it has been called the *tonsillar lymph-gland* (Wood). There are also communications with the submaxillary and superficial cervical lymphatic nodes. The tonsillar lymphatic vessels connect also with those of the lingual tonsil in the root of the tongue.

The **innervation** of the palatine tonsil is from the middle and posterior palatine nerves, and from the tonsillar branches of the glossopharyngeal, forming a plexus, the *circulus tonsillaris*.

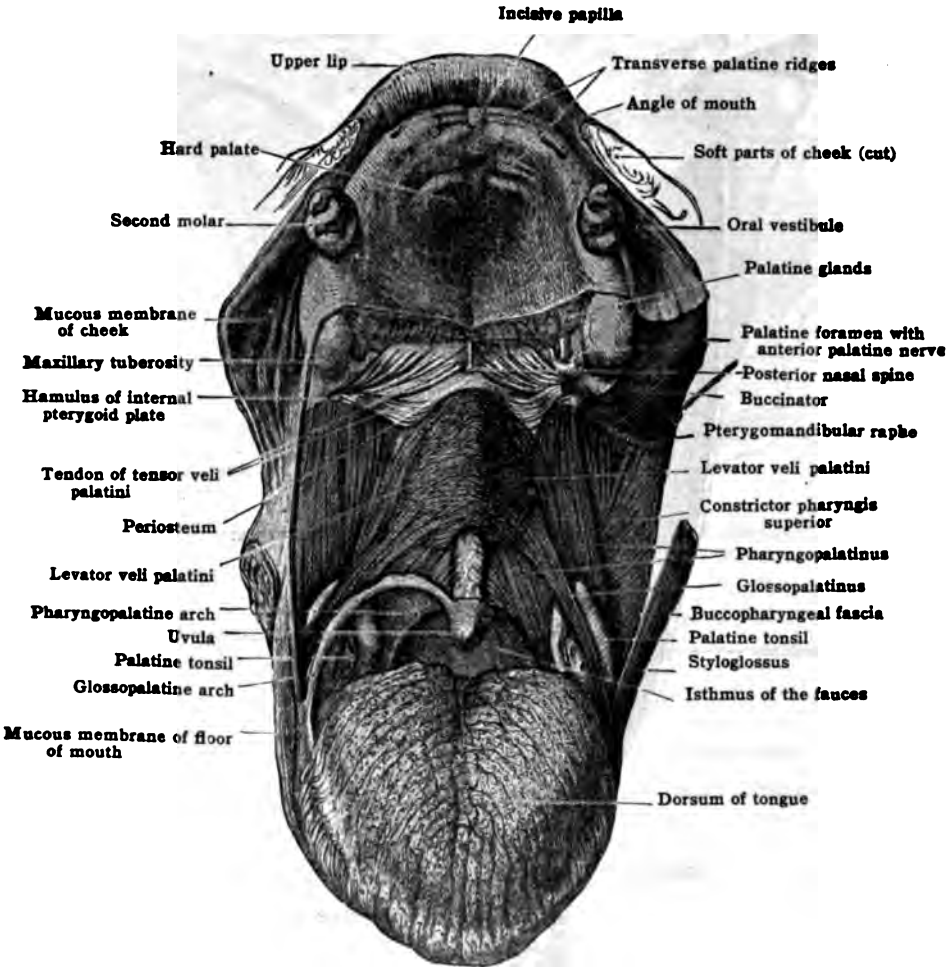
The tonsillar ring.—The two palatine tonsils, together with the lingual tonsil below and the pharyngeal tonsil above, form an almost complete ring of characteristic tonsillar tissue surrounding the pharynx and known as Waldeyer's 'tonsillar ring.' It is a highly specialized development of the diffuse lymphoid tissue which is found everywhere in the mucosa of the alimentary and respiratory tracts. It may be noted that the 'tonsillar ring' corresponds to the anterior limit of the embryonic foregut, hence the epithelium is of endodermic origin. The arrangement of the tonsils, together with their lymphatic connections, has suggested the widely accepted view that they are to be considered as protective mechanisms whose function is to intercept infectious material which has entered the mouth or nasal cavities. This theory is supported by the experiments of v. Lenart, who found that substances injected into the nasal mucosa are intercepted partly in the tonsils, and partly in the cervical lymph nodes. Oppel, however, opposes this view, holding that the function of the tonsils, as of lymphoid tissue elsewhere, is merely the production of lymphocytes.

Development of the tonsil.—For the development of the palatine tonsil in the floor of the second branchial pouch, see p. 42. The later fetal development of the tonsil is subject to

considerable individual variation. The supratonsillar fossa is a remnant of the upper part of the primitive sinus tonsillaris, which may be transformed into a canal by growth of adenoid tissue around it. It is inconstant and quite variable in size and extent. A portion of the sinus may likewise persist anteriorly (anterior tonsillar fossa) between the tonsil and the plica triangularis, but this portion is usually obliterated by fusion of the plica with the tonsil. The occasional retrotonsillar fold and fossa are said to arise secondarily (Hammar).

Variations in the tonsil.—The palatine tonsil, like the lingual and pharyngeal tonsils, is an exceedingly variable organ. Many of the variations are developmental in origin, as above indicated, and are therefore *congenital*. Furthermore, the tonsils, like all lymphoid structures, are subject to marked *age-variations* (see p. 36). Though fairly well formed at birth, they are yet somewhat undeveloped. They rapidly increase in relative size and complexity, however, being best developed in childhood. After the age of puberty, they usually undergo certain retrogressive changes, become smaller in size, and in old age become almost entirely atrophied and lost. They are also markedly subject to inflammatory hypertrophy, especially in children Variations in the relations of the *blood-vessels* were mentioned above.

FIG. 910.—THE MUSCLES OF THE SOFT PALATE AND THE PALATAL ARCHES AS SEEN FROM IN FRONT. (After Toldt, 'Atlas of Human Anatomy,' Rebman, London and New York.)

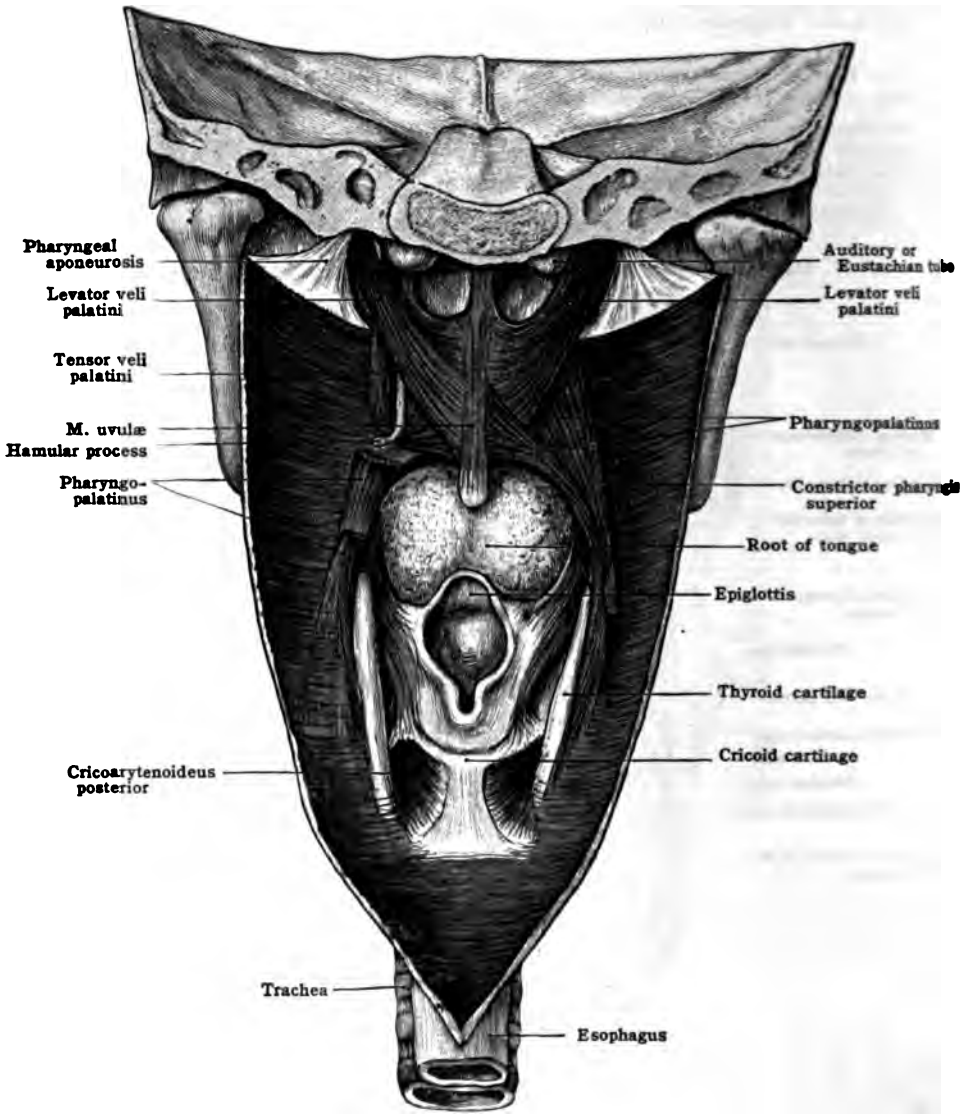


The laryngeal pharynx (fig. 876) is the lower portion leading from the oral pharynx above into the esophagus below (at the level of the lower border of the cricoid cartilage, usually opposite the sixth cervical centrum). It is wide above and narrow below (fig. 907). Its *posterior* walls are continuous with those of the oral pharynx and in relation with the vertebral centra. Its *lateral* walls are attached to the hyoid bone and the posterior part of the medial surface of the thyroid cartilage. *Anteriorly* it is in relation with the larynx (fig. 907). In the median line above is the epiglottis, below which is the superior aperture of the larynx. Still lower is the posterior wall of the larynx, containing the arytenoid and lamina of the cricoid cartilage. Laterally are the pharyngoepiglottic folds,

and below these on each side a deep, elongated fossa, the *recessus piriformis*, bounded laterally by the medial surface of the thyroid cartilage. The mucosa of the laryngeal pharynx is similar to that of the oral pharynx, and contains racemose mucous glands, which are especially numerous in its anterior wall.

Muscles of the pharynx and soft palate.—These muscles (figs. 910-912), which are here grouped together for convenience of description, are chiefly sphincter-like constrictors in function. They include the constrictors of the faucial isthmus (mm. glossopalatini), the constrictors of the pharyngeal isthmus

FIG. 911.—VIEW OF MUSCLES OF SOFT PALATE, AS SEEN FROM BEHIND, WITHIN THE PHARYNX. (Modified from Bourgery.)



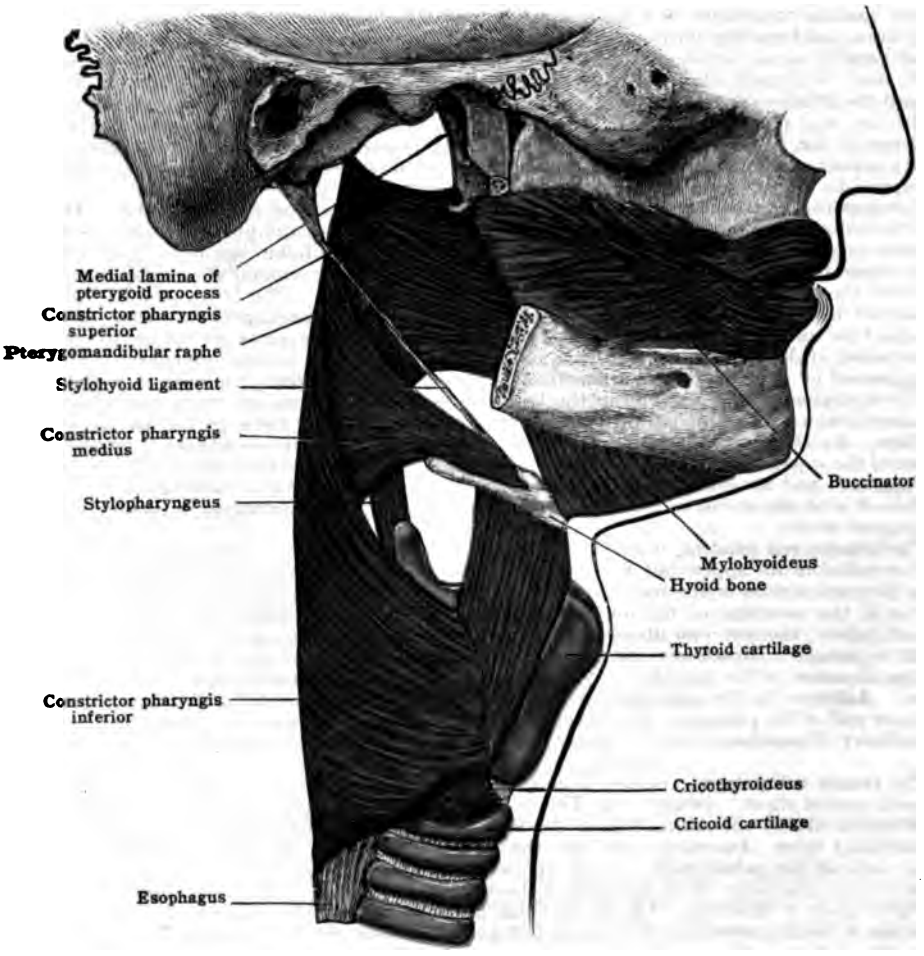
(mm. pharyngopalatini), the three pharyngeal constrictors, and also the levator and the tensor veli palatini, the m. uvulæ and the stylopharyngeus. The stylopharyngeus and pharyngopalatine muscles form an incomplete longitudinal layer within the more circularly arranged constrictors of the pharynx.

The muscles are arranged in layers either behind or in front of the palatal aponeurosis, and in a horizontal section of the soft palate the following layers are met with from behind forward: (1) The mucous membrane on the pharyngeal surface; (2) the posterior layer of the pharyngopalatinus (palatopharyngeus); (3) the m. uvulæ; (4) the levator veli palatini; (5) the anterior layer of the

pharyngopalatinus; (6) the palatal aponeurosis with the tensor veli palatini; (7) the glossopalatinus (palatoglossus); and (8) the mucous membrane on the oral aspect.

The glossopalatinus (palatoglossus) is a cylindrical muscle extending between the soft palate and the lateral border of the tongue. *Origin.*—From the oral surface of the palatal aponeurosis. *Insertion.*—(1) The superficial layer of muscles which covers the side and adjacent part of the under surface of the tongue; (2) the transversus linguæ. *Structure.*—At its origin the muscle forms a thin sheet, but the fibers, passing lateralward, quickly concentrate to form a cylindrical bundle, which passes downward beneath the mucous membrane of the pharynx and in front of the palatine tonsil, forming the glossopalatine arch of the fauces. It reaches the side of the tongue at the junction of its middle and posterior thirds, and some of its fibers continue forward to join with those of the styloglossus and hyoglossus, while the majority pass

FIG. 912.—THE MUSCLES OF THE PHARYNX, LATERAL VIEW.



medially to become continuous with the transversus linguæ. *Nerve-supply.*—From the pharyngeal branches (plexus) of the vagus. *Action.*—(1) To draw the sides of the soft palate downward; (2) to draw the sides of the tongue upward and backward. The combination of these actions tends to constrict the faucial isthmus. (The origin and insertion of the glossopalatinus as given above are often described as reversed.)

The **pharyngopalatinus** (palatopharyngeus)—named from its attachments—is a thin sheet. *Origin.*—(1) From the aponeurosis of the soft palate by two heads which are separated by the insertion of the levator veli palatini; (2) by one or two narrow bundles from the lower part of the cartilage of the auditory (Eustachian) tube (*salpingopharyngeus*). *Insertion.*—(1) By a narrow fasciculus into the posterior border of the thyroid cartilage near the base of the superior cornu; (2) by a broad expansion into the fibrous layer of the pharynx at its lower part. *Structure.*—The upper head of the muscle consists of scattered fibers which blend with the opposite muscle across the middle line; the lower head is thicker, and follows the curve of the posterior border of the palate. The two heads with the fasciculus from the auditory (Eustachian) tube form a compact muscular band in the posterior palatine arch; the fibers mingle with those of

the stylopharyngeus, at the lower border of the superior constrictor, and then expand upon the lower part of the pharynx. *Nerve-supply.*—From the pharyngeal branch (plexus) of the vagus. *Action.*—(1) Approximates the posterior arches of the fauces; (2) depresses the soft palate; (3) elevates the pharynx and larynx. (The origin and insertion above given are often described as reversed.)

The **inferior constrictor** [M. constrictor pharyngis inferior] is thick and strong. It *arises* from the thyroid cartilage immediately behind the oblique line and superior tubercle (thyropharyngeus), and from a tendinous arch extending between the inferior tubercle of the thyroid and the cricoid cartilage and also from the lateral surface of the cricoid cartilage (cricopharyngeus) (fig. 912). The fibers spread backward and medialward, the lowest horizontally, while those above ascend more and more obliquely, and are *inserted* into the fibrous raphé of the pharynx. Some of the lowest fibers are continuous with the muscular fibers of the esophagus, and the upper overlap the middle constrictor (fig. 912). The *nerve-supply* of all three constrictors is from the pharyngeal plexus.

Near the upper border the superior laryngeal nerve and artery pierce the thyrohyoid membrane to reach the larynx. The inferior laryngeal nerve ascends beneath the lower border immediately behind the cricothyroid articulation.

The **middle constrictor** is a fan-shaped muscle which *arises* from the lesser cornu of the hyoid bone and from the stylohyoid ligament (chondropharyngeus), and from the whole length of the greater cornu (ceratopharyngeus). The diverging fibers are *inserted* into the median raphé, and blend with those of the opposite side. The lower fibers of the muscle descend beneath the inferior constrictor, to the lower part of the pharynx; the upper overlap the superior constrictor, and reach the basilar process of the occipital bone, while the middle fibers run transversely (fig. 912). The glossopharyngeal nerve passes downward above its upper border, the stylopharyngeus passes between it and the superior constrictor, and near its origin it is overlapped by the hyoglossus and crossed by the lingual artery.

The **superior constrictor** is quadrilateral in shape, pale, and thin (figs. 374, 912). It *arises* from the lower third of the hinder edge of the medial lamina of the pterygoid process and its hamular process (pterygopharyngeus), from the pterygomandibular ligament (buccopharyngeus), from the posterior fifth of the mylohyoid ridge of the mandible (mylopharyngeus), and from the side of the root of the tongue (glossopharyngeus). The fibers pass backward to be *inserted* into the median raphé, the highest reaching the pharyngeal tubercle. The Eustachian tube and the levator veli palatini are placed above the superior arched border, and the space (*sinus of Morgagni*) between this and the basilar process, devoid of muscular fibers, is strengthened by the pharyngeal aponeurosis, this portion of it being semilunar in shape.

The **stylopharyngeus** *arises* from the base of the styloid process internally (figs. 490, 881). It passes downward and medialward to reach the pharynx between the superior and middle constrictors. Its fibers spread out as it descends beneath the mucous membrane. At the lower border of the superior constrictor some of its fibers join fibers of the pharyngopalatinus (palatopharyngeus), and are *inserted* into the posterior border of the thyroid cartilage (fig. 912); the rest blend with the constrictors. The *nerve-supply* of the stylopharyngeus is from the glossopharyngeal nerve.

The **levator veli palatini**—named from its action on the velum of the soft palate—is somewhat rounded in its upper, but flattened in its lower, half. *Origin.*—(1) The inferior surface of the petrous portion of the temporal, anterior to the orifice of the carotid canal; (2) the lower margin of the cartilage of the auditory (Eustachian) tube. *Insertion.*—The aponeurosis of the soft palate; the terminal fibers of the muscles of each side meet in the middle line in front of the m. uvulæ. *Structure.*—Its origin is by a short tendon; the muscle then becomes fleshy and continues so to its insertion. *Nerve-supply.*—From a pharyngeal branch (plexus) of the vagus. *Action.*—(1) To raise up the velum of the soft palate, and bring it in contact with the posterior wall of the pharynx; (2) to narrow the pharyngeal opening and to widen the isthmus of the auditory (Eustachian) tube. (According to Cleland, it closes the pharyngeal opening of this tube.)

The **tensor veli palatini**—named from its action on the velum of the soft palate—is a thin, flat, and narrow sheet. *Origin.*—(1) The scaphoid fossa of the sphenoid; (2) the angular spine of the sphenoid; (3) the lateral side of the membranous and cartilaginous wall of the auditory (Eustachian) tube. *Insertion.*—(1) Into the transverse ridge on the lower surface of the horizontal plate of the palate bone; (2) the aponeurosis of the soft palate.

Structure.—Its belly as it descends between the pterygoideus internus and the internal pterygoid plate is muscular. On approaching the hamular process it becomes tendinous, and continues so to its insertion. A bursa is interposed between the hamular process and the tendon. The belly of the muscle is at nearly a right angle with its tendon. *Nerve-supply.*—From the mandibular division of the trigeminus through the tensor veli palatini branch of the otic ganglion. *Actions.*—(1) Tightens the soft palate; (2) opens the auditory (Eustachian) tube during deglutition.

The **musculus uvulæ**—so named by reason of its position in the uvula. *Origin.*—(1) From the aponeurosis of the soft palate and tendinous expansions of the two tensores veli palatini. *Insertion.*—Into the uvula. *Structure.*—The muscle consists of two narrow parallel strips lying on each side of the middle line of the palate. *Nerve-supply.*—From the pharyngeal branches (plexus) of the vagus. *Action.*—To draw up the uvula.

Development of the muscles.—According to W. H. Lewis, the tensor veli palatini is a derivative of the mandibular arch (probably split off from the pterygoid mass); the levator veli palatini and m. uvulæ come with the facial musculature from the hyoid arch; the glossopalatine, stylopharyngeus and pharyngeal constrictors probably from the third visceral arch, in a premuscle mass visible in a 9 mm. embryo. The adult innervation of the pharyngeal muscles does not agree entirely with this, however. The pharyngeal muscles (as above stated) are innervated chiefly from the vagus, whereas if derived from the third arch their innervation from the glossopharyngeus would be expected.

Process of swallowing.—In the act of swallowing, practically all of the muscles of the mouth, tongue, palate and pharynx are involved. By compression of the lips and cheeks, together with elevation of the tongue, the food is forced backward through the faucial isthmus into the oral pharynx. Constriction of the faucial isthmus by the glossopalatine muscles assists in preventing a return to the mouth. By the action of the levator and tensor veli palatini, and pharyngopalatine muscles, the soft palate is retracted and tightened, with constriction of the pharyngeal isthmus, so as to prevent the passage of the food upward into the nasal pharynx. The pharynx is drawn upward by the stylopharyngeus, and the pressure produced by the pharyngeal constrictors (the contraction beginning above and extending downward) forces the food downward through the laryngeal pharynx and into the esophagus. Passage of the food into the larynx is prevented by constricton of the superior aperture of the larynx.

Vessels and nerves.—The vessels of the tonsil and the motor nerves of the various muscles have already been mentioned. In general, the *arteries* to the pharynx are derived chiefly from the ascending pharyngeal, the ascending palatine branch of the external maxillary, and the descending palatine and pterygopalatine branches of the internal maxillary. The *veins* form a venous plexus between the pharyngeal constrictors and the pharyngeal aponeurosis, and also an external plexus, communicating with the pterygoid plexus above and with the posterior facial or internal jugular vein below. The *lymphatic* vessels pass chiefly to the deep cervical nodes, those from the upper portion (including the pharyngeal tonsil) ending partly in the retropharyngeal nodes. The *nerves* of the pharynx, both motor and sensory, are derived chiefly from the glossopharyngeal and vagus, by way of the pharyngeal plexus.

The development of the pharynx.—For the development of the pharynx, including the branchial arches and pouches, and the pharyngeal tonsils, see p. 41.

Variations.—Variations in the palatine and pharyngeal tonsils and in the pharyngeal bursa have already been mentioned. Remnants of the visceral clefts may persist as aberrant diverticula or as 'branchial fistulæ' connected with the pharynx. Many additional *muscles* have been described, chiefly longitudinal muscles arising from the base of the cranium either by splitting of those normally present, or as separate slips. A detailed description of these may be found in Poirier-Charpy's work. Abnormally extensive fusion of the posterior arches of the palate with the walls of the pharynx may produce a congenital stenosis of the pharyngeal isthmus.

Comparative.—The pharynx is not distinctly separated from the mouth cavity in the lower vertebrates. It is the region containing the branchial or visceral clefts and is thus both respiratory and alimentary in function. The *nasal* pharynx, including the apertures of the auditory tubes, becomes distinct along with the nasal cavity when the palate is formed (from the reptiles upward). In the air-breathing vertebrates, the laryngeal aperture appears in the ventral wall of the pharynx just anterior to the beginning of the esophagus. Of the *tonsils*, the *pharyngeal* are the most primitive, being present in the roof of the pharynx in amphibia, well developed in reptiles, birds, and mammals (Killian). The *palatine* tonsils, on the other hand, are characteristic of mammals, being rarely absent, however (e. g., rat, guinea pig). From the embryological point of view, Hammar has classified the palatine tonsils in the various mammals under (1) the primary type (including rabbit, cat, and dog), in which the tonsil is formed from the embryonic tonsillar tubercle (described above under development of tonsil); and (2) the secondary type (including pig, ox, sheep and man), in which the tonsillar tubercle disappears and the tonsil is developed from the wall of the surrounding tonsillar sinus. Typical epithelial crypts (highly branched in the ox) are found only in the secondary type. The tonsil may form a single (lymphoid) lobe (cat, pig, rabbit) or may develop typically two lobes (ox, sheep, man), separated by the intratonsillar fold. There are great variations among different species as to relative size, number and character of folds, crypts, etc. The intimate relation of the epithelium with the underlying lymphoid tissue is characteristic and constant.

THE ESOPHAGUS

The **esophagus** [œsophagus] (figs. 913, 914) is that portion of the alimentary canal which extends from the pharynx to the stomach. It is a constricted portion of the canal, being narrowest at its commencement opposite the lower border of the cricoid cartilage. It is again somewhat contracted behind the tracheal bifurcation, and at its passage through the diaphragm, which is opposite the tenth or eleventh thoracic vertebra (figs. 913, 914).

In its course downward the esophagus follows the curve of the vertebral column until it finally passes forward in front of, and slightly to the left of, the aorta to gain the esophageal opening in the diaphragm. In addition to this curve it presents two lateral curvatures, one convex toward the left side at the root of the neck and in the upper part of the thorax, and the other concave toward the left in the lower part of the thorax where it leaves the vertebral column. It lies in the middle line at its commencement (usually opposite the sixth cervical vertebra), and again, at a lower level, opposite the fifth thoracic vertebra.

The following **average measurements** *in situ* (range in parenthesis), were observed by v. Hacker on male cadavers (females slightly less): Teeth to cricoid level, 14.9 (14–16) cm.; total esophagus, 25.0 (23–30) cm.; cricoid to tracheal bifurcation, 10.4 cm.; tracheal bifurcation to cardia, 14.6 (12–17) cm. The average width is about 2.0 cm.; but at the upper end only 1.3 cm., and at the lower end (hiatus esophageus), 1.6 cm.

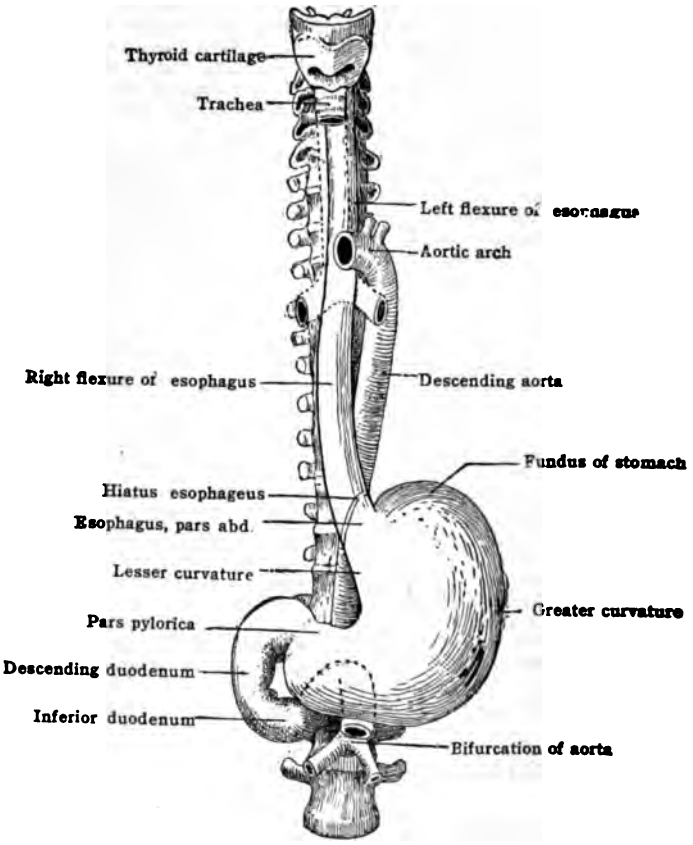
After death the esophagus is somewhat flattened from before backward, but it is more rounded during life. It is closed except during the passage of food, etc. The *peristaltic movements* of the esophagus can readily be observed by means of the Rœntgen-rays. Solids often

lodge a short time at the level of the arch of the aorta, but pass quickly through the cardiac orifice. A swallow of liquid, on the other hand, is usually detained at the lower end of the esophagus (probably by sphincteric action of the cardia) for about seven seconds before passing into the stomach (Pfahler).

The esophagus is divided into three parts: cervical, thoracic and abdominal.

Cervical portion.—The esophagus has anteriorly the trachea, the posterior portion of the left lateral lobe of the thyroid gland, and the left recurrent nerve, branches of the inferior thyroid artery, and the carotid sheath. *Posteriorly*, it rests upon the vertebral column, the longus colli muscles, and prevertebral fascia. *On its right side* are placed the right carotid and right recurrent nerve; and *on the left side* the left inferior thyroid vessels, left carotid artery, left subclavian, and the thoracic duct. The recurrent nerves pass upward on each side to gain the interval between the trachea and esophagus. The left nerve, as already described, lies in front of the tube, and the right along its right border.

FIG. 913.—THE ESOPHAGUS AND STOMACH. (Testut.)



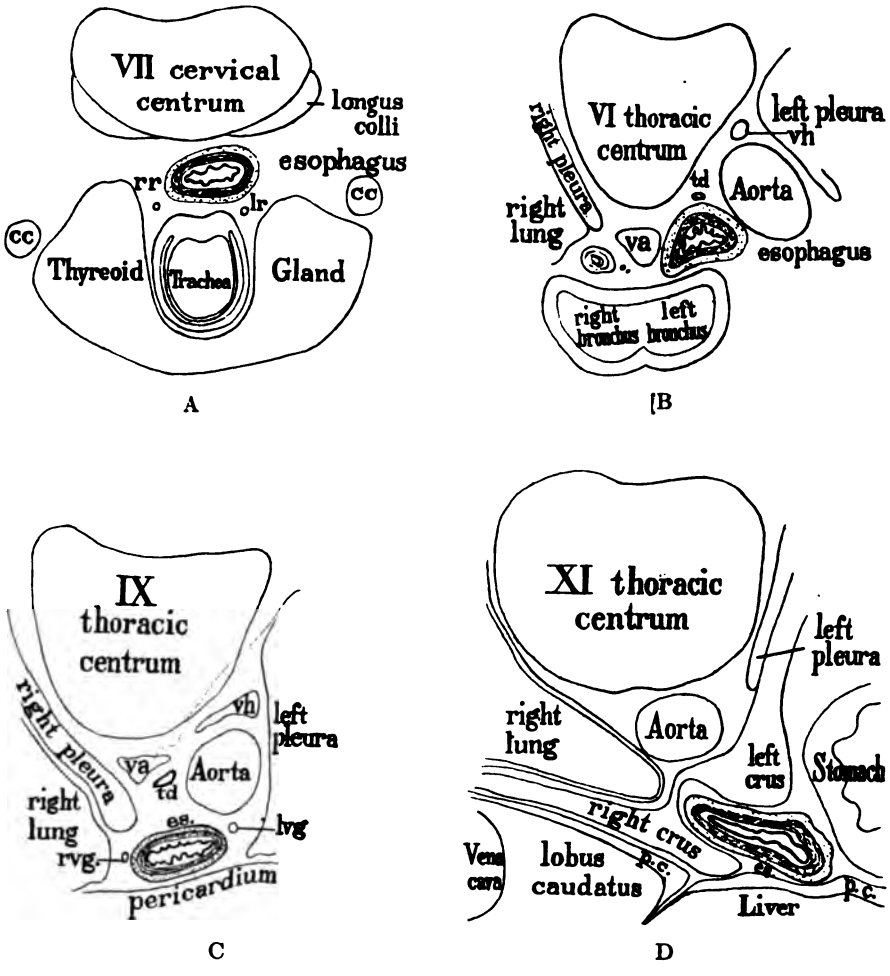
Thoracic portion.—The esophagus descends in the thorax through the superior and the posterior mediastina. In the *superior mediastinum* its anterior relations are the trachea, with the deep cardiac plexus in front of its bifurcation, the left subclavian and carotid arteries crossing its left border obliquely, the left recurrent nerve, and the arch of the aorta. To the *left* are the left carotid and subclavian arteries, the end of the arch of the aorta, and the left pleural sac. To the *right* it is in relation with the right vagus nerve and the right pleural sac. *Posteriorly*, it rests upon the vertebral column, the left longus colli muscle, and it overlaps the thoracic duct. As it enters the *posterior mediastinum* it passes behind the bifurcation of the trachea (or left bronchus) and the right pulmonary artery, resting posteriorly on the vertebral column and thoracic duct. In the posterior mediastinum it has *anteriorly* the pericardium, which separates it from the left atrium and a portion of the diaphragm; *posteriorly* it rests upon the vertebral column, accessory hemiazygos and hemiazygos veins, the right aortic intercostal arteries, the thoracic duct, and the descending aorta. To the *right* is the right pleural sac, the vena azygos, which it partly overlaps, and below, the thoracic duct. To the *left* in the upper part is the descending thoracic aorta, and, below, the left pleural sac is separated from it by a little loose areolar tissue. It is surrounded by the esophageal plexus formed by the vagus nerves, and, as they emerge from the lower part of the plexus, the left vagus lies in front of the esophagus and the right vagus behind.

Abdominal portion.—The terminal portion of the esophagus lies below the diaphragm, at the level of the xiphoid process, just to the left of the midline. *Anteriorly* is the left lobe of the liver; to the *left* the left lobe of the liver and the fundus of the stomach; to the *right* the

caudate (Spigelian) lobe of the liver; and *posteriorly* the decussating fibers of the crura of the diaphragm and the left inferior phrenic artery. The abdominal portion is very short, usually not more than 2 cm. (⅘ inch) in length (see figs. 914D, 929). According to Lerche, this portion of the esophagus is comparable to the pyloric canal of the stomach.

Structure.—The thick-walled esophagus presents the four typical tunics of the alimentary canal (fig. 915). The mucosa and the muscularis are the most important, the submucosa and the external adventitia being accessory layers. The **mucosa** (fig. 915) is thick and strong, of reddish color in its upper portion and more grayish below. It presents deep longitudinal folds to allow for distention, and when empty the lumen is therefore stellate in cross-sections. The lamina propria presents numerous papillæ, and is limited externally by a *muscularis mucosæ*. This is a comparatively thick layer (except at the upper end) and is composed of smooth muscle-fibers, longitudinally arranged.

FIG. 914.—CROSS SECTIONS SHOWING THE RELATIONS OF THE ESOPHAGUS AT VARIOUS LEVELS.



The submucosa (fig. 915) is a thick, very loose fibrous layer connecting the mucosa with the muscularis. It contains numerous vessels and nerves, and *mucous glands*. The latter [gl. œsophageæ] are of the racemose type, like those of the mouth, and are variable in number. There are also two sets of *superficial* glands, confined to the lamina propria, and resembling the fundus glands of the stomach. The upper set (Rüdinger-Schaffer glands) are found in 70 per cent. of cases, occurring above the level of the fifth tracheal ring. The lower set (esophageal cardiac glands) form a ring around the esophagus just above the cardiac aperture. A few small lymph nodes also occur in the sunmucosa, often around the ducts of the mucous glands.

The **muscularis** (fig. 915) is a thick reddish tunic with two distinct layers, approximately equal in thickness. The fibers of the *inner* layer are arranged circularly and are continuous with the inferior constrictor above and with the oblique fibers of the stomach below. The fibers of the *outer* layer are longitudinal and commence above as three flattened bands: a strong anterior band arising from the ridge on the back of the cricoid cartilage, and two lateral bands blending with the fibers of the stylopharyngeus and the pharyngopalatine. These all unite into a continuous layer which below passes into the muscular coat of the stomach. The upper third or fourth of the esophagus contains exclusively cross-striated muscle fibers, like those

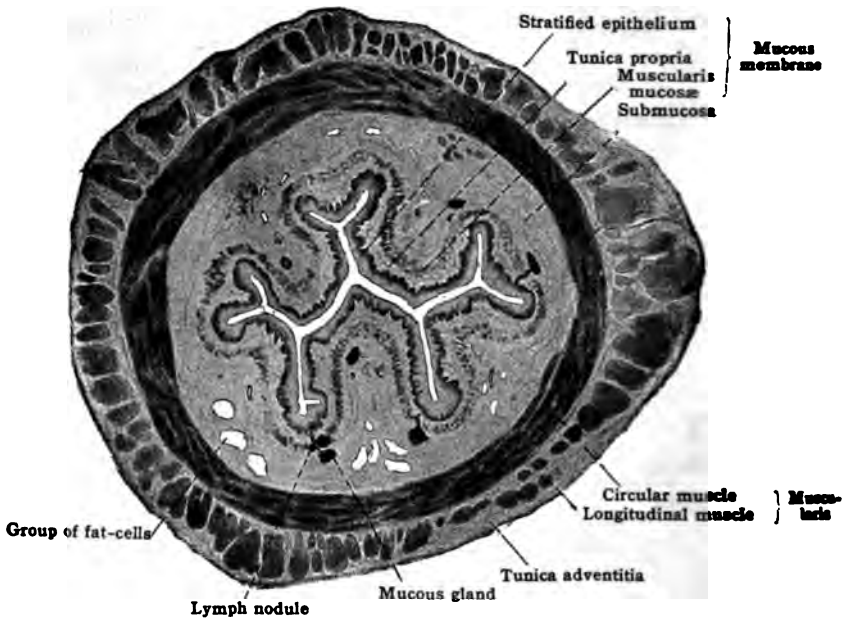
of the pharynx. Below this, there is a zone of intermingled smooth and cross-striated fibers. The lower half of the esophagus muscle is usually composed exclusively of smooth fibers.

Around the muscular coat is a thin loose *fibrous* layer [tunica adventitia] connecting the esophagus with neighboring structures.

Vessels and nerves.—The *arterial* supply of the esophagus is derived from the inferior thyroid, the esophageal branches of the aorta, the intercostals, the inferior phrenic and the left gastric arteries. Branches pierce the wall and supply the various coats. The *veins* accompany the arteries. They form on the outer surface of the esophagus a venous plexus opening into the gastric coronary vein below and the azygos and thyroid veins above (thus establishing a communication between portal and systemic veins). There are also numerous *lymphatics* in the esophagus arising chiefly in the mucosa and draining into the lower deep cervical, posterior mediastinal and superior gastric nodes (fig. 612). The *nerves* form two sympathetic plexuses, the submucous and the myenteric, from which the walls are supplied as will be described later for the stomach and intestine. Branches are received from the sympathetics, and from the vagus, including the recurrent nerve.

Development.—The embryonic esophagus is at first relatively very short, but lengthens rapidly in connection with the descent of the stomach. It is relatively longer in the newborn than in the adult (Kolster). The upper end is still high in children, corresponding to the

FIG. 915.—TRANSVERSE SECTION OF THE UPPER THIRD OF THE HUMAN ESOPHAGUS. X 5. (Lewis and Stöhr.)



higher vertebral level of the larynx. The primary longitudinal folds of the mucosa appear early (third month) and at the lower end seem to participate in the rotation of the stomach (F. P. Johnson). The superficial esophageal glands appear about the fourth month (78 mm.), the deep glands at 240 mm. (Johnson). Of the muscular layers, the circular appears first (at about 10 mm.), the longitudinal slightly later (17 mm.).

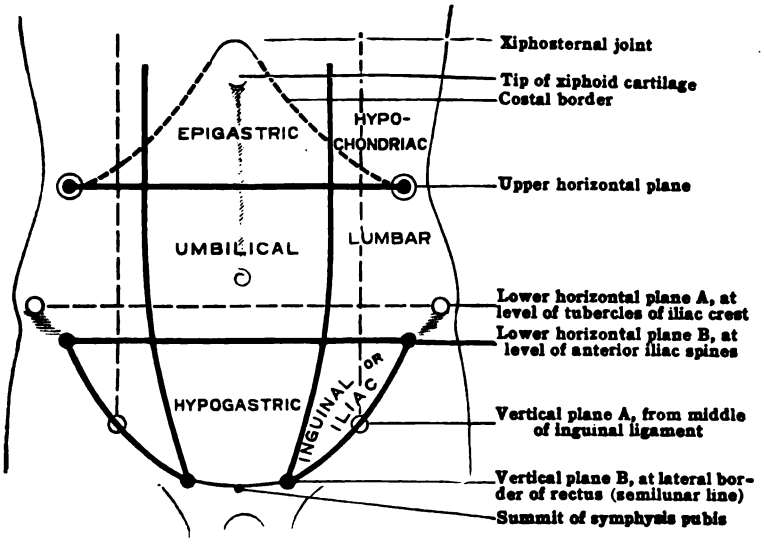
Variations.—Usually a bundle of smooth *muscle* connects the esophagus with the left bronchus [m. bronchoœsophageus], and another similarly with the left mediastinal pleura [m. pleuroœsophageus]. More rarely there are similar bands connecting with the trachea, pericardium, etc. Pouch-like *dilatations* of the esophagus may occur, especially in the upper part of its posterior wall or at the lower end. According to C. R. Robinson, the latter include (1) *ampulla phrenica*, just above the diaphragm, and (2) *antrum cardiacum*, in the abdominal portion of the esophagus. *Diverticula* also occur, some of which may be derived from the embryonic vacuolization of the epithelium previously described, as may likewise the occasional congenital *atresia*. Abnormal *strictures* of the esophagus may occur, oftenest at the upper end, at the left bronchus, and near the lower end. Finally, the esophagus may be in part either double or absent, and may communicate by fistula with the trachea.

Comparative.—The *length* of the esophagus varies with the length of the neck, being shortest in fishes and amphibia where the esophagus is not well marked off from the stomach. *Mucous glands* are absent in fishes, but occur typically in all higher forms. They are found best developed toward the lower end of the esophagus, except in mammals, where they are usually more numerous at the upper end. *Dilatations* may occur normally, as in the crop of birds, which is richly supplied with glands. The *musculature* of the esophagus is primitively entirely smooth (Oppel) as found in amphibia, reptiles and birds. A secondary replacement by cross-striated muscle is found to a variable extent in the majority of mammals and fishes.

THE ABDOMEN

The **abdomen** proper consists of that part of the body situated between the thorax and the pelvis. It is limited *above* by the diaphragm; *below*, by the brim of the true pelvis; *behind*, by the vertebral column, diaphragm, quadratus lumborum and psoas muscles, and by the posterior portions of the ilia. *At the sides* it is limited by the anterior parts of the ilia and the posterior portions of the muscles which compose the anterior abdominal wall, viz., the transversus, internal oblique, and external oblique. *In front*, besides these muscles, there are the two recti and pyramidales muscles. External to the peritoneum the abdomen is lined by a special layer of fascia. In a broad sense, the term abdomen is also used to include the pelvis, with which it is directly continuous below.

FIG. 916.—DIAGRAM OF THE ABDOMINAL REGIONS. Old method in broken lines. New method (BNA) in solid lines.

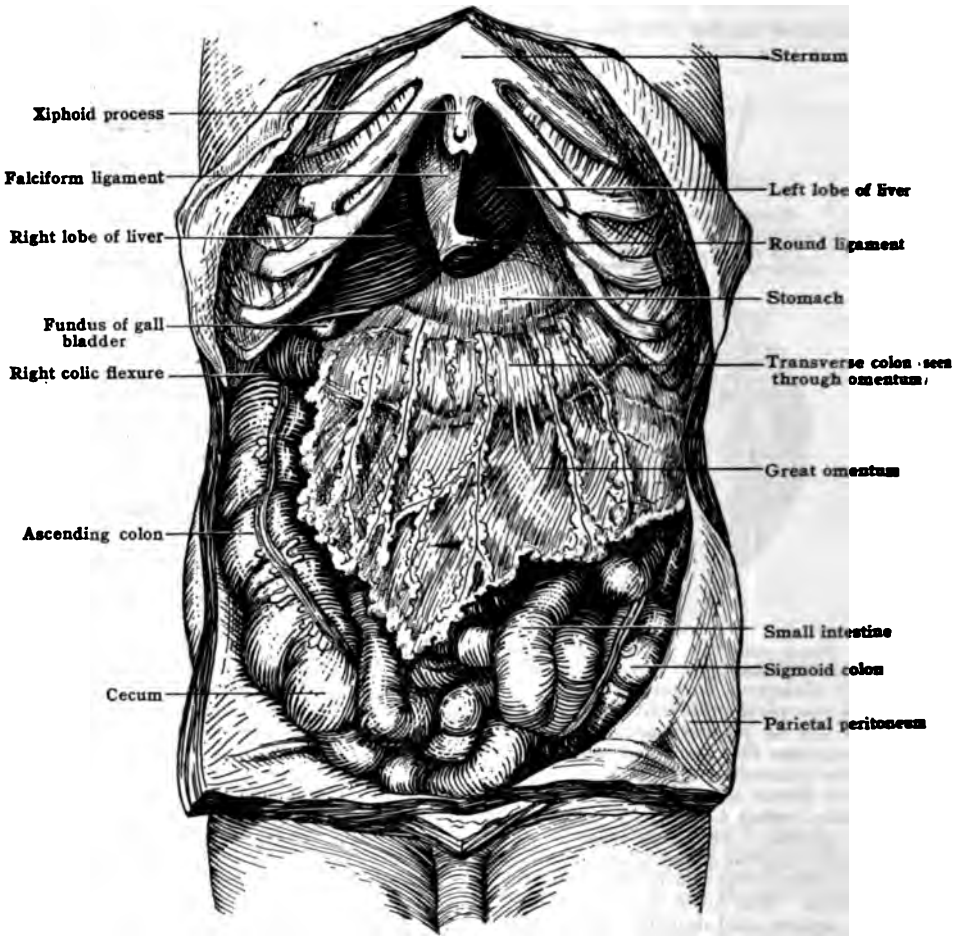


Abdominal regions.—For purposes of description, it is customary to divide the ventral surface of the abdomen, by means of two horizontal and two vertical lines, into nine regions (fig. 916). A complete uniformity in the use of the boundary lines marking these regional subdivisions has not as yet been attained, although the variations in the schemes used are not marked as concerns the main features. It should be borne in mind that the boundary lines used should be converted into planes, carried through the whole depth of the abdomen and defined on the dorsal as well as the ventral surface, and that the relations defined can only be approximate, owing to the wide range of the physiological variation in the position of the abdominal contents. The nine regions or subdivisions may be outlined as follows: The upper horizontal line or plane passes through the lowest point of the tenth costal cartilages. This lies about 3 to 5 cm. above the umbilicus, and passes dorsally through the second or third lumbar vertebra. The lower horizontal line and plane pass through the level of the anterior superior iliac spines, and dorsally about 2.5 cm. below the promontory of the sacrum. Cunningham has proposed that this line be passed through the tuberculum cristæ, therefore in a plane slightly higher than the interspinous plane. For the longitudinal lines and planes it has been customary to run vertical lines parallel with the midbody line or midsagittal plane, and from the middle of the inguinal ligaments. The preferable plan (BNA) is to use for this purpose the semilunar lines (lateral margin of the rectus muscle) extending from the costal border to the pubic spine on each side. This leaves on each side an inguinal region which includes the whole of the inguinal canal. The boundary lines here indicated may be made intelligible by a reference to fig. 916. The regions thus outlined are known as the right and left hypochondriac and epigastric regions, found above the upper horizontal line; the right and left lumbar and the umbilical regions, found between the two horizontal lines; the right and left inguinal or iliac and the hypogastric regions, found below the lower horizontal lines. According to the BNA, the lumbar regions are termed 'lateral abdominal.'

On laying open an abdomen from the front, the general form of the space is seen to be an irregular hexagon, the sides of which are formed as follows (fig. 917): The upper two by the margins of the costal cartilages with the xiphoid cartilage between; the two lateral sides by the edges of the lateral boundary; and the two lower by the two inguinal ligaments which extend to the pubes.

In this irregular hexagon the following organs can be observed without disarranging their normal position. Above, on the right side, under the costal cartilages, can be seen the liver, which extends from the right across the median line to a point below the left costal cartilages. Below the liver, and lying to the left side, can be seen the anterior surface of the stomach; from the lower border of the stomach the omentum extends downward, and shining through it can be seen the middle part of the transverse colon. On each side and below the irregularly folded omentum are exposed the coils of the small intestine; in the right iliac fossa appears a part of the cecum, above which extends the ascending colon; and on the left side part of the descending colon and the sigmoid colon.

FIG. 917.—ABDOMINAL VISCERA IN SITU. Ventral view. (After Toldt.)



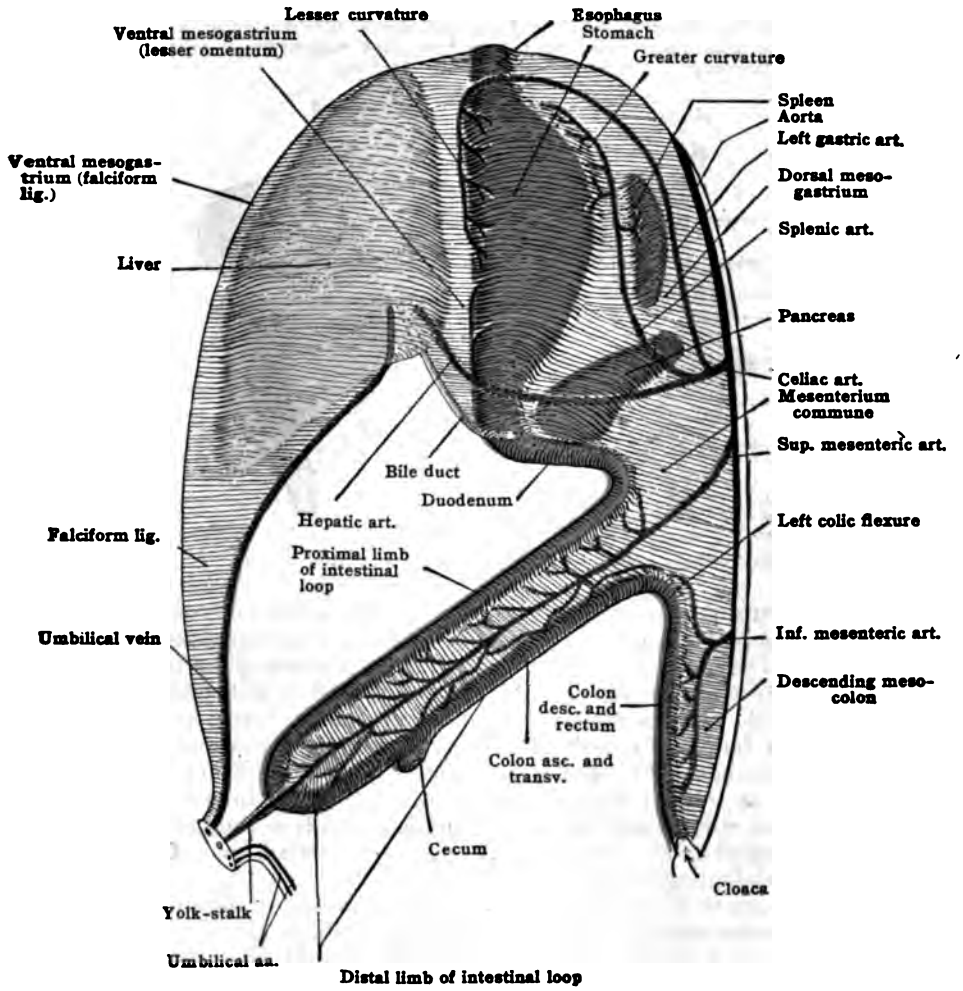
To the left of the stomach and under cover of the lower ribs of the left side the edge of the spleen may possibly be observed; and just below the edge of the liver, and about the level of the tip of the right ninth rib, the gall-bladder may be seen. The vertex of the urinary bladder may be noticed just behind the symphysis pubis and in the median line.

General morphogenesis.—Before taking up the various individual organs included in the abdominal and pelvic portions of the alimentary canal, a brief consideration of their general morphology is desirable. The primitive canal, as already described in the early embryo (in the section on DEVELOPMENTAL ANATOMY), and as found in the lower vertebrates is a comparatively straight, simple tube extending ventral to the body axis from mouth to anus. In the abdominal region (and primitively throughout the whole trunk), the canal lies within the body-cavity (celom), which is lined by parietal peritoneum. The visceral peritoneum is reflected from the mid-dorsal line as a double layer, the *primitive dorsal mesentery* [mesenterium commune] (fig. 918), within which the vessels and nerves pass to the walls of the canal. Within the dorsal mesentery are also the spleen and pancreas. In the anterior (upper) region of the abdomen there is also a similar primitive *ventral* mesentery, which contains the liver.

The relations above mentioned are indicated diagrammatically in fig. 918, which represents a comparatively early stage in the development of the intestinal canal. The liver is already somewhat separated from the diaphragm (with which it was intimately associated in the earlier septum transversum) (fig. 963). The ventral mesentery persists in the form of (1) the lesser omentum, connecting the stomach with the liver; and (2) the falciform ligament, connecting the liver with the ventral body-wall.

The stomach undergoes a rotation on its longitudinal axis so that its anterior border (lesser curvature) is turned to the right, and its posterior border (greater curvature) to the left (fig. 919). Thus the dorsal mesentery of the stomach [mesogastrium] bulges to the left and forward, carrying with it the spleen and pancreas. The portion of the mesentery corresponding to the pancreas, and that from the spleen to the root of the mesentery, become fused with the posterior

FIG. 918.—DIAGRAMMATIC REPRESENTATION OF AN EARLY STAGE IN THE DEVELOPMENT OF THE ALIMENTARY CANAL AND THE PERITONEUM (side view). (After Sobotta-McMurrich.)



body-wall (fig. 921). The portion of the primitive mesogastrium between the stomach and spleen persists as the *gastrolienal ligament*, while the lower portion arches forward and downward as an extensive fold, the *great omentum* (figs. 919, 922). The upper part of the dorsal layer of the great omentum soon fuses with the transverse mesocolon; while the lower portion later fuses with the adjacent ventral layer of the great omentum, converting this part of the omentum into the single apron-like fold found in postnatal life (figs. 917, 919, 922). The part of the great omentum extending from the greater curvature to the transverse colon forms the adult *gastrocolic ligament*. The portion of the peritoneal cavity left behind the stomach is termed the *bursa omentalis*, or lesser sac, the remainder of the peritoneal cavity being the greater sac. The two sacs communicate through the *epiploic foramen* (of Winslow) (figs. 921–923).

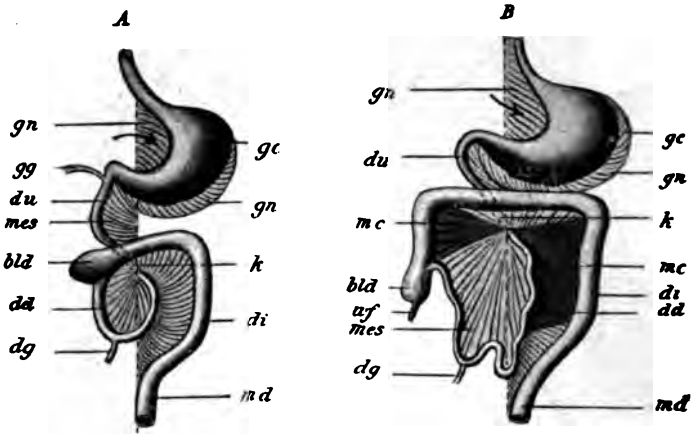
Along with the pancreas, the duodenum becomes adherent to the posterior wall. The remainder of the intestine forms a loop (figs. 918, 919), the upper portion of which forms the jejuno-ileum, the lower portion the large intestine. The intestinal loop rotates around the superior mesenteric artery as an axis, so that the cecum and ascending colon are carried over to the

right side of the body-cavity, where (with the corresponding portion of the primitive mesentery) they become adherent to the posterior body-wall (figs. 919, 920). The mesentery of the transverse colon persists (though becoming fused partly with the great omentum). The descending colon becomes displaced to the left side, and (together with its mesentery) becomes adherent to the posterior wall of the abdomen (figs. 919B, 920, 1016). The mesentery of the sigmoid colon usually persists (in part), while that of the rectum is obliterated. Through these modifications of the peritoneum, and through unequal growth in the different regions, the simple primitive intestinal tube is transformed into the complicated adult canal. The details of the transformation will be more fully discussed later, with the development of the intestines.

Under certain rare conditions, the developmental process is modified so as to produce *situs inversus*, which may be partial or complete, involving both thoracic and abdominal viscera. In this case, the viscera are transposed, the right and left sides being reversed.

FIG. 919.—DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE GREAT OMENTUM, MESENTERY, ETC. A, EARLIER STAGE; B, LATER STAGE. Areas of obliteration in green.

bld, Cecum; ji, small intestine; ys, yolk-stalk; dc, descending colon; du, duodenum; g, greater curvature of the stomach; bd, bile duct; dm, dorsal mesogastrium; k, point where the loops of the intestine cross; mc, mesocolon; md, rectum; mes, mesentery; v, vermiform appendix. (McMurrich after Hertwig.)



THE PERITONEUM

The **peritoneum** is a serous membrane which lines the body-cavity from the diaphragm to the pelvic floor, and invests or covers to a varying extent the viscera of the abdominal cavity. It may be regarded as a closed sac, the inner surface of which is smooth, while the outer surface is rough and is attached to the tissues which surround it. In the male subject the peritoneum forms actually a closed sac; but in the female its wall exhibits two minute apertures, which correspond to the openings of the Fallopian tubes. That part which lines the walls of the abdomen is termed the *parietal* peritoneum; that which is reflected on to the viscera is the *visceral* peritoneum. The disposition of the peritoneum in the adult may be studied first by noting its arrangement as made evident in transverse sections of the abdomen at certain levels.

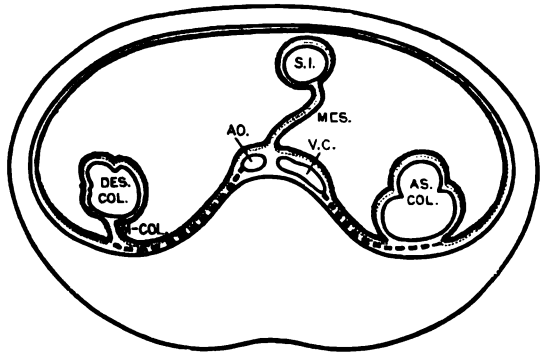
The first section to be described shows the peritoneum in its simplest relations. This is a transverse section through the body, at about the level of the fourth lumbar vertebra, and therefore about the site of the umbilicus (fig. 920).

Starting on the inner surface of the anterior abdominal wall, the peritoneum covers the transversalis fascia and the anterior abdominal muscles; then, passing to the left, it lines the side of the abdomen, until it reaches the descending colon. This it covers, as a rule, in front and on the sides, though occasionally it forms a mesocolon. Then it passes over the bodies of the vertebræ with the large vessels upon them, and leaves the back of the abdomen to run forward and enclose the small intestine, returning again to the spine. The two peritoneal layers thus form the mesentery, having between them a middle layer [lamina mesenterii propria] containing the terminal branches of the superior mesenteric vessels. It then passes over the right half of the posterior abdominal wall, covering the ascending colon in front and at the sides only (unless there be a mesocolon), and then passes on to the side and front of the abdomen to the point from which it was first traced. The areas of peritoneal reflection from the posterior wall are well shown in fig. 923.

In tracing the peritoneum in a transverse section of the body opposite the stomach (fig. 921), on a level about the first lumbar vertebra, its course becomes more complicated and difficult to follow.

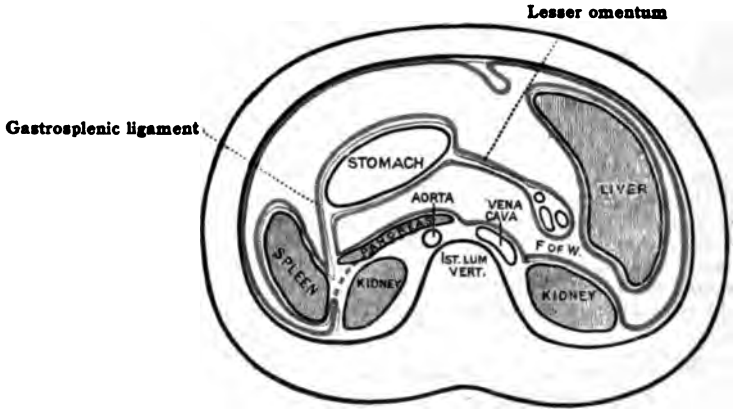
In the section already described, the peritoneum as a simple closed sac can be readily understood; but at the level now exposed the serous membrane has been so introverted (in connection with the primitive rotation of the stomach, as explained above) that there appear to be two sacs, one leading from the other, and known respectively as the greater and the lesser sac of the peritoneum. The *lesser sac* [bursa omentalis] is situated behind the stomach, so that on first opening the abdomen no trace of it is seen. The vestibule [vestibulum bursæ omentalis] is the portion which lies just behind the lesser omentum, and communicates with the greater sac through the epiploic foramen. The extensions upward and downward will be described later, in the sagittal section. In general, the lesser sac is limited *anteriorly* by the liver, stomach, and omenta; *posteriorly* by the posterior abdominal wall and the transverse mesocolon (fig. 922).

FIG. 920.—DIAGRAM OF CROSS-SECTION OF THE ABDOMEN, SHOWING THE PERITONEAL RELATIONS AT THE LEVEL OF THE UMBILICUS. *AO*, Aorta. *AS. COL.*, Ascending colon. *DES. COL.*, Descending colon. *MES.*, Mesentery. *M. COL.*, Descending mesocolon. *SI*, Small intestine. *V.C.*, Vena cava inferior. Peritoneum red; dotted lines indicate sites of obliteration.



The **epiploic foramen (foramen of Winslow)** (figs. 921–924) is situated just below the liver, and will readily admit one or two fingers. It is bounded *superiorly* by the caudate lobe of the liver; *inferiorly*, by the duodenum (pars superior); *posteriorly*, by the vena cava; and *anteriorly* by the right margin of the lesser omentum, containing the root-structures of the liver (bile-ducts, hepatic artery and portal vein). Through the epiploic foramen, the greater sac communicates with the lesser sac which extends to the left.

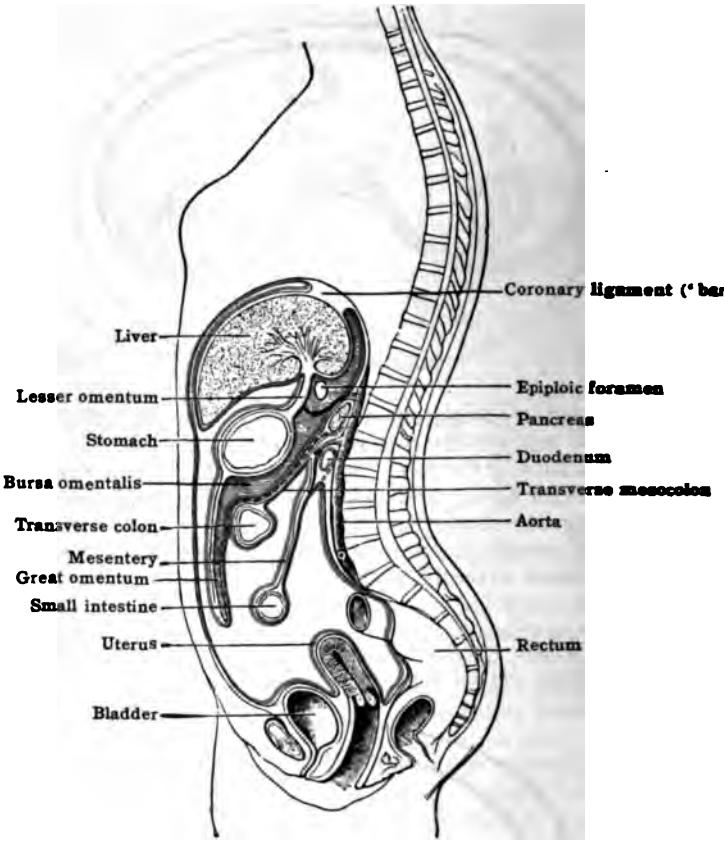
FIG. 921.—DIAGRAM OF CROSS-SECTION OF THE ABDOMEN, SHOWING THE PERITONEAL RELATIONS AT THE LEVEL OF THE EPIPLOIC FORAMEN OF WINSLOW (F. of W.). Peritoneum of greater sac in red; lesser sac (bursa) blue; dotted lines indicate site of obliteration.



The peritoneum may now be traced in a transverse section of the body at the level of the epiploic foramen (fig. 921), which is opposite the last thoracic or first lumbar vertebra. Starting at the front of the abdomen and going to the right, the peritoneum is seen to line the anterior abdominal wall, and to be reflected over the falciform ligament and ligamentum teres. It then passes backward over the side of the abdomen, and covers the front of the right kidney. It then extends on to the vena cava, when it enters the epiploic foramen and becomes a part of the lesser sac. Then it passes along the lesser sac, over the aorta and pancreas, which separate it from the vertebral column. Next it approaches the gastric surface of the spleen near the

hilus. Here it meets with another layer of peritoneum, and helps to form the phrenolienal and gastrolienal ligaments. Leaving the spleen, it passes forward and runs to the greater curvature of the stomach, forming the inner layer of the gastrolienal ligament. It now continues to the right, covering the posterior surface of the stomach, and leaves its medial border (lesser curvature) to form the posterior layer of the lesser omentum. At a slightly higher level, it passes upward and to the right to the liver. In this transverse section it merely passes around the right (free) margin of the lesser omentum, where it forms the anterior boundary of the epiploic foramen. Here it encloses the hepatic vessels and bile-duct, continuing to the left as the anterior layer of the lesser omentum. Then passing to the left it again reaches the stomach at the lesser curvature, and extends over its anterior surface to the greater curvature. It thus forms the outer layer of the gastrolienal ligament, and once more reaches the spleen. It now

FIG. 922.—DIAGRAM OF A SAGITTAL SECTION OF THE TRUNK, SHOWING THE RELATIONS OF THE PERITONEUM. Greater sac in red; lesser sac (bursa) in blue; dotted lines indicate sites of obliteration.



passes around the spleen to the region behind the hilus, where it is reflected on to the left kidney as the outer layer of the phrenolienal (lienorenal) ligament (fig. 922). The peritoneum then passes along the side and front of the abdomen to the point from which it started. In this section the liver is so divided as to appear separated from all connection with the other viscera and the abdominal wall, and to be surrounded by peritoneum. At a slightly higher level its peritoneum would join with that of the lesser omentum medially and that of the falciform ligament anteriorly, in accordance with the location of the liver in the primitive ventral mesogastrium (fig. 918).

The course of the peritoneum in a **longitudinal (midsagittal) section of the body** will now be considered (fig. 922).

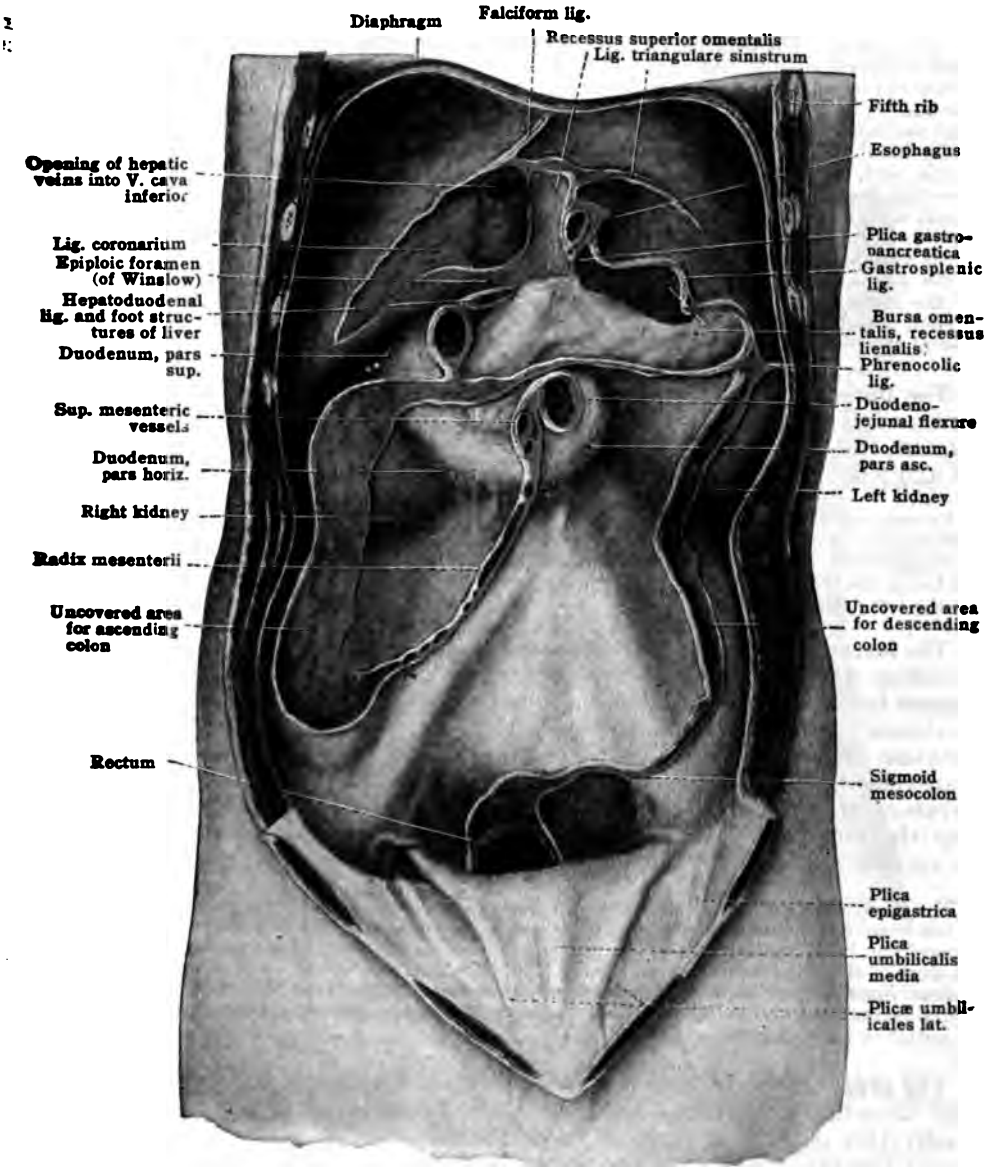
Starting at the umbilicus and passing downward, the peritoneum is seen to line the anterior abdominal wall. For some little way above the pubis the peritoneum is loosely connected with the abdominal wall, and the distended bladder can detach it to some extent.

On reaching the pubis it is reflected onto the upper surface of the bladder, covering it in the male as far back as the base of the trigone. Thence it is reflected onto the rectum, which it covers in front and at the sides on its upper part. Between the bladder and rectum it forms in the male the **rectovesical pouch** [excavatio rectovesicalis]. In the female the peritoneum is reflected from the bladder onto the uterus, forming the *vesicouterine* pouch [excavatio vesicouterina]. It then covers the uterus and extends so far down in the pelvis as to pass over the

[illegible]per part of the vagina behind. Thence it extends to the rectum as the **rectouterine pouch,** or [illegible]ch of Douglas [excavatio rectouterina; cavum Douglasi]. The membrane has now been [illegible]ced back to the posterior pelvic wall.

Following it upward, the sigmoid colon will be found to be completely covered by peri[illegible]neum, a mesocolon attaching the gut to the abdominal wall. A little higher up in the median line [illegible]e peritoneum passes forward, to enclose the small intestine, and, returning to the spinal column, [illegible]rms the mesentery (fig. 922). It now passes over the third part of the duodenum to the

FIG. 923.—REFLECTIONS OF THE PERITONEUM ON THE POSTERIOR ABDOMINAL WALL. (From Rauber-Kopsch, modified.)



pancreas, from which point it again passes forward to form the lower layer of the transverse mesocolon. It invests the transverse colon below and partly in front, and then leaves it to pass downward, forming the posterior layer of the great omentum. Then it returns and forms the anterior layer of the great omentum. Between the colon and stomach it forms the anterior layer of the gastrocolic ligament. On reaching the greater curvature of the stomach it goes over the anterior surface, and at the upper border (lesser curvature) forms the anterior layer of the lesser omentum, which extends between the stomach and the liver. It next invests the inferior surface of the liver in front of the porta hepatis (transverse fissure), and, turning over the anterior border of the liver, covers its upper surface. At the posterior part of the upper surface it leaves the liver and goes to the diaphragm, forming the anterior layer of the coronary

ligament. It covers the anterior part of the dome of the diaphragm, and, once more reaching the anterior abdominal wall, can be followed to the umbilicus, where the description began. This completes the boundary of the greater sac. On reference to the diagram (fig. 922) the student might be led to suppose that the two sacs are quite separate. This, of course, is not the case, since they communicate through the epiploic foramen (foramen of Winslow), as shown in the transverse section (fig. 921).

The peritoneum has been traced in this sagittal section only so far as it concerns the greater sac. It now remains to follow upon the same section (fig. 922) such part of the membrane as forms the **lesser sac** [bursa omentalis]. The peritoneum here will be seen to cover the posterior surface of the stomach; thence from the lesser curvature it runs upward to the liver, forming the posterior layer of the lesser omentum. It reaches the liver behind the porta hepatis, and covers the posterior surface of the caudate lobe. It is now reflected onto the diaphragm, forming the posterior layer of the coronary ligament. This portion of the bursa behind the liver is the *recessus superior*. The peritoneum now goes downward over the posterior part of the diaphragm to the vertebral column, separated from the latter by the great vessels. It passes over the anterior border of the pancreas, and then extends forward, to form the upper layer of the transverse mesocolon. It then covers the upper aspect of the transverse colon, and, descending, forms the inner layers of the great omentum. (The inner layers of the great omentum are usually fused in the adult, however, thus obliterating this portion of the lesser sac.) It then ascends, and, arriving at the greater curvature of the stomach, passes onto its posterior wall where the description began. The general relations of the greater and the lesser sac are also evident in fig. 923 showing the lines along which the parietal peritoneum is reflected from the posterior abdominal wall as the visceral peritoneum, forming the various mesenteries and covering the various abdominal organs.

The precise manner in which certain organs—such as the liver, the cecum, the duodenum, and the kidneys—are invested by peritoneum is described in the accounts of those viscera. To such accounts the reader is referred for a description of the many 'ligaments' (such as those of the bladder and liver) which are formed by the peritoneum.

The **bursa omentalis** (lesser sac) has already been described during development and as it appears in transverse and midsagittal sections of the adult (figs. 920, 921, 922). The general relations of the bursa are also well shown in figures 923 and 933.

The portion of the bursa behind the lesser omentum, adjacent to the epiploic foramen, is the *vestibulum bursæ omentalis*. From the vestibulum, the *recessus superior* extends upward behind the caudate lobe of the liver. A slight fold, the *plica gastropancreatica*, crosses the posterior wall below the recessus superior. The lower portion of the bursa is termed the *recessus inferior*, and the left extremity forms the *recessus lienalis*.

The **lesser omentum** [omentum minus] consists of a double layer of peritoneum extending between the stomach and the liver (figs. 922, 924, 933). If the two anterior layers of the great omentum are traced upward, they are seen to enclose the stomach, and then join together again at the lesser curvature to form the lesser omentum (fig. 922.) It is connected *above* with the liver at the porta hepatis (transverse fissure) and the fissure for the ductus venosus; ***below***, with the lesser curvature of the stomach and the first part of the duodenum; the *left* extremity joins the esophagus; the *right* border is free, forming the anterior boundary of the epiploic foramen (see fig. 924).

The lesser omentum is divided into two parts. The portion of the lesser omentum connecting the lesser curvature of the stomach with the fissure of the ductus venosus is the *gastrohepatic ligament* [lig. hepatogastricum]. The portion connecting the portal fissure of the liver with the first part of the duodenum, and enclosing the root-structures of the liver, is called the *hepatoduodenal ligament* [lig. hepatoduodenale]. Within this portion, near the right free border, are the root-structures of the liver; the bile-ducts on the right, the hepatic artery on the left, and the portal vein behind them (figs. 921, 933).

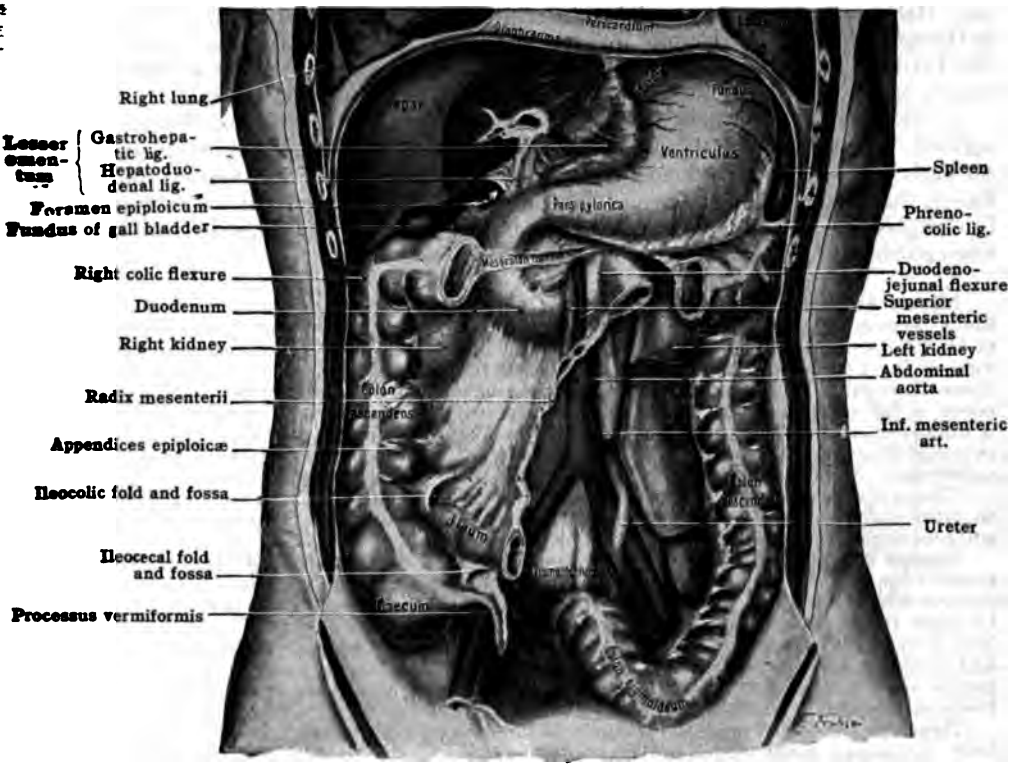
The great omentum.—As is evident from its development (figs. 919, 922), the great omentum [omentum majus] is formed of four layers of peritoneum, though usually this is quite impossible to demonstrate in an adult, the inner layers having become adherent. The great omentum acts as an apron (fig. 917), protecting the intestines and providing them with a heat-economizing covering of fat. It is nearly quadrilateral in shape, and is variable in extent. In fig. 922 the great omentum is shown to be connected with the greater curvature of the stomach, on the one hand, and the transverse colon, on the other. Originally it extended backward above the transverse colon and mesocolon to the posterior abdominal wall. The line along which it fuses with the transverse colon and mesocolon during development is shown in fig. 922. Superiorly it forms the gastrocolic and is continuous with the gastrolienal, and (on the left) with the phrenocolic ligaments (fig. 924).

Mr. Lockwood has made some investigations on the lengths of the transverse mesocolon and great omentum in thirty-three cases. In twenty, under the age of forty-five, only one subject had a great omentum long enough to be drawn beyond the pubic tubercle; in five, the omentum reached as far as the pubes. In the cases beyond forty-five years it was the exception rather than the rule to find an omentum which could not be pulled beyond the lower limits of the peritoneal cavity.

The **gastrosplenic ligament** [lig. gastrolienale] connects the left portion of the stomach with the spleen, continuing the layers of peritoneum which enclose the stomach (fig. 921). It is continuous below with the great omentum.

The **gastrocolic ligament** [lig. gastrocolicum] is that portion of the great omentum extending from the greater curvature of the stomach to the transverse colon. Superiorly it is continuous with the gastrosplenic ligament, and on the left it terminates in the phrenocolic ligament (figs. 922, 924).

FIG. 924.—ABDOMINAL VISCERA, ANTERIOR VIEW, AFTER REMOVAL OF A PART OF THE LIVER AND INTESTINES. (Rauber-Kopsch.)



The gastrophrenic and phrenocolic ligaments.—As the peritoneum passes from the diaphragm to the stomach it forms a small fold just to the left of the esophagus. This is the gastrophrenic ligament. A strong fold of the membrane also extends from the diaphragm (opposite the tenth and eleventh ribs) to the left colic (splenic) flexure, and is known as the phrenocolic (costocolic) ligament [lig. phrenicocolicum]. (See figs. 923, 924.)

Reflections of peritoneum.—The reflections of the peritoneum upon the posterior abdominal walls are well shown in fig. 923. As previously explained under 'general morphogenesis' (p. 1173), they represent chiefly transposed attachments of the primitive dorsal mesentery. The *coronary ligament* (with enclosed (bare area') represents a persistent portion of the primitive intimate relation between the liver and diaphragm (septum transversum). From the coronary ligament, the *falciform ligament* extends forward and downward along the anterior abdominal wall to the umbilicus, representing a portion of the primitive ventral mesentery (figs. 918, 923).

Upon the lower part of the anterior abdominal wall appear certain peritoneal folds of variable size (fig. 923). In the midline, the *plica umbilicalis media*

extends from the umbilicus to the apex of the bladder, and encloses the urachus (median umbilical ligament), a fibrous remnant of the embryonic allantoic stalk. Lateral to this median fold there appears on each side the *plica umbilicalis lateralis*, enclosing a fibrous cord (lateral umbilical ligament) representing the obliterated umbilical artery of prenatal life. Still more laterally on each side is a small inconstant fold, the *plica epigastrica*, enclosing the inferior epigastric vessels.

Corresponding to these peritoneal folds, three peritoneal fossæ appear on each side in the lower part of the abdominal wall. Between the median and the lateral umbilical plica is the *fovea supravesicalis*. Between the lateral umbilical and the epigastric plica is the *fovea inguinalis medialis*; while just lateral to the epigastric plica is the *fovea inguinalis lateralis*. The lateral inguinal fovea corresponds to the abdominal inguinal ring. For the relations of these peritoneal fossæ to hernia, see section XIV, p. 1397.

Within the pelvis, the peritoneal floor presents on each side two or three distinct transverse folds, forming corresponding fossæ. The most anterior is a somewhat variable fold, the *transverse vesical fold* [plica vesicalis transversa] (fig. 1041) extending from the bladder laterally to the pelvic wall. Behind this is the *ureteral fold* in the male, or the *broad ligament* in the female. Posterior to the bladder is the *sacrogenital fold* in the male (enclosing a part of the seminal vesicle and ductus deferens), and the *sacrouterine* fold in the female.

Corresponding to these folds, three pairs of pelvic peritoneal fossæ are described. Beside the bladder, and anterior to the ureteral fold (or broad ligament) on each side, is the *paravesical fossa* crossed by the transverse vesical fold. Between the ureteral fold (or broad ligament) and the sacrogenital (or sacrouterine) fold is the *paragenital fossa*, communicating with that of the opposite side through the *excavatio rectovesicalis* (rectouterine).

Minute anatomy.—The peritoneum, like all serous membranes, consists of two layers: a lining layer composed of simple squamous epithelium (mesothelium), and an underlying layer of fibrous connective tissue. The latter is highly elastic, and denser in the parietal than in the visceral layer. It often contains fat. In mesenteries and similar structures, the connective tissue is usually very scanty, except surrounding the vessels and nerves. Ruptures often occur in the omenta, which thus become fenestrated in structure. The visceral peritoneum is usually closely attached to the organs for which it forms the outer serous tunic, but the parietal peritoneum is often loosely attached to the adjacent wall by a fatty subserous layer [tela subserosa]. Smooth muscle occurs frequently in the various peritoneal folds.

The peritoneal cavity contains normally a very slight amount of watery fluid, which serves to lubricate the smooth peritoneal surface and thus to eliminate friction between adjacent surfaces during the movements of the alimentary canal.

Vessels and nerves.—The peritoneum is in general somewhat sparsely supplied with *blood-vessels* from various adjacent trunks. *Lymph-vessels* also occur, but they probably do not connect directly with the peritoneal cavity by stomata (as is found in the frog and as claimed by some to occur in man). They communicate with the lymphatics of neighboring regions. The *nerves* are also comparatively scarce. They are partly of sympathetic origin (vasomotor), and partly sensory nerves from the intercostal (7th to 12th) and lumbar nerves. The sensory nerves are more frequent in the parietal peritoneum and end in the connective tissue, either freely or in special end-organs (varying from simple end-bulbs to Pacinian corpuscles).

Development.—The principal features in the development of the peritoneum have already been mentioned in the section on DEVELOPMENTAL ANATOMY (p. 53) and in the remarks on the general morphogenesis of the peritoneum (p. 1172). Further details will be included later under the development of the intestine, etc.

Variations.—Variations in the form and relations of the peritoneum are exceedingly common, and are frequently of developmental origin. Variations in the form and relations of the various abdominal organs necessarily involve corresponding modifications in the peritoneum. The diaphragm may be incompletely formed, leaving the peritoneal cavity in communication with the pleural, or more rarely the pericardial cavity. The primitive dorsal mesentery of the intestine [mesenterium commune] may rarely persist unmodified, or the various secondary changes may be inhibited at any stage. Thus the stomach or the intestinal loop may fail, either wholly or partly, to undergo their characteristic rotations. The adhesions of the various mesenteries may be incomplete, or they may be more extensive than usual. For example, the sigmoid mesocolon may be more or less completely obliterated by adhesion, and numerous unusual peritoneal pockets or ligamentous bands may be formed in this way in various localities. Variations thus due to extensions of the normal developmental process are sometimes difficult to distinguish from pathological adhesions caused by peritonitis.

Comparative.—As previously mentioned, the cœlom or primitive body-cavity in vertebrates extends throughout the trunk region. In the cyclostomata, this primitive relation persists, the pericardial cavity remaining in communication with the general body-cavity. In all higher forms, however, the pericardial cavity becomes entirely separated. In amphibia the lungs lie in the general (pleuroperitoneal) body-cavity; in the reptiles and birds, they are partially separated; but a complete separation of the pleural cavities with the formation of the definite diaphragm occurs generally only in mammals.

ormation in the peritoneal cavity of a complete dorsal mesentery, and an incomplete
ıesentery (in the hepatic region) is typical for all classes of vertebrates. Slight modi-
in the form of the mesenteries depend chiefly upon the different degrees of complexity
:velopment of the various parts of the intestinal tract. The marked changes asso-
ith extensive secondary adhesions of the primitive peritoneal structures are found
›ng the higher mammalia, especially in man.

THE STOMACH

stomach [ventriculus; gaster] is a dilation of the alimentary canal suc-
the esophagus. In the stomach the food is mixed with the gastric juice
luced to a viscid, pulpy liquid, the chyme [chymus], which undergoes a
amount of digestion and absorption before passing into the duodenum.
stomach (figs. 924, 929) is a somewhat J-shaped sac located in the upper
: of the abdominal cavity. It presents a *body* [corpus ventriculi], with

25.—DIAGRAM OF THE PARTS OF THE
ɔMACH, ACCORDING TO FORSSELL.

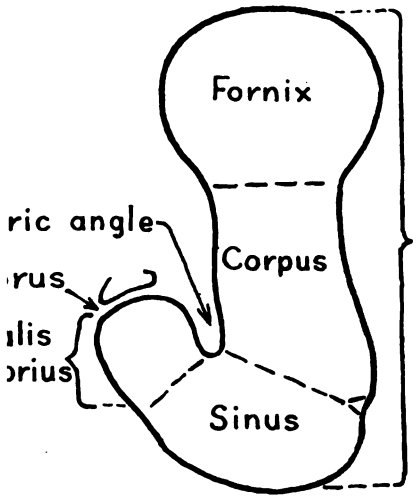
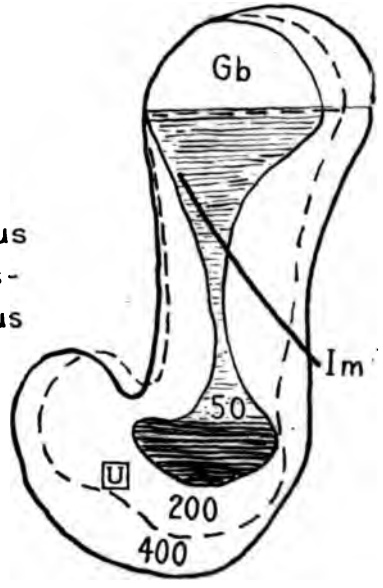


FIG. 926.—CHANGES IN THE FORM OF THE STOMACH. (Forssell.) Outlines as shown by the Röntgen-rays during upright posture after ingestion of 50, 200 and 400 cc. of Bi-meal. Gb, gas bubble; U, umbilicus; Im, infracostal margin.



·ged upper end or *fundus*, on the right side of which is the *cardia*, the aper-
nmunicating with the esophagus. The body of the stomach is extremely
: in form, as will be explained later, but is in general divisible into a more
:d upper two-thirds, the *cardiac portion* [pars cardiaca], which is nearly
, and a more constricted lower third, the *pyloric portion* [pars pylorica],
urves toward the right. The junction of the cardiac and pyloric portions
he *gastric angle*. The pyloric portion presents a variable dilation, the
pylori, succeeded by a short constricted *pyloric canal* (Jonnesco) (fig.
At the lower end of this canal the *pylorus* forms the aperture leading into
denum, and contains a thick sphincter derived from the circular fibers of
scular layer. The stomach has two borders and two surfaces. The
border forms the *lesser curvature* [curvatura ventriculi minor], which is
: (except near the pylorus) and gives attachment to the lesser omentum.
teral (or lower) border forms the *greater curvautre* [curvatura ventriculi
which is convex, and gives attachment to the great omentum. The
res separate the *anterior surface* [paries anterior], which faces forward and
, from the *posterior surface* [paries posterior], which is placed backward
vnward.

result of careful and extensive researches upon the anatomy of the stomach, with
eference to the form of the living stomach shown by the Röntgen-rays, Forssell divides

the organ into *saccus digestorius* and *canalis egestorius* (fig. 925). The saccus is divided fornix, corpus and sinus. The sinus corresponds roughly to the antrum pylori above mentio The canalis egestorius is the constricted pyloric canal, whose primary function is to reg the passage of food from the digestive sac.

Form.—The form of the stomach varies especially with the amount of tents (fig. 926). When nearly empty it presents throughout a narrow, tul form, excepting in the region of the fundus (fornix). This region, which con the gas-bubble, remains somewhat distended even when the remainder o stomach is empty and contracted. When food is introduced, it fills succes the various portions of the stomach as shown in fig. 926, the antrum (sinus) filled first and the pyloric canal usually last.

FIG. 927.—RADIOGRAPH OF STOMACH, PARTLY FILLED; BODY IN UPRIGHT POSTU This form is most pronounced in individuals of hyposthenic type. Gas-bubble in (fornix) region. Duodenal antrum visible just above the pylorus in the midline. (Fro by Dr. R. W. Mills, Washington University Medical School.)

The J-shape is typical for the upright posture; but in the dorsal position the lower curvature of the stomach becomes elevated and r stricted, the fundus (fornix) more distended and displaced to the left, so tends to assume the 'cow-horn' form (fig. 928A), with the axis of the car tion more obliquely placed.

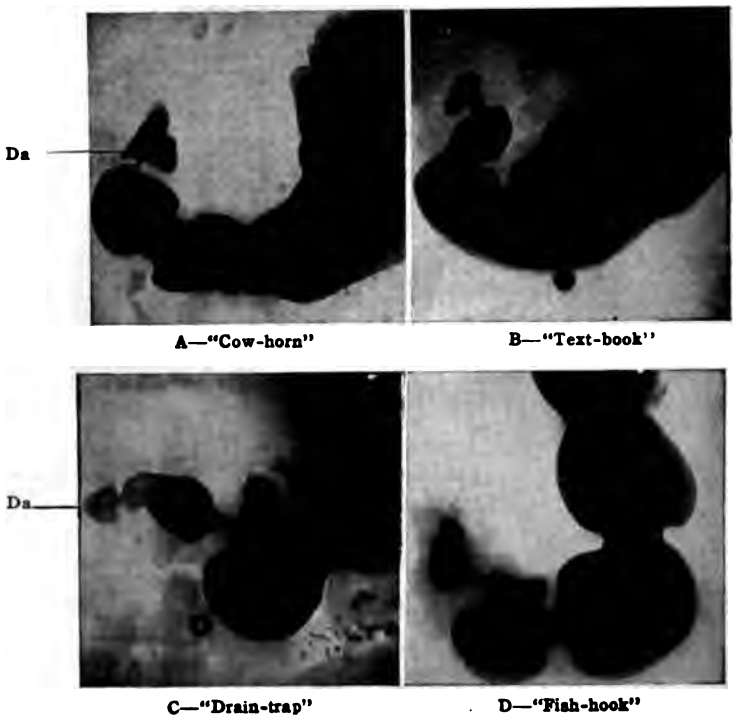
Dimensions.—The dimensions of the stomach are subject to great variation. Th the lesser curvature averages about 10 cm. (7.5 cm. to 15 cm.), and that of the greater is three or four times as great. The *diameter* varies exceedingly according to the contents. When nearly empty, it presents (excepting the fundus region) a narro form, with a diameter of about 4 or 5 cm. The diameter of the pylorus, which is the point in the alimentary canal below the esophagus, when constricted is only about 1.5 distensible, however, as hard bodies with diameters of 2 cm. or more may readily pas The average *capacity* of the stomach is about 1 liter, being subject to extreme variations. In the newborn, it averages about 30 cc. (see p. 44). The average we adult stomach is about 135 gm.

Position and relations of the stomach.—The position and relation stomach, like its form and structure, are subject to many variations in

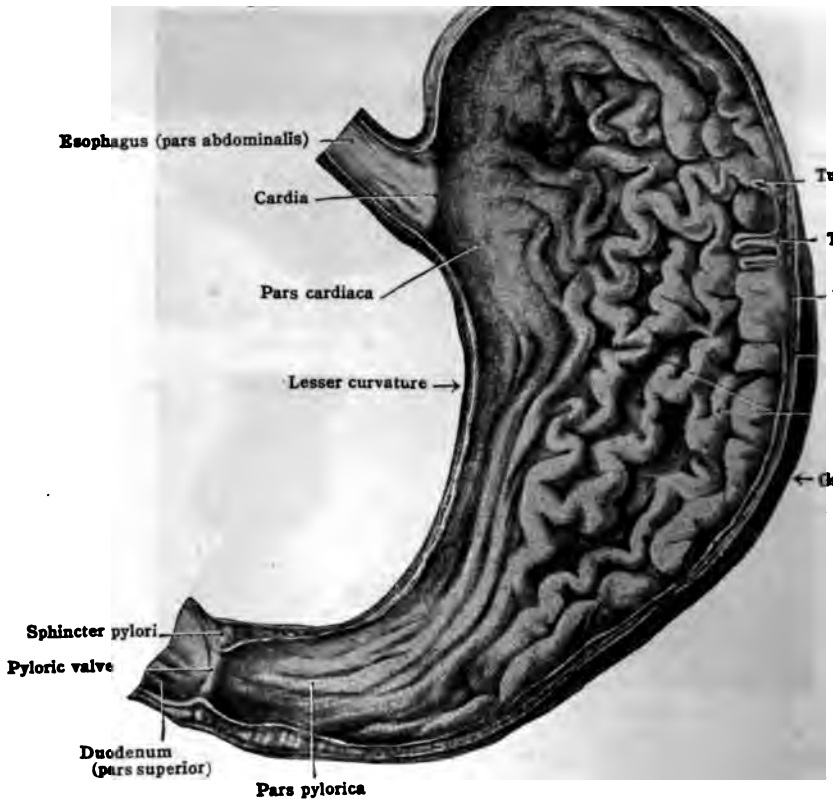
viduals, and in the same individual according to changes in physiological dition, distention, posture, etc. It is therefore difficult to give a concise and urate description. The stomach is fixed and supported chiefly by (1) the achment at the cardia; (2) the attachment at the pylorus; (3) the support of adjacent viscera, especially (in the upright posture) by the transverse meso- on and adjacent intestines, which in turn are supported by the musculature of abdominal wall.

Topography.—In *surface relation* (figs. 917, 926, 1095), the stomach lies within left hypochondriac and the epigastric regions. Often, however, especially hen distended, it extends into the umbilical and even the right hypochondriac egion. When empty, it usually lies almost entirely in the left half of the body,

FIG. 928.—DIFFERENT FORMS OF THE STOMACH AS SHOWN BY THE RŒNTGEN RAYS. (Cole.) Fundus not represented. DA, Duodenal antrum. Position of umbilicus shown in B and C.



with the pylorus near the midsagittal plane. When distended, the stomach is lengthened and the pylorus may be displaced 5 cm. or more to the right and downward. In distention, the stomach expands in all directions (fig. 926); it changes in form, as above mentioned, but does not appear to rotate as is sometimes stated. The position of the stomach, especially when distended, also varies appreciably according to the *posture* of the body. It sags downward when the body is in the upright position, so the lowest part may normally reach considerably below the umbilicus (fig. 927). The stomach is also displaced to the right or left when the body is placed on the corresponding side. The *cardia*, which is the most fixed point, lies on the left side of the 10th or 11th thoracic vertebra, and corresponds to a surface point behind the left 7th costal cartilage about 2.5 cm. from its sternal end. The *pylorus* usually lies opposite the right side of the 1st. lumbar vertebra, about midway between the xiphoid cartilage and umbilicus, (in Addison's 'transpyloric line,') when the body is recumbent; but descends to the 2d or 3d vertebra (rarely lower) in upright posture. The *fundus* corresponds to the left dome of the diaphragm (which separates it from the lung and heart), opposite the sixth sternocostal junction. The fundus necessarily rises and falls with respiratory movements of the diaphragm, the excursion ordinarily being from 2 to 6 cm. The variations in the position of the stomach according to types of physique, and the changes during peristalsis, are mentioned later.



Peritoneal relations.—The stomach is covered by peritoneum i
extent, except immediately along the curvatures and upon a small
space behind the cardiac orifice, where the viscus lies in direct c
the diaphragm, and possibly with the upper part of the left supra

3. 930.—Longitudinal Section of the Pyloric Portion of the Stomach. (Cunningham, Trans. Royal Soc. Edinb., vol. 45.)

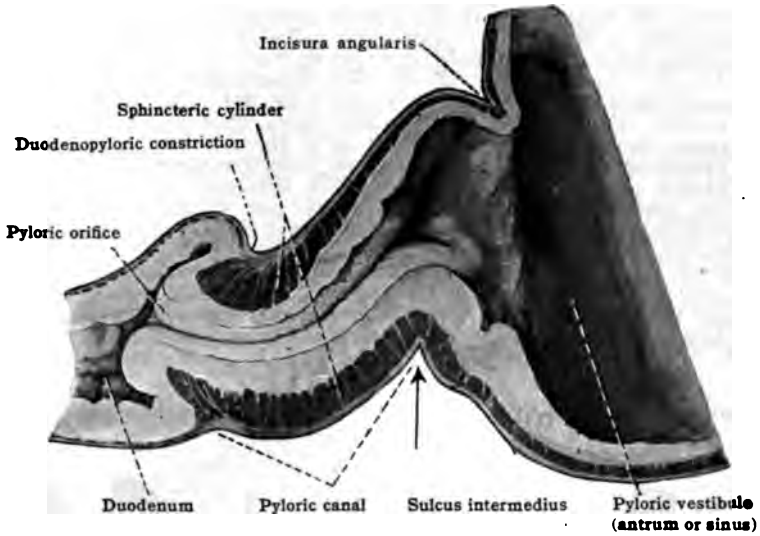
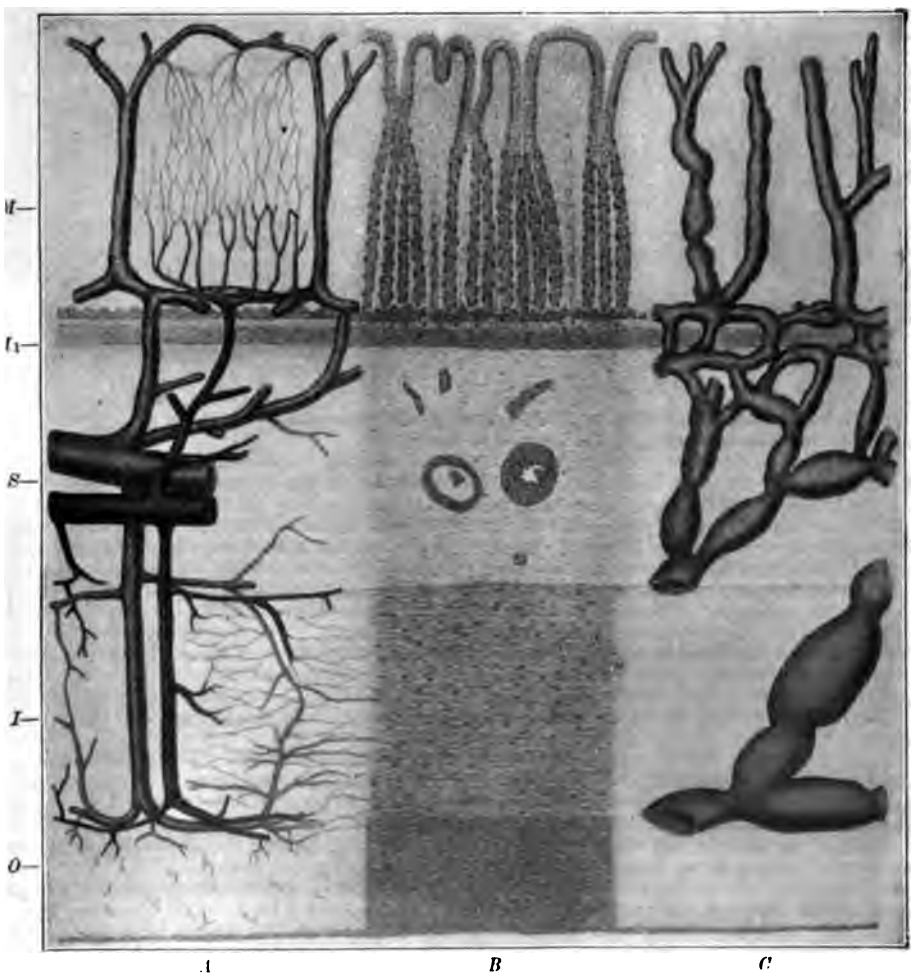


Fig. 931.—Diagrammatic Section of the Stomach Wall Showing (*A*.) The Blood sels, (*B*) the Tunics, and (*C*) the Lymphatics. *M*, Mucosa. M_1, Muscularis mucosæ. *S*, bmucosa. *I*, Circular, and *O*, longitudinal muscle-layer. (Szymonowicz, after Mall.)

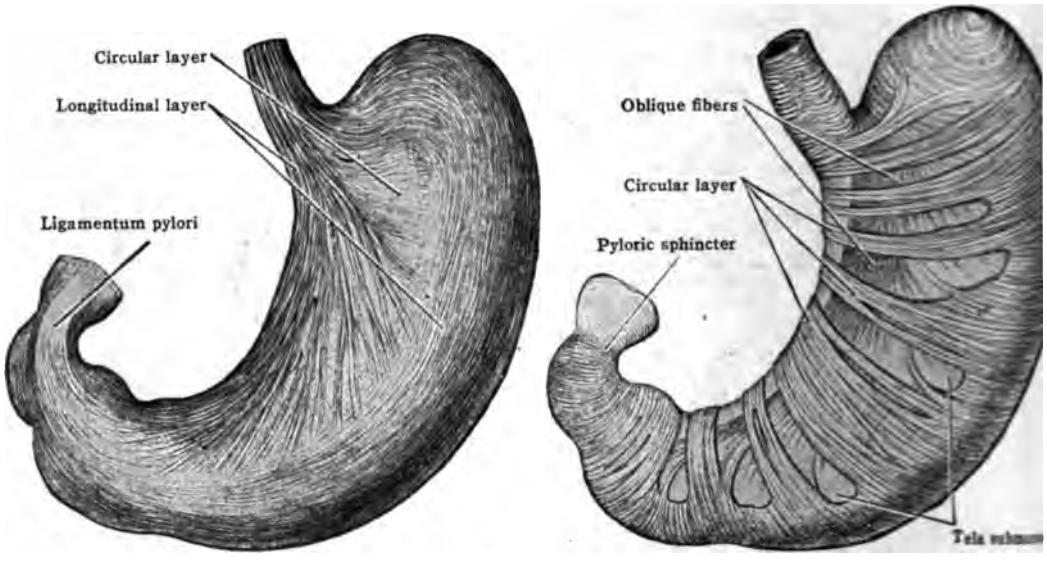


from cardia to pylorus. Upon closer examination the inner surface of the mucosa presents a somewhat warty ('mammilated') appearance, due to numerous small elevated areas (*areæ gastricæ*), varying from 1 to 6 mm. in diameter. When examined with a lens, it is seen that each area is beset with numerous small *pits* [foveolæ gastricæ], separated by partitions which sometimes (especially in the pyloric region) bear villus-like prolongations [plicæ villosæ]. The average number of foveolæ is estimated at 89 per sq. mm., or nearly 7 millions for the entire stomach (Toldt). Into each pit or foveola open 3 to 5 gastric glands.

The relations of the mucosa in section are shown in fig. 931. The thickness of the mucosa varies, being greatest (about 2 mm.) in the pyloric region, decreasing to less than .5 mm. in the cardiac region (Kölliker). The *lamina propria* is crowded with *glands*, of which three varieties are distinguished. The *cardiac* glands are tubuloracemose (chiefly mucous) glands occupying a narrow zone a few millimeters in width adjacent to the cardiac orifice. The *fundic* glands [gl. gastricæ propriæ] occupy the greater part of the stomach, and are simple (partly branched) tubular glands (fig. 931). The *pyloric* glands [gl. pyloricæ] are branched tubular glands occupying the pyloric region.

The interstitial tissue of the lamina propria contains diffuse lymphoid tissue and often small *lymph nodules*, especially in the pyloric region. The *muscularis mucosæ* is a thin sheet of smooth muscle lying just below the fundus of the glands and is composed of an inner circular and an outer longitudinal layer.

FIG. 932.—DISSECTIONS SHOWING THE MUSCULAR LAYERS OF THE STOMACH. (From Toldt's Atlas.)



The *tela submucosa* (fig. 931) is a very loose areolar, vascular layer which permits the wrinkling of the mucosa according to the degree of distention.

The *tunica muscularis* contains three layers of smooth muscle (fig. 932). The outer or *longitudinal* layer [stratum longitudinale] is thickest along the lesser curvature, and is continuous with the longitudinal fibers of the esophagus and the duodenum. On the anterior and posterior walls of the antrum pylori, the longitudinal fibers form thickened bands, the *ligamenta pylori*. The middle or *circular* layer [stratum circulare] is continuous with the circular fibers of esophagus and duodenum and surrounds the entire stomach. It is especially thickened in the region of the pyloric canal, at the lower end of which it forms a thickened ring-like band, the pyloric *sphincter* [m. sphincter pylori]. The inner or *oblique* layer [fibræ obliquæ] is composed of fibers continuous with the deepest circular fibers of the esophagus. They form an incomplete layer which encircles the fundus and passes obliquely downward around the body of the stomach toward the greater curvature. Forssell has shown the fundamental importance of the arrangement of the musculature in determining the form of the stomach under various conditions.

The external *tunica serosa* is formed by the peritoneum, and has the smooth shiny appearance and the structure typical for a serous membrane.

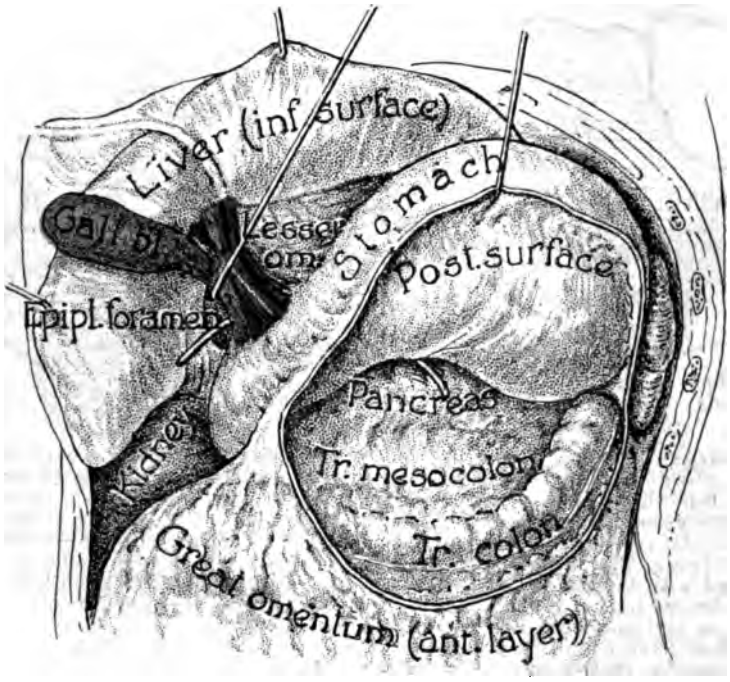
Blood-vessels.—The stomach receives its blood-supply from many branches. From the coeliac axis there is the left gastric artery, which runs along the lesser curve from left to right anastomosing with the right gastric branch of the hepatic. Along the greater curvature run the right and left gastroepiploic arteries, anastomosing at the middle of the border, the left being a branch of the splenic, the right a branch of the hepatic, through the gastroduodenal artery. The stomach also receives branches from the splenic (vasa brevia) at the fundus. The vascular arches along the curvatures of the stomach are comparable to those in the intestinal mesentery (Mall). The blood of the stomach is returned into the portal vein. The coronary vein and pyloric vein open separately into the portal vein; the right gastroepiploic vein opens into the superior mesenteric, the left into the splenic. The arrangement and distribution of the blood-

vessels within the stomach wall are illustrated in fig. 931. The rich capillary plexus in the mucosa supplies the glands and also serves for absorption.

Lymphatics.—There is a set of nodes lying along the lesser curvature and the pyloric portion of the greater curvature, and others at the pyloric and cardiac ends. These are entered by lymphatic vessels which, beginning in the mucous membrane (fig. 931), accompany all the gastric veins, but chiefly those of the lesser curvature. Vessels also accompany the left gastroepiploic veins to terminate in the splenic nodes (see fig. 617). On its way to the cisterna chyli, the gastric lymph passes through groups of nodes [lymphoglandulæ pancreaticolienales] situated above and behind the head and neck of the pancreas.

Nerves.—The nerves of the stomach are derived in part from the vagi (which form the motor fibers of the stomach), the right vagus descending on the posterior wall, and the left on the anterior wall. The stomach also receives sympathetic branches from the celiac plexus, following the arteries. Small ganglia occur along both vagus and sympathetic branches (Remak). The nerves join the gangliated plexuses, myenteric and submucous, in the wall of the stomach, from which branches are distributed to the muscularis and the mucosa as for the intestine in general.

FIG. 933.—GASTRIC REGION. Liver elevated and omental bursa opened by section along the gastrocolic ligament. Probe passed through the epiploic foramen. (After Hertzler.)



Development.—For development of the stomach, see DEVELOPMENTAL ANATOMY, p. 42; also *general morphogenesis*, p. 1173.

Glands.—According to Johnson, in an embryo of 16 mm., the lining epithelium shows the primitive foveolæ as pit-like depressions which become elongated, forming irregular anastomosing grooves, separated by villus-like projections. The pits multiply and deepen, and from their bottoms the gastric glands bud off (at 120 mm.).

Variations.—The great variability of the stomach in form, position and relations has already been repeatedly emphasized. These variations, which depend chiefly upon the factors already mentioned, have been observed both in properly fixed dead bodies and in the living body by means of the Rœntgen-rays.

Physique.—As has recently been emphasized by Mills, visceral form and topography in general, while subject to marked individual variations, are often closely correlated with certain types of general physique. The extremes are the hypersthenic type, with broad thorax and capacious upper abdomen, and the asthenic slender type, with narrow thorax and small upper abdomen. In the hypersthenic type, the stomach ('cow-horn' type) and transverse colon are placed high, scarcely reaching the umbilical zone; while in the asthenic type, both sag low, toward the pelvic region, approaching the condition known as *gastroptosis* (visceroptosis). Between these two extremes are the sthenic and hyposthenic types, in which the conditions are intermediate in character.

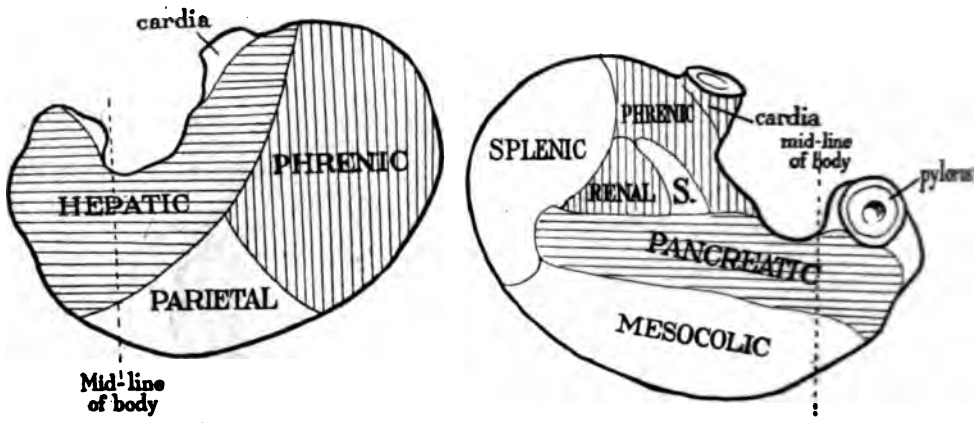
Peristalsis.—It would appear that many of the variations in the form of the stomach that have been described are merely various phases in the series of changes undergone by the stomach during the normal process of physiological digestion. Observations by various investigators upon the living stomach of man and lower animals (especially the radiographic study of the cat by Cannon) have shown that the pyloric portion during digestion usually presents

distinct peristaltic contractions passing pylorusward. Peristaltic contractions may also be observed to begin in the cardiac portion, although they are usually most distinct in the pyloric portion (fig. 928). In addition to the peristaltic waves, stationary constrictions may appear at various points, but all of these are transient in character (Forssell). The constrictions most frequently observed form the *incisura angularis* on the lesser curvature near the gastric angle and the *sulcus intermedius* on the greater curvature between the sinus (antrum) and the pyloric canal (figs. 925, 927, 928, 930).

In the earlier stages of gastric digestion the pylorus usually remains closed, but after a variable time it relaxes slightly (lumen about 3 mm. in diameter) at intervals, allowing the chyme to be spurted into the duodenum. This forms the 'duodenal antrum' seen with the *X*-rays (figs. 927, 928).

Thus the various constrictions often found in the formalin-hardened stomachs, and the pyloric antrum, appear to be merely transient phases of the digestive process. The 'hour-glass' stomach (fig. 927) is in most cases to be explained in this way; in others, however, the constriction is pathological and permanent. Various forms of abnormal lobulations and dilations also rarely occur.

FIG. 934.—DIAGRAM OF THE CONTACT AREAS OF THE STOMACH, ANTERIOR AND POSTERIOR VIEWS.



Comparative.—The primitive stomach is perhaps merely a receptacle for food, true digestive glands being absent in many of the fishes. The vertebrate stomach is a dilated sac of variable form, but is typically somewhat looped, with cardiac and pyloric segments. In *birds*, there is a peculiar arrangement, correlated with the absence of teeth. The stomach is divided into an anterior glandular *proventriculus*, and a posterior muscular *gizzard* with a horny lining serving to grind the food. The *mammalian* stomach is most variable in form and structure, which are correlated with the method and character of alimentation. The three kinds of glands, cardiac, fundic and pyloric, are typically present. In general, the stomach is larger and more complicated in herbivora than in carnivora. Instead of being a single sac, the stomach may be more or less divided into chambers. An incomplete division into cardiac and pyloric portions is so common that it may be considered typical. The most extreme specialization is found in the ruminants. In these the stomach has four chambers, the first two of which, however, are expansions of the esophagus.

THE SMALL INTESTINE

The **small intestine** [intestinum tenue] extends from the pylorus to the ileocecal orifice, and occupies most of the abdominal cavity below the liver and stomach. It is a cylindrical tube whose diameter decreases from about 4 cm. above to about 2.5 cm. at the lower end. Its *length*, when removed from the body and measured fresh, averages about 7 meters (23 ft.); but when formalin-hardened *in situ*, the length (which is probably nearer that during life) is only about 4 meters. The length does not seem to vary according to sex, height or weight in the adult.

The small intestine includes two main divisions, the ***duodenum*** and the *mesenteric small intestine*, the latter being further subdivided into ***jejunum*** and *ileum*.

THE DUODENUM

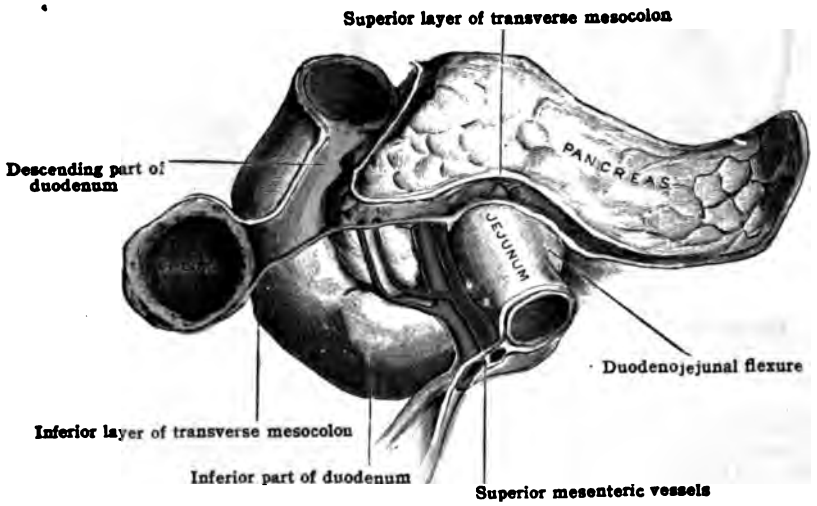
The **duodenum** is the first part of the small intestine, and is very definite in position and extent. It is firmly attached to the posterior abdominal wall, being almost entirely retroperitoneal. It is the widest part of the small intestine, the

average width being 4 cm. or more, and is also the shortest segment, being only about 25 cm. in length. In general, it is somewhat C-shaped, the concavity enclosing the head of the pancreas (figs. 935, 936).

Parts.—For convenience of description, the duodenum is divided into the following parts: (1) the *superior portion* [pars superior] which is short (5 cm. or less), leading from the pylorus and forming the *superior flexure* [flexura duodenalis superior]; (2) the *descending portion* [pars descendens], about 7 or 8 cm. in length, which receives the bile and pancreatic ducts and joins the inferior portion at the *inferior flexure* [flexura duodenalis inferior]; (3) the *inferior portion* [pars inferior], which is again subdivided into (a) *horizontal* portion [pars horizontalis], about 10 cm. long, which usually ascends slightly and passes gradually into (b) the *ascending portion* [pars ascendens], 2 or 3 cm. long, terminating in the *duodenojejunal flexure* [flexura duodenojejunalis].

Position and relations.—As shown in fig. 965, the duodenum usually lies chiefly in the lower part of the epigastric region, only the inferior (horizontal) portion extending into the umbilical region. All but the terminal (ascending) portion of the duodenum usually lies to the right of the midline.

FIG. 935.—THE DUODENUM AND PANCREAS, ANTERIOR VIEW.



The *superior* portion usually lies at the level of the first lumbar vertebra (or the disk below). It is covered anteriorly, and to a variable extent posteriorly, by a prolongation of the peritoneum from the corresponding surfaces of the stomach. It is somewhat freely movable. When the stomach is empty, it extends from the pylorus almost horizontally to the right and backward. As the stomach becomes distended, however, the pylorus is carried to the right and downward for a variable distance, and the position of the superior part of the duodenum is correspondingly altered.

Superiorly it is in contact with the liver (quadrate lobe) and the neck of the gall-bladder and forms the lower boundary of the epiploic foramen; *anteriorly*, with the liver and (often) the transverse colon; *inferiorly* and *posteriorly*, with the head of the pancreas below, and with the common bile-duct, hepatic vessels and portal vein above.

The second or *descending* portion of the duodenum extends along the right side of the first to the third lumbar vertebra. It is covered anterolaterally by peritoneum, excepting (usually) the area of contact with the transverse colon (fig. 935).

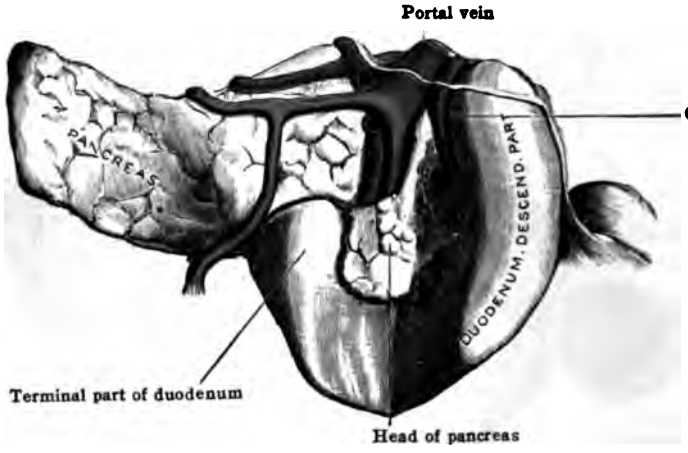
Posteriorly (fig. 965) it is in contact with the right kidney, ureter and renal vessels, and below with the psoas muscle. *Anteriorly* (fig. 924) it is crossed by the transverse colon (the layers of the transverse mesocolon usually separated by an area of direct contact); above the colon, it may be in contact with the gall-bladder, and below the colon with coils of small intestine. The *left or medial* aspect of the descending duodenum (figs. 935, 936) is in contact with the head of the pancreas, and some fibers from the muscular tunic are said to become intermingled with the pancreatic lobules. Somewhat posteriorly the common bile-duct descends between pancreas and duodenum, and enters the descending duodenum, in common with the pancreatic duct, about 10 cm. below the pylorus (fig. 964). The loop formed by the pancreaticoduodenal arteries also runs along the descending duodenum.

The third or *horizontal* portion of the duodenum usually crosses the body of the third lumbar vertebra, ascending slightly from the right to the left side (figs. 935, 936). It is covered anteriorly with peritoneum, excepting a small space where the superior mesenteric vessels enter the root of the mesentery.

Anteriorly it is further in contact with coils of small intestine; *superiorly*, with the head of the pancreas, and the inferior pancreaticoduodenal vessels; *posteriorly*, with the vena cava.

The terminal or *ascending* portion is covered anteriorly and laterally by peritoneum, and is in contact with coils of the ileum. To the *right* it is in relation with the head of the pancreas (processus uncinatus) and the superior mesenteric vessels; and *posteriorly* with the psoas muscle, aorta and left renal vessels. The *duodenojejunal flexure* usually lies opposite the second lumbar vertebra, and is in contact above with the inferior surface of the body of the pancreas, and the root of the transverse mesocolon.

FIG. 936.—THE DUODENUM AND PANCREAS, POSTERIOR VIEW.



The lower end of the duodenum is firmly fixed in its place by the *musculus suspensorius duodeni*, or *suspensory ligament of Treitz*. This name has been given to a fibromuscular band that contains, according to Treitz, smooth muscular fibers, and descends to the terminal part of the duodenum from the lumbar part of the diaphragm, passing to the left of the celiac artery and behind the pancreas. Lockwood points out that this band is continued on, after being inserted into the duodenum, between the layers of the mesentery. He suggests the name of the 'suspensory muscle of the duodenum and mesentery,' and says, 'together with the other constituents of the root of the mesentery, it forms a band of considerable strength, sufficient not only to support the weight of the intestines and mesentery, but also to resist the pressure of the descent of the diaphragm.'

In connection with this fourth portion of the duodenum, mention may be made of certain peritoneal folds and fossæ which are of some surgical interest by reason of their being associated with retroperitoneal hernia. Four such fossæ may be mentioned, namely, the superior and inferior duodenal fossæ, paraduodenal and the retroduodenal fossæ. On drawing the terminal portions of the duodenum to the right, two triangular folds of peritoneum, the superior and inferior duodenal folds, which extend from the wall of the duodenum to the posterior abdominal wall, may be observed (fig. 937). Each fold has a free edge. Beneath each fold is found a pouch of peritoneum, constituting the superior and inferior duodenal fossæ. The former, the smaller, opens downward and is present in about 50 per cent., while the latter opens upward and is present in about 75 per cent. of the subjects examined (Jonnesco). The paraduodenal fossa (fossa of Landzert) is not often found in the adult; when present, it is situated to the left of the last part of the duodenum, and is formed by a fold of peritoneum enclosing the inferior mesenteric vein. The retroduodenal fossa is a rare form extending from below upward behind the transverse portion of the duodenum.

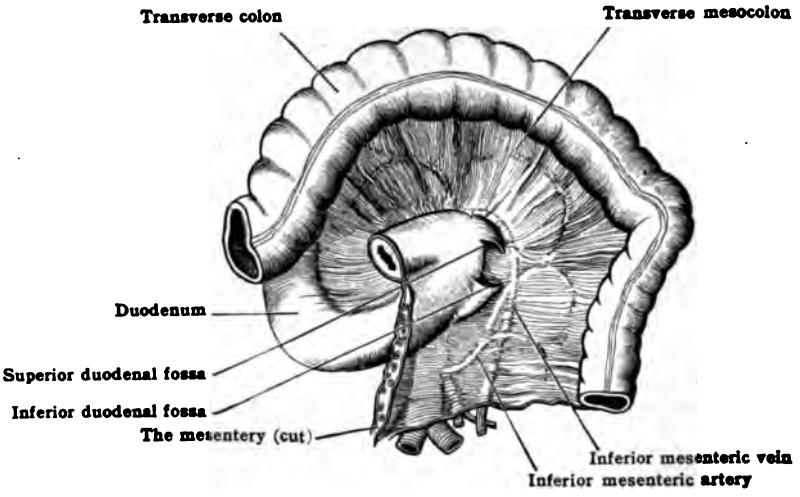
Interior of the duodenum.—The interior of the first part of the duodenum is smooth. The pylorus is often somewhat invaginated, much in the same way that the uterus projects into the vagina (fig. 930). On account of this arrangement (which renders the complete emptying of the cavity somewhat difficult) and also on account of the distensibility of this portion, it is frequently seen very distinctly in radiographic pictures as a 'cap' (antrum) at the pyloric end of the stomach during digestion (fig. 928). In the lower portions of the duodenum, transverse ridges or folds of the mucosa appear which are also apparent in radio-

graphs occasionally. On the medial wall of the descending portion, posteriorly, about half-way down, is a more or less distinct *longitudinal fold* [plica longitudinalis duodeni], toward the lower end of which is a small elevation, the bile papilla or *papilla major* [papilla duodeni], upon which open the common bile duct and the pancreatic duct, either separately or by a common aperture.

Above the papilla there is usually a prominent *hood-like fold* (valvula connivens), and below it a variable fold or *frenum* which forms a continuation of the plica longitudinalis. About 2 cm. (0.9 to 3.5 cm., Baldwin) above and in front of the bile papilla there is a second, smaller, rounded *papilla minor*, upon which the accessory pancreatic duct (of Santorini) ends.

The minute structure, vascular relations, development, variations, etc., of the duodenum will be considered later, with those of the small intestine as a whole.

FIG. 937.—DOUDENAL FOSSÆ AND FOLDS. Paraduodenal fossa is not shown. (After Cunningham.)



THE JEJUNUM AND ILEUM

The mesentric portion of the small intestine is divided into an upper portion, the *jejunum*, and a lower portion, the *ileum*. Although the character of the gut changes considerably from the upper end of the jejunum to the lower end of the ileum, the transition is gradual, and there is no definite line of demarcation. In general, the jejunum is somewhat wider, has thicker walls, is more vascular and has a more complicated mucosa. The lymphoid organs (Peyer's patches) are, however, characteristic of the ileum.

The **jejunum** begins at the duodenojejunal flexure. The first coil is variable in direction, being found (in order of frequency) as follows: (1) downward, forward and to the left; (2) directly forward and downward; (3) to the left, then downward; (4) forward and to the right (Harman). Some further details as to the position of the various succeeding coils are given later under the development of the intestine (figs. 942, 943). While there is considerable individual variation it is true in general that the coils of *jejunum* occupy the upper and left portion of the body cavity, while those of the *ileum* occupy the lower and right side, the lower portion lying in the pelvic cavity. The ileum finally passes upward over the pelvic brim to the right iliac fossa where it terminates in the ileocecal orifice.

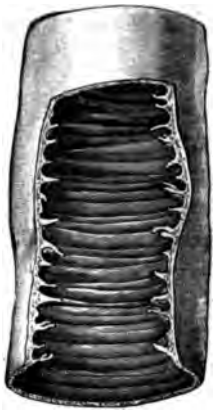
The **mesentery** [mesenterium] is a fan-shaped fold extending from the duodenojejunal flexure to the ileocecal junction. It is composed of a double layer of peritoneum which encloses and supports the jejunum and ileum and their vessels, connecting them with the abdominal wall. The *root* of the mesentery [radix mesenterii], or parietal attachment, is only about 15 cm. long, corresponding to a line extending from the duodenojejunal flexure obliquely downward and to the right, across the transverse duodenum, the great vessels and the vertebral column to the ileocecal junction (fig. 923).

The *visceral* attachment of the mesentery to the intestine, corresponding to the length of the jejunoileum, is nearly 7 meters long, and is thinner than at the root. The *width* of the

mesentery, measured from parietal to visceral attachment, varies somewhat in different parts of the canal, the average being 18 or 20 cm. (ranging from 15 to 22.5 cm.). It is narrow above (also at the lower end), but reaches its full width, about 30 cm., below its upper end. Between the two peritoneal layers of the mesentery is a third layer [lamina mesenterii propria] containing the superior mesenteric vessels (arteries, veins and lymphatics) with their branches and accompanying nerves, the small mesenteric lymph-nodes (50 to 100 in number), and a variable amount of fibroadipose connective tissue.

Minute anatomy.—The small intestine has the four typical layers—mucosa, submucosa, muscularis and serosa (fig. 941). They are, in general, somewhat similar in structure to those of the stomach (fig. 931), excepting the mucosa.

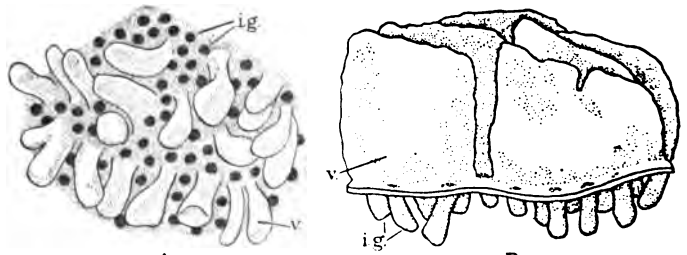
FIG. 938.—PORTION OF THE SMALL INTESTINE, LAID OPEN TO SHOW THE PLICÆ CIRCULARES. (Brinton.)



The **mucosa** is lined with a simple cylindrical epithelium, underneath which is a fibrous *lamina propria*, limited externally by a *muscularis mucosæ*, as in the stomach. The muscularis mucosæ sends slender muscular bundles upward into the villi. The inner surface of the mucosa (fig. 938) presents numerous coarse, closely set, transverse folds [*plicæ circulares*]. These are permenent, crescentic folds, involving both mucosa and submucosa, and usually extending one-half to two-thirds of the way around the lumen. They often branch and anastomose, sometimes forming circles or spirals. The largest exceed 5 cm. in length and 3 mm. in width. The plicæ circulares are absent from the first part of the duodenum, but become well marked in the descending portion. They are largest and best developed in the lower duodenum and upper half of the jejunum, below which they gradually become smaller (fig. 938) and disappear at the lower end of the ileum. The total number of plicæ in the adult is about 800 (Gundobin).

The digestive and absorptive surface of the small intestine is further greatly increased by multitudes of small processes, the *villi* (fig. 939), which give the mucosa a velvety appear-

FIG. 939.—*A*, SURFACE VIEW OF THE HARDENED MUCOSA OF THE SMALL INTESTINE. (After Kölliker.) *B*, SIDE VIEW OF A WAX RECONSTRUCTION OF THE EPITHELIUM IN THE HUMAN DUODENUM. (Huber.) *i.g.*, Intestinal gland. *v.*, Villus.

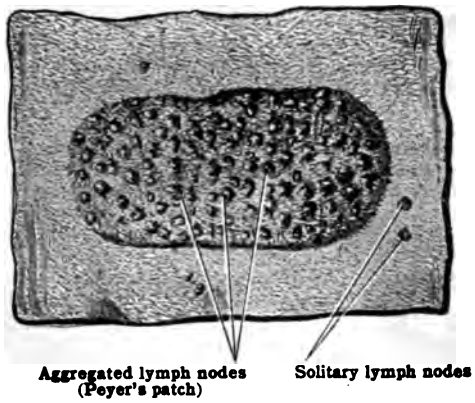


ance. They are largest (0.5 to 0.7 mm. in height) and most numerous in the duodenum and jejunum, where they are typically leaf-shaped, and gradually become smaller, scattered and conical in the ileum. The villi are much reduced in distention of the intestine, and may even be temporarily obliterated. Between the bases of the villi there open short, simple tubular glands—the crypts of Lieberkuehn [gl. intestinales]. In the duodenum there are found, in addition, the larger tubuloracemose glands of Brunner [gl. duodenales], which occupy the submucosa, and are especially numerous in the upper portion of the duodenum. They are purely mucous in character, according to Bensley.

Scattered over the whole of the mucous membrane of the small intestine are numerous small lymph-nodules, the larger of which extend into the submucosa; these are the so-called *solitary glands* [noduli lymphatici solitarii]. Aggregations of lymph-nodules, known as *Peyer's*

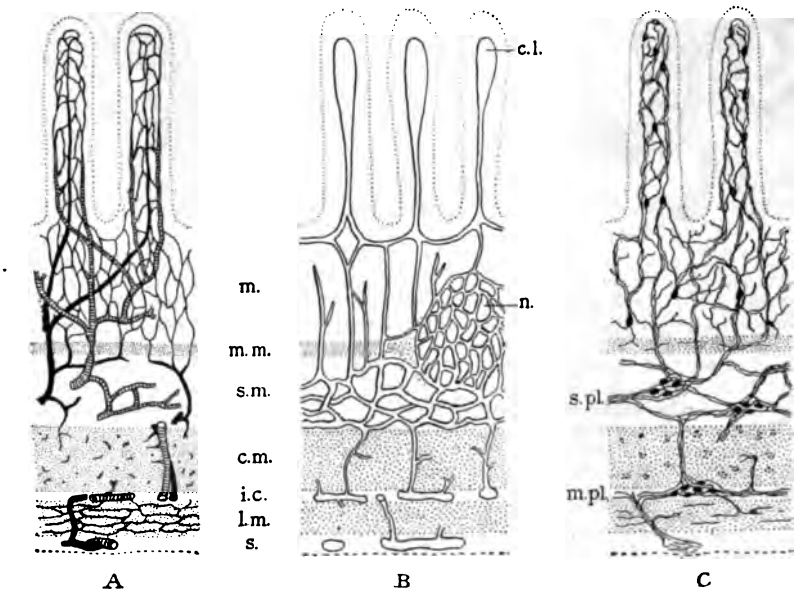
patches [noduli lymphatici aggregati], situated in the mucosa and submucosa, are found in the ileum especially toward the lower end (fig. 940). They are oval, from 1.2 to 7.5 cm. in length and about 1 to 2.5 cm. in breadth, and are placed in the long axis of the bowel along a line most remote from the mesentery. They are variable in number, the average being about 20 to 30.

FIG. 940.—SURFACE VIEW OF THE MUCOSA OF THE ILEUM, SHOWING AGGREGATED LYMPH-NODES (Peyer's Patch). (From Toldt's Atlas.)



The **submucosa** is in general a loose areolar layer containing vascular and sympathetic plexuses (fig. 941). The **muscularis** is composed of smooth muscle arranged in the two typical layers—a thinner, outer longitudinal and a thicker, inner circular— both of which become thinner toward the lower end of the ileum. The **serosa** is typical in structure, the squamous epithelial covering being absent in the retroperitoneal areas of the duodenum.

FIG. 941.—DIAGRAMS OF THE VASCULAR SUPPLY AND NERVES OF THE SMALL INTESTINE. *A*, Blood vessels; arteries as coarse black lines, capillaries as fine lines, veins shaded (after Mall). *B*, Lymphatics (after Mall). *C*, Nerves, based on Golgi preparations (after Cajal). *m*, Mucosa. *mm.*, Muscularis mucosæ. *s.m.*, Submucosa. *c.m.*, Circular muscle. *i.c.*, Intermuscular connective tissue. *l.m.*, Longitudinal muscle. *s*, Serosa. *c.l.*, Central lymphatic. *n.*, Nodule. *s.pl.*, Submucous plexus. *m.pl.*, Myenteric plexus. (Lewis and Stöhr.)



Blood-supply of the small intestine.—The small intestine receives its blood from the superior mesenteric artery and a branch coming indirectly from the hepatic, the superior pancreaticoduodenal. The superior mesenteric artery runs between the layers of the mesentery and gives off six or seven relatively large branches and a variable number of smaller branches. The first two or three of the larger branches divide into an ascending and a descending branch, which join above and below with the corresponding branches of the contiguous arteries, form-

ing thus a single row of arches. From about the beginning of the second quarter of the small intestine a second tier of arches, formed in a similar manner, is often noted, and below the middle of the jejunoileum more than two tiers of arches may be present, the complexity of the arches increasing, while the size of the vessels diminishes. From the convex border of the most distally placed arches there pass to the intestine straight branches, so-called **vasa recta**. Near the beginning of the jejunum these are numerous and large, and have a length of about 4 cm. and are quite regular. After the first third of the intestine is passed the vasa recta become smaller and shorter, and toward the lower end of the ileum they become short and irregular and are often less than 1 cm. in length (Dwight). The blood is returned by means of the superior mesenteric vein, which, with the splenic vein, forms the portal. The vascular arrangement in the intestinal wall is shown in fig. 941.

The **lymphatic** vessels form a continuous series, which is divided into two sets—viz., that of the mucous membrane and that of the muscular coat. The lymph-vessels of both sets form a copious plexus (fig. 941). The efferent lymphatic vessels form the so-called lacteals, which

FIG. 942.—MODEL SHOWING COURSE OF INTESTINE, MADE FROM SAME CADAVER FROM WHICH FIG. 943 WAS DRAWN. (Mall.)

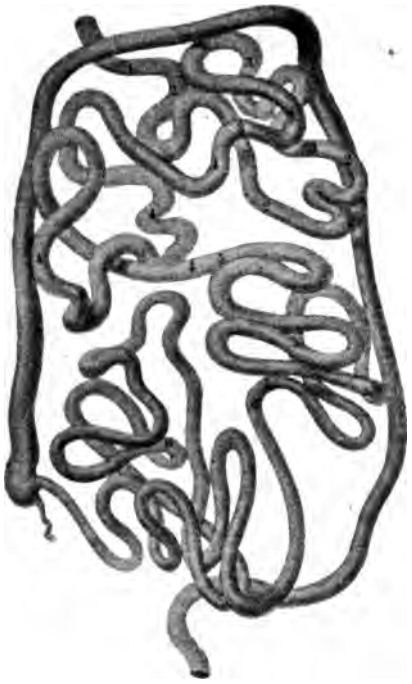
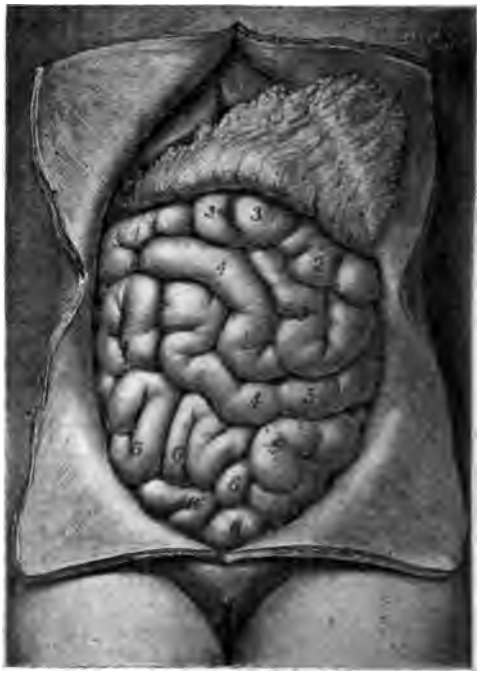


FIG. 943.—THE USUAL POSITION OF THE INTESTINE IN THE ABDOMINAL CAVITY. The numbers in the figure mark the parts which are homologous with the primary bends and groups of coils numbered from 1 to 6. (Mall.)



pass through the mesenteric lymph-nodes, finally reaching the cisterna (receptaculum) chyli.

The nerves.—The small intestine is supplied by means of the superior mesenteric plexus which is continuous with the lower part of the celiac (solar) plexus. The branches follow the blood-vessels, and finally form two plexuses: one (Auerbach's or myenteric) which lies between the muscular coats; and another (Meissner's) in the submucous coat. The nerve-fibers are chiefly from the sympathetic, partly from the vagus.

Development of the small intestine.—The early stages in the formation of the intestines have been described in Section I (p. 44), and also in connection with the *general morphogenesis* (p. 1173). Even in an embryo of 19 mm., while the intestine is still in the umbilical cœlom, Mall described six primary coils of the small intestine which could still be recognized after the return of the intestines to the general body cavity, and could usually be identified even in the adult (fig. 942). In the adult, as also through the various stages of development, loop 1 forms the duodenum. From the primary groups of coils marked 2 and 3 are developed the greater part of the jejunum, arranged in two distinct groups of loops, situated in the left hypochondriac region. The part of the intestine developed from group 4 of the primary coils passes across the umbilical region to the right upper part of the abdomen. That part developed from group 5 of the primary coils recrosses the median line to the left iliac fossa, while that part derived from group 6 of the primary coils is found in the false pelvis and the lower part of the abdominal cavity between the psoas muscles. They present what may be regarded as the normal arrangement of the small intestine, having been found 21 times in 41 cadavers examined. Variations from this arrangement occur; the great majority of such variations are, however, not of sufficient importance to require special mention.

According to Johnson (upon whose descriptions the following account is based), there is in embryos of 13 mm. to 23 mm. a formation of vacuoles in the duodenal epithelium, which leads to complete temporary occlusion of the lumen. A persistence of this condition may cause permanent atresia. In the epithelium of the small intestine numerous pockets or cysts occur, which usually disappear, but may persist and form permanent diverticula or accessory pancreas. The *villi* begin to appear at 19 mm., first in the mucosa of the upper portion of the intestine, as localized outgrowths which become arranged in longitudinal rows. The crypts of Lieberkuehn bud off from the epithelium at 55 mm., and from those in the duodenum, the duodenal (Brunner's) glands begin to bud off at 78 mm. The plicæ circulares begin to appear at the mid-region of the small intestine at 73 mm. The circular muscle-layer begins to appear at about 12 mm., the longitudinal at 75 mm.

Variations in the small intestine.—Although relatively fixed in position, the *duodenum* is quite variable in form. The C-shape previously described is the most common. When the pylorus and the duodenojejunal flexure are approximated, the form is nearly circular. When the two ends are more widely divergent, it approaches a U-form. Not infrequently, the inferior portion ascends abruptly from the inferior angle, giving a V-form. Finally, the terminal ascending portion may be very small or absent, in which case the duodenum approaches an L-form. Variations in the position of the various coils of the jejunum and ileum have already been discussed. The lymph-nodules, including Peyer's patches, like all lymphoid structures, are prominent during youth, but become atrophied in old age.

Meckel's diverticulum, which represents a derivation from the embryonic yolk-stalk and sac, is found in about 2 per cent. of all adults. It is a blind tube or diverticulum of variable size, usually approaching the intestine in width and averaging 5 cm. in length (ranging from 1 cm. to 13 cm.). Its attachment to the intestine varies from 15 cm. to 360 cm. (average 80 cm.) above the cecum. It is usually attached opposite the mesentery. It may end freely, but is occasionally adherent to adjacent intestinal coils or connected with the anterior abdominal wall by a cord or band-like process.

Other diverticula of variable size and number may occur, usually along the mesenteric border of the intestine. They may be either congenital (probably from the embryonic pockets previously mentioned) or acquired. They occur most frequently in the duodenum (found by Baldwin in 15 of 105 cases) where they are usually associated with the openings of the bile and pancreatic ducts.

Comparative.—The comparative anatomy of the small intestine will be discussed later together with that of the large intestine.

THE LARGE INTESTINE

The **large intestine** [intestinum crassum] is that part of the alimentary canal which extends between the ileum and the anus. It is divided into the following parts: Cecum, ascending, transverse, descending, and sigmoid colons, and rectum. It is so arranged as to surround the small intestine, making a circuit around the abdominal cavity from right to left (figs. 917, 948). The *cecum* lies in the right iliac fossa; thence the colon passes vertically upward on the right side (*ascending colon*) until the liver is reached. Here it forms a more or less rectangular bend (the right colic or hepatic flexure), and then passes transversely across the belly (*transverse colon*) below the stomach. It then reaches the spleen, where it makes a second sharp bend (the left colic or splenic flexure), and, passing vertically downward on the left side (*descending colon*), reaches the left iliac fossa. At this point it forms the loop of the sigmoid colon, and finally passes through the pelvis as the rectum (fig. 924).

Dimensions.—The large intestine is much larger in diameter than the small intestine, and is not so much convoluted. Excepting the dilated portion of the rectum, it is wider at the beginning than at the end. It varies in width at different parts from 3 to 8 cm. The length from the tip of the cecum to the point where the mesocolon ends is, in the male, about 140 cm., and in the female about 130 cm. The average total length, including the rectum, is about 150 cm. (5 ft.). The extremes found are 100 to 200 cm.

The large intestine, in all parts except the rectum, has a peculiar arrangement of its walls, which makes it in appearance very different from the small intestine. It is *sacculated*, and the sacculations [*haustra*] are produced by the gut having to adapt its length to three shorter muscular bands [*tæniæ coli*] which run the course of the intestine. These bands, which are about 12 mm. wide and 1 mm. thick, are really the longitudinal fibers of the muscular wall, which are chiefly collected along three lines (fig. 947).

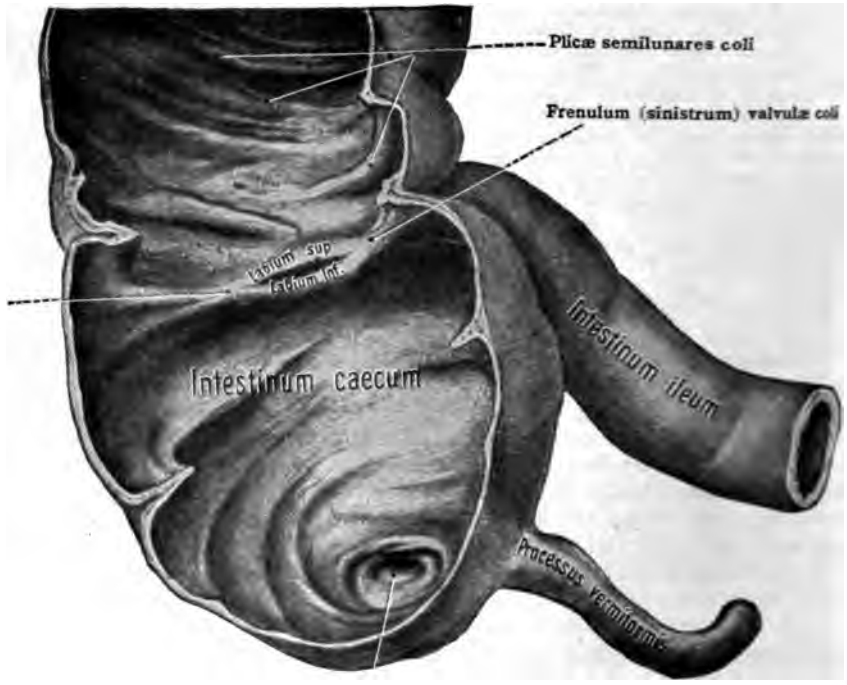
One band [*tænia mesocolica*], corresponding to the attachment of the mesocolon, is posterior on the transverse colon, and posteromedial on the ascending and descending colons. A second band [*tænia omentalis*] is anterosuperior on the transverse colon, elsewhere posterolateral. The third band [*tænia libera*] is free; it is inferior on the transverse colon, anterior elsewhere. All these bands start on the cecum at the vermiform process, and spread out to form a uniform layer on the rectum. Between the sacculations are *semilunar folds* [plicæ semilunares coli], which involve the entire thickness of the intestinal wall, forming crescentic ridges of the mucosa which project into the lumen (figs. 944, 947).

Along the free surface of the colon, especially near the teniæ, are numerous small appendages [*appendices epiploicæ*], which are pouches of peritoneum containing fat (fig. 294).

The cecum.—The cecum [intestinum cæcum] is a *cul-de-sac* forming the first part of the large intestine. It is defined as that part of the tube which is situated below the entrance of the ileum. Its breadth is about 7.5 cm., and its length about 6 cm. (fig. 944.) There is usually a more or less well marked constriction of the colon opposite the ileocecal orifice marking the boundary between cecum and colon. The cecum itself also sometimes presents a constriction dividing it into two sacculations.

It lies in the right iliac fossa, and is usually situated upon the iliopsoas muscle, and so placed that its apex or lowest point is just projecting beyond the medial border of that muscle (figs. 917, 924). It is usually entirely enveloped in peritoneum, and projects free in the peritoneal cavity, but is more or less adherent in

FIG. 944.—INTERIOR OF THE CECUM, ANTERIOR VIEW. (Rauber-Kopsch.)



Ostium et valvula processus vermiformis

about 10 per cent. of all cases. The apex of the cecum usually corresponds to a point a little to the medial side of the middle of the inguinal ligament. Less frequently the cecum will be found to be in relation with the iliacus muscle only; or the bulk of it will lie upon that muscle, while the apex rests upon the psoas. In some cases the cecum is entirely clear of both psoas and iliacus muscles, and hangs over the pelvic brim, or is lodged entirely within the pelvic cavity. Sometimes the cecum may pass even to the left of the median line of the body. This part of the intestine is also liable to marked variation in form.

The *variations* in the form of the cecum may be described under four types:

1. The fetal type is conical in shape, the appendix arising from the apex, and forming a continuation of the long axis of the colon. The three muscular bands which meet at the appendix are nearly at equal distances apart (fig. 945, A). When the cecum is empty and contracted it tends to approach this type.

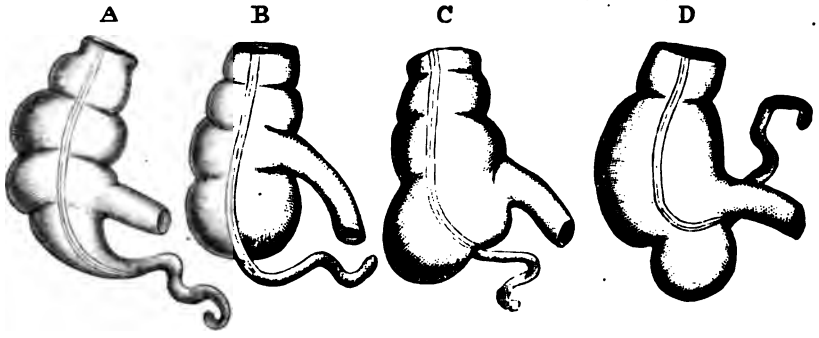
2. The second form is more quadrilateral in shape than the last; the three bands retain their relative positions; the appendix appears between two bulging sacculi, instead of at the summit of a cone (fig. 945, B).

3. In the third type, that part of the cecum lying to the right side of the anterior band grows out of proportion to that part to the left of the band. The anterior wall becomes more developed than the posterior, so that the apex is turned so much to the left and posteriorly

that it nearly meets the ileocecal junction. A false apex is formed by the highly developed part to the right of the anterior band. This is the usual cecum found (fig. 945, C).

4. In the fourth type, the development of the part to the right of the anterior band is excessive, while the segment to the left of the band has atrophied. In this form the anterior band runs to the inferior angle of junction of the ileum with the cecum. The root of the appendix is posterior to that angle. There is no trace of the original apex, and the appendix appears to spring almost from the ileocecal junction (fig. 945, D).

FIG. 945.—THE FOUR TYPES OF CECUM. (Treves.)



The ileocecal valve.—The ileocecal valve [valvula coli] is situated at the entrance of the ileum into the large intestine at the upper border of the cecum, on the posterior aspect and toward the medial side (fig. 944). The valve usually lies nearly opposite the middle of a line from the right anterior superior iliac spine to the umbilicus. The ileum passes from below upward and toward the right, and terminates obliquely. The valve is formed by two lip-like folds projecting into the large intestine, the upper [labium superius], and the lower [labium inferius]. They are not quite horizontal in direction (fig. 944). The opening between

FIG. 946.—RADIOGRAPH SHOWING CECUM AND UNUSUALLY LONG VERMIFORM PROCESS, EXTENDING INTO THE PELVIC CAVITY. (Dr. R. D. Carman, Mayo Clinic.)

them takes the form of a narrow transverse slit about 1.2 cm. in length. At the ends of the slit the valves unite and are prolonged at either end as a ridge [frenulum valvulæ coli] partially surrounding the intestine.

The efficiency of the valve in preventing the return of feces is due largely to its oblique position. (Symington.)

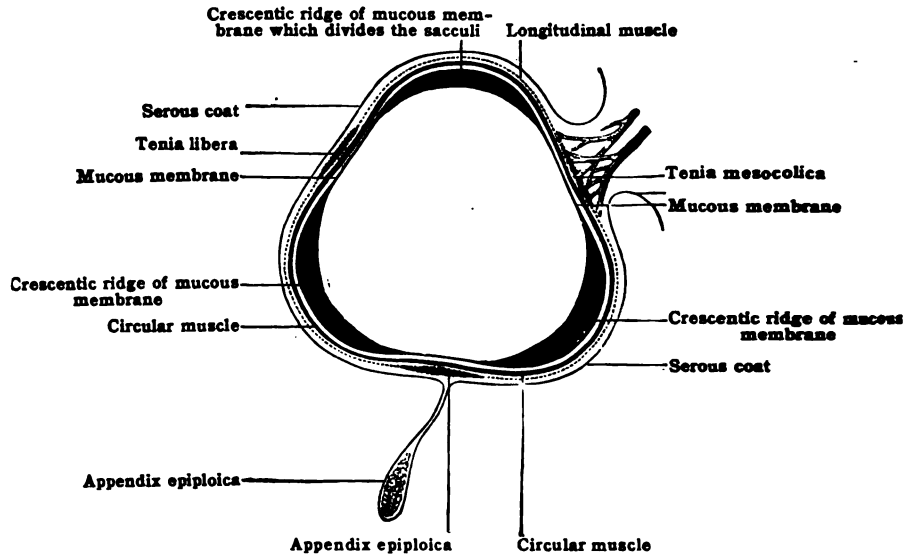
Villi cover that surface of the folds looking toward the ileum; the surface toward the large intestine is free from villi. In the formation of this valve the longitudinal muscular fibers pass across from the ileum to the large intestine without dipping down between the two layers of each fold. The circular muscular fibers, on the other hand, are contained between the mucous and submucous layers which form these folds.

Ileocecal fossæ.—About the cecum, and especially in the vicinity of the ileocecal junction, are certain fossæ collectively known as the ileocecal fossæ. Two only appear to be fairly constant, although a third is now and then present.

The first, the *superior ileocecal* or *ileocolic fossa*, is formed by the passage across the junction of the cecum and ileum of the anterior cecal artery, a branch of the ileocolic artery, which produces a fold of peritoneum [plica ileocolica] limiting a pouch. It is on the anterior aspect of the ileocolic junction, and the pouch opens downward (fig. 924). It is present in about one-third of all cases.

The second fossa is not quite so simple. If the cecum be turned upward so as to expose its posterior surface as it lies *in situ*, and if the appendix be drawn down so as to put its mesentery on the stretch, a peculiar fold will be found to join that mesentery. This fold arises from the border of the ileum opposite the insertion of its mesentery. It then passes over the ileocecal junction on its inferior aspect, is adherent to the cecum, and finally joins the surface of the mesentery of the appendix. This fold is peculiar in the absence of any visible vessels, and is often known as the 'bloodless fold of Treves.' Between it and the appendix there is an almost constant fossa, the *inferior ileocecal fossa*. It is usually large, admitting two fingers, and occurs in nearly 85 per cent. of all cases. It is bounded on one side by the small intestine, and on the other by the cecum. The appendix is occasionally found in the fossa.

FIG. 947.—CROSS-SECTION OF THE ASCENDING COLON. (Allen Thomson.)



The *subcecal* or *retrocolic* fossa is behind the cecum and is found in about 10 per cent. of all cases. It may extend for some distance behind the ascending colon. The appendix may be lodged in this fossa. *Paracecal* fossæ rarely occur, at the side of the cecum.

Variations.—In addition to variations already mentioned the cecum may vary in its general development. It is sometimes small and insignificant; in other cases it reaches a large size. It may be so rotated that the ileum passes behind the colon and opens on the right side. The posterior part has been seen much more developed than the anterior, so that the ileum has entered from the front, and the appendix has come off from the anterior wall. The cecum may remain undescended, and be found just under the liver or in the vicinity of the umbilicus. In case the rotation of the embryonic intestinal loop fails to occur (which rarely happens) the cecum may remain permanently upon the right side. If the normal process of adhesion fails to occur, the cecum and colon, along with the small intestine, may remain suspended from the middorsal line by the primitive *mesenterium commune*. Or any of the intermediate stages of partial adhesion may persist.

The vermiform process (appendix).—Attached to what was originally the apex of the cecum is a narrow, blind tube, the *vermiform process* [processus vermiformis] or *appendix*. It comes off at a variable distance (usually about 2.5 cm.) below the ileocecal valve on the posteromedial aspect of the cecum, though sometimes from the lower end of the cecum, or elsewhere. On the interior, at the point where it joins the cecum (fig. 944), there is a slight inconstant valve [valvula processus vermiformis]. The appendix joins the cecum at the point where the three teniæ meet, and the anterior tenia forms the best guide to this point. In the adult, the average length of the appendix is between 8 cm. and 10 cm., the extremes being 2 cm. to 25 cm. It is usually much twisted and coiled upon itself. Its direction is most frequently downward toward the pelvic cavity, or upward and medialward behind the ileum in the direction of the spleen. It occasionally turns lateralward, or more rarely upward behind the cecum.

The vermiform process does not have a true mesentery, but usually (in about 90 per cent. of cases) is provided with a falciform fold [mesenteriolum] or *meso-*

appendix of peritoneum, continuous with the left (lower) layer of the mesentery of the ileum (figs. 924, 1096).

In general outline this mesoappendix is triangular. In the adult it does not extend along the whole length of the tube. It is, in fact, too short for the appendix, and it is this that accounts for the twisted condition of this process. Along the free margin of the fold runs a branch of the ileocolic artery (fig. 1096).

The ascending colon.—The ascending colon [colon ascendens] (figs. 924, 933) extends in the right lumbar (lateral abdominal) region from the cecum to the inferior surface of the liver, lateral to the gall-bladder, forming there the right colic [flexura coli dextra] or hepatic flexure. Its average length is about 20 cm. (or somewhat less when measured *in situ*).

Peritoneal relations.—The ascending colon is covered by peritoneum in front and on the side (fig. 920), but in certain proportion of cases (26 per cent. according to Treves) this part of the large intestine is connected with the posterior wall of the abdomen by a mesocolon (usually very short) and is therefore surrounded by peritoneum. Connected with the ascending colon is sometimes found a fold of peritoneum, extending from the right side of the gut to the abdominal wall at a little above the level of the highest part of the iliac crest. It forms a shelf upon which rests the extreme right margin of the liver. It might be called the *sustentaculum hepatis*.

The ascending colon is in relation *behind* with the right kidney, and the iliacus and quadratus lumborum. *In front* are some of the coils of the ileum (fig. 917), separating it from the anterior abdominal wall.

The transverse colon.—The transverse colon [colon transversum], smaller in diameter than the ascending, extends from the lower surface of the liver to the spleen. Its average length is from 40 cm. to 50 cm. It describes an arch with its convexity forward and downward. It crosses through the umbilical region from the right hypochondrium to the left hypochondrium (figs. 917, 924, 933).

In the majority of cases the superficial part of the colic arch—as seen before the viscera are disturbed—is either in whole or in greater part above a straight line drawn transversely across the body between the highest points of the iliac crest. In about one-fourth of all cases it lies, in whole or in greater part, below this line.

Certain remarkable bends are sometimes formed by the transverse colon. The bending is always in the same direction, namely, downward, and is usually abrupt and angular. The apex of the V or U-shaped bend thus formed may reach the pubes. This bend appears to be due to various causes, including long-continued distention, congenital malformation, and movements of the stomach (to which it is attached by the gastrocolic ligament).

The transverse colon is in relation *above* with the liver and gall-bladder, the stomach, and at its left extremity with the spleen. The second portion of the duodenum passes *behind* it. *Below* are the coils of the small intestine. It is almost completely surrounded by peritoneum, being connected with the posterior abdominal wall (chiefly the anterior border of the pancreas) by the transverse mesocolon. This is usually lacking on the right of the midline, however, where the colon crosses the descending duodenum and the head of the pancreas (fig. 923).

The **descending colon** [colon descendens] is 25 cm. to 30 cm. in length (less when *in situ*) and extends from the spleen nearly to the pelvic brim (figs. 924, 1095). It is more movable than the ascending colon and is also narrower. At its beginning it is usually connected with the diaphragm, on a level with the tenth and eleventh ribs, by a fold of peritoneum, the *phrenocolic ligament* [lig. phrenicocolicum] (or *sustentaculum lienis*, from the fact that it supports the spleen). The bend between the transverse colon and descending colon is called the left colic or splenic flexure [flexura coli sinistra].

The descending colon is situated in the left hypochondriac, lumbar and iliac regions (fig. 924). Its relations to the peritoneum are the same as obtain with the ascending colon, that is, it is covered in front and on the sides. A mesocolon is met with oftener on this side than on the right, occurring in 36 per cent. of all cases (Treves) (see figs. 920, 923). It is found especially in the lower part of the descending colon, in the iliac fossa. This portion, extending from the iliac crest to the brim (superior aperture) of the pelvis, is sometimes described as a separate segment, the iliac colon (Jonnesco).

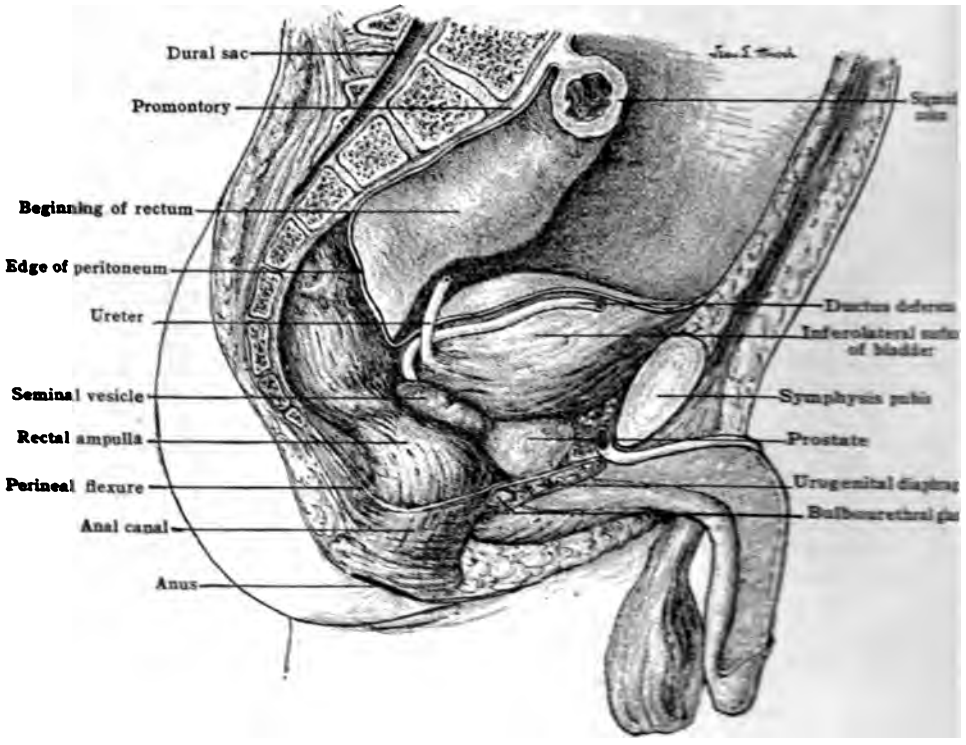
The descending colon is covered *anteriorly* by coils of small intestine; *posteriorly* it is in contact with the lower part of the left kidney, the quadratus lumborum, iliacus and psoas muscles. It terminates by crossing medialward over the psoas muscle and the external iliac vessels to join the sigmoid colon.

The **sigmoid colon** [colon sigmoideum] or pelvic colon, extends from the descending colon to the rectum (figs. 924, 948). It includes the parts formerly described as the 'sigmoid flexure' and the 'first portion' of the rectum. These together form a single loop which cannot conveniently be divided into parts.

Anteriorly is the bulb of the urethra and the posterior margin of the urogenital trigone in the male (fig. 950), while in the female it is separated from the vestibule and the lower part of the vagina by the 'perineal body' (fig. 951). *Posteriorly* it is connected with the tip of the coccyx by the anococcygeal body. *Laterally* it is in contact with the margins of the levatores ani, which act as an accessory sphincter, and help to support the ampulla recti.

The anus.—The anus is the aperture by which the intestine opens externally. During life it is contracted by the sphincters, so as to give the surrounding skin a wrinkled appearance. Around the lower part of the rectum and anus certain muscles that are connected with its proper function are situated. They are the internal sphincter, the levator ani, and the external sphincter. The levator ani and external sphincter will be found described in the section on MUSCULATURE. The *internal sphincter* is a thickening of the circular fibers of the rectum, situated around the second portion or anal canal. It forms a complete muscular ring 2 mm. to 3 mm. thick, and is composed of smooth muscle.

FIG. 950.—LATERAL VIEW OF THE MALE PELVIC VISCERA. (After His models.



Structure.—The rectum differs from the colon in having smoother walls and no appendices epiploicæ. At the upper end of the rectum, the tenia libera and tenia omentalis join to form a broad band which spreads out, covering the entire anterior aspect of the rectum. Similarly the tenia mesocolica spreads out upon the posterior aspect. Thus the rectum has a complete longitudinal muscle-layer, which, however, is thicker anteriorly and posteriorly than laterally. It sends a bundle of fibers to the coccyx, the rectococcygeus. Below, the longitudinal layer passes between the two sphincters and breaks up into numerous bundles which are interwoven with the external sphincter and levator ani, some of them terminating in the circumanal skin.

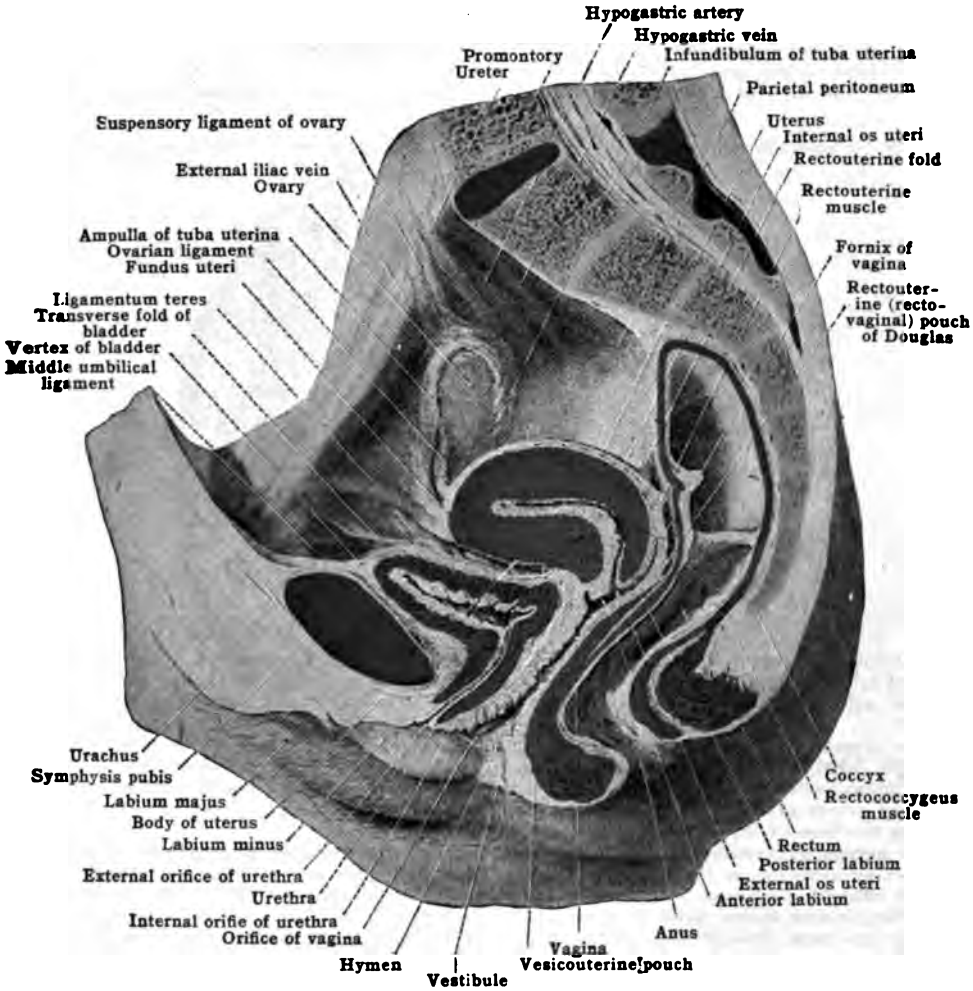
The rectal mucous membrane is thicker than that of the rest of the large intestine. [illegible] is chiefly longitudinal in direction, as seen in the lax state of the tube, which disappears when the rectum is distended. Its most characteristic feature are the permanent oblique **transverse folds**, some of which [illegible] (fig. 949), are formed by the mucous membrane and submucous tissue, which project into the lumen of the tube. One of these is on the right at the level of the reflection of the peritoneum from the rectum, and is [illegible] the right fold. That upon the right side is the largest [illegible] is sometimes called the [illegible]. It [illegible] is like the corresponding semilunar fold [illegible] wall.

[illegible] of the anal canal presents a series of vertical [illegible] rectal columns [illegible] of M[illegible] [illegible] [illegible] [

the small fossæ formed by them are known as the **rectal sinuses.** The area below the valves and extending to the anus is termed the *annulus hemorrhoidalis* (fig. 949). This is lined by a modified skin, while the area above the valves forms a transition to the typical mucosa of the rectum.

Minute structure of the large intestine.—In general, the large intestine has the four coats (fig. 952)—mucosa, submucosa, muscularis, and serosa—characteristic of the alimentary canal. The *mucosa* lacks the villi and plicæ circulares characteristic of the small intestine. It contains many solitary lymphatic nodules, but no Peyer's patches. It differs from the stomach in the absence of foveolæ, and in the presence of large numbers of mucous 'goblet cells' found both on the surface and along the numerous crypts of Lieberkuehn. The *submucosa* is much as in the small intestine. The *muscularis* has a continuous inner circular layer,

FIG. 951.—MIDSAGITTAL SECTION OF THE FEMALE PELVIS. (Spalteholz.)



the outer longitudinal fibers being chiefly gathered into the three bands, the teniæ coli, as above mentioned. The serosa is typical, excepting extraperitoneal areas where the epithelium is lacking. The appendices epiploicæ were also mentioned above. The cecum and colon present no special features worthy of mention, beyond the typical structure above outlined.

The *vermiform process* (appendix), however, differs in several important respects (fig. 953). The walls are relatively thick and the lumen small. The solitary lymph-nodules are closely packed or confluent (especially in young people). They occupy the greater part of the submucosa, and somewhat resemble the Peyer's patches of the ileum. They, like all the lymphoid structures in general, tend to become atrophied in old age. Fat cells are usually abundant in the submucosa. The *muscularis* presents an inner circular layer and also a thin but complete outer longitudinal layer. The serosa is typical. The lumen shows a progressive tendency to obliteration as age advances (Ribbert). This condition is never found in infancy but occurs usually (only partial) in over 25 per cent. of adults and in 50 per cent. of all cases over 50 years of age. It is, however, somewhat uncertain whether this represents a normal process. In obliteration, the glands and lymphoid nodules disappear, and the entire mucosa is transformed into an axial mass of fibrous connective tissue.

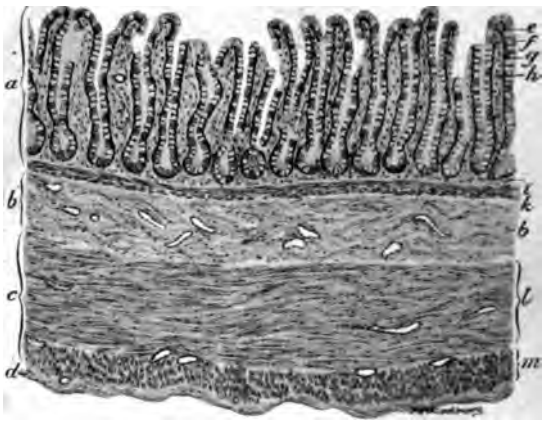
The *rectum* also presents several peculiarities of structure. Attention has already been called to the transverse folds (of Houston) and the rectal columns, sinuses and valves. Just above the valves, the mucosa is transitional, the epithelium being partly stratified, and the crypts of Lieberkuehn few and scattering. Below the valves, the annulus hemorrhoidalis is lined by a modified skin. Hairs and sebaceous and sweat-glands do not appear until just outside the anal orifice. The thickening of the circular muscle to form the internal sphincter, and the somewhat uniform disposition of the longitudinal muscle have already been mentioned as well as the absence of a serous coat in the lower portions.

Blood-vessels.—The large intestine is supplied with blood by the branches of the superior mesenteric and inferior mesenteric arteries, while it also receives a blood-supply from the internal iliac at the rectum. The vessels form a continuous series of arches from the cecum, where the vasa intestini tenuis anastomose with the ileocolic, the first branch of the superior mesenteric given to the large intestine.

The blood-supply of the rectum is from the inferior mesenteric by the superior hemorrhoidal, from the hypogastric (internal iliac) by the middle hemorrhoidal, and from the internal pudic by the inferior hemorrhoidal. The vessels at the lower end of the rectum assume a longitudinal direction, communicating freely near the anus, and less freely above.

The blood of the large intestine is returned into the portal vein by means of the superior mesenteric and inferior mesenteric veins. At the rectum a communication is set up between

FIG. 952.—CROSS-SECTION OF THE LARGE INTESTINE. *a*, Mucosa. *b*, Submucosa. *c*, Muscularis. *d*, Serosa. (Radasch.)



the systemic and portal system of veins, since some of the blood of that part of the intestine is returned into the hypogastric (internal iliac) veins. In the lower end of the rectum the veins, like the arteries, are arranged longitudinally. This arrangement is called the hemorrhoidal plexus.

The vermiform process (appendix) is supplied by a special branch of the ileocolic artery (figs. 523, 1096). This branch, the appendicular artery, crosses behind the terminal portion of the ileum (where pressure may obstruct the circulation) to enter the mesenteriolum. An accessory artery of small size also descends along the medial margin of the colon and cecum, entering the base of the appendix.

The **nerves** and **lymphatics** of the large intestine differ in no important particular from those of the small intestine, so far as their relations within the intestinal wall are concerned.

The efferent lymphatic vessels in general follow the blood-vessels and pass through corresponding lymph nodes in the various regions (see p. 769). Those of the cecum and vermiform process pass through the appendicular and ileocecal nodes; those of the colon through mesocolic and mesenteric nodes. Those of the descending and sigmoid colons connect with the inferior mesenteric and lumbar nodes. The superior zone of the rectum is drained by lymphatics passing to the anorectal and inferior mesenteric nodes; the middle zone (region of rectal columns) to nodes along the three hemorrhoidal arteries; the inferior zone (anal integument) chiefly to the superficial inguinal nodes.

Development of the large intestine. For the earlier stages, see Section I, p. 44, also *general morphogenesis*, p. 1173. The ascending and descending colons, the sigmoid mesocolon in part, and the rectum with corresponding portions of the mesorectum, become adherent to the posterior body wall during the fourth and fifth fetal months. At the same time, the posterior layer of the great omentum becomes fused with the upper (anterior) surface of the transverse mesocolon. The layer of retroperitoneal fascia corresponding to the obliterated mesocolon is shown in figs. 919, 920, 922, 1016. Variations in the process of fusion give rise to numerous peritoneal variations in the adult.

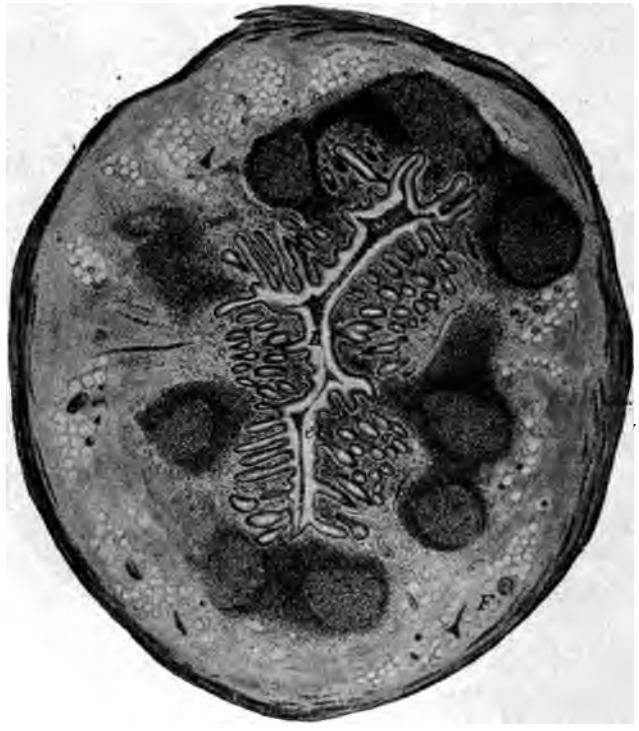
In fetuses of four to six months (length 100 mm. to 240 mm.) transitory villi appear in the mucosa throughout the large intestine, including the vermiform process. Their early obliteration is possibly due to distention of the gut by the meconium. The glands bud off like those of the small intestine. Lymphoid nodules are present abundantly in the vermiform process at birth (Johnson). The circular muscular-layer begins to appear in the lower part of the large intestine in embryos at 23 mm.; the teniæ at 75 to 99 mm. (F. T. Lewis.)

Development of the rectum and anus.—Earlier stages are described in Section I, p. 45. **Folds** of the mucosa representing the rectal columns, valves and sinuses appear in embryos **during** the the third month, and are well developed during the latter half of the fetal **period** (Johnson).

Variations.—The large intestine is exceedingly variable in its structure and relations, **especially** with reference to the peritoneum—so much so that it has been found more convenient **to** include a consideration of the variations along with the preceding description of the individual **parts**. The contents of feces (and gas) is as a rule relatively greatest in the cecum, decreasing **in** ascending and transverse colons. The descending colon is usually empty, or nearly so, the **sigmoid** colon and rectum somewhat variable. The rectal ampulla is usually more dilated in **women**.

Comparative.—The morphology of both small and large intestines will be briefly considered **here**. As previously mentioned, the primitive form of intestine is a comparatively straight **tube** extending from stomach to anus, and connected by a primitive mesentery to the mid-**dorsal** line of the body cavity. There is in many of the lower forms no clear division into small

FIG. 953.—TRANSVERSE SECTION OF THE HUMAN VERMIFORM PROCESS. (× 20.) (Stöhr and Lewis, from Sobotta.) Note absence of villi and abundance of lymph-nodules. *F*, Clusters of fat cells in submucosa. Only the inner part of the circular muscle is shown.



and large intestine, though the rectal region is usually more dilated, and opens into a cloaca. *Diverticula* often occur in the region between large and small intestine. In many fishes, numerous 'cæca' occur just below the pylorus, and in others an extensive *spiral valve* projects into the lumen of the intestine. The absorptive and digestive surface of the mucosa is further increased by the formation of various kinds of *folds*, and (beginning in amphibia) of *villi*. *Lymphoid tissue* is typically present in the mucosa, often localized in definite masses. Solitary nodules appear in amphibia, and Peyer's patches in birds. Tubular mucous glands occur in the lower forms, but Brunner's glands and crypts of Lieberkuehn apparently only in mammals. A *cecum* is usually present from the reptiles upward (double in birds), and often forms an important organ of digestion. The bile and pancreatic ducts open constantly a short distance below the pylorus. The small intestine is always longer than the large, but there is extreme variation in length among the various species. The four tunics—mucosa, submucosa, muscularis and serosa—are typical for vertebrates, the muscularis consisting of inner circular and outer longitudinal smooth muscle-fibers.

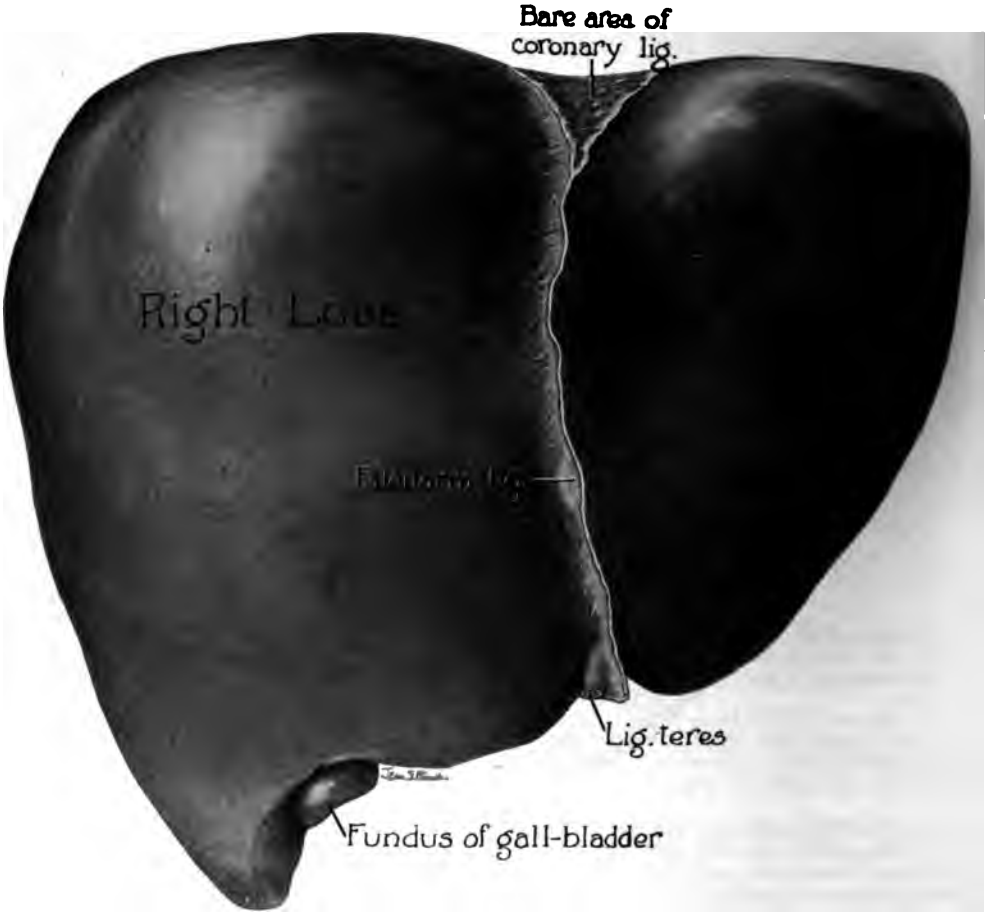
Among *mammals*, the divisions of the intestine correspond in general to those found in the human species, but there is exceedingly great variation in the relative development of the various parts. In general, the length, size and complexity of structure is relatively greatest in the *herbivora* (whose food is more difficult of digestion), least in the *carnivora*, and intermediate in the *omnivora*. Even in the same species, the structure of the intestine may be appreciably modified according to habitual diet. The large intestine varies, but is always shorter and wider than the small intestine. In mammals the rectum only is said to be homologous with the large intestine of lower vertebrates. The *cecum* is rarely absent and is enormously developed in herbivora. It often contains large amounts of lymphoid tissue, which, in pig and ox, forms a

so-called 'intestinal tonsil.' The *vermiform process* (found typically developed in man and higher anthropoids) apparently represents a retrogressive evolutionary change in the cecal apex, although this interpretation is denied by some (Berry), who interpret the appendix as a progressive, functional lymphoid organ.

THE LIVER

The **liver** [hepar] is the largest gland in the body. Its secretion, the bile [bilis; fel], is poured into the duodenum through the common bile-duct. In addition it has important functions as a 'ductless gland' in connection with the nitrogenous and carbohydrate metabolism. In form it is a variable somewhat irregular mass.

FIG. 954.—ANTERIOR VIEW OF THE LIVER.



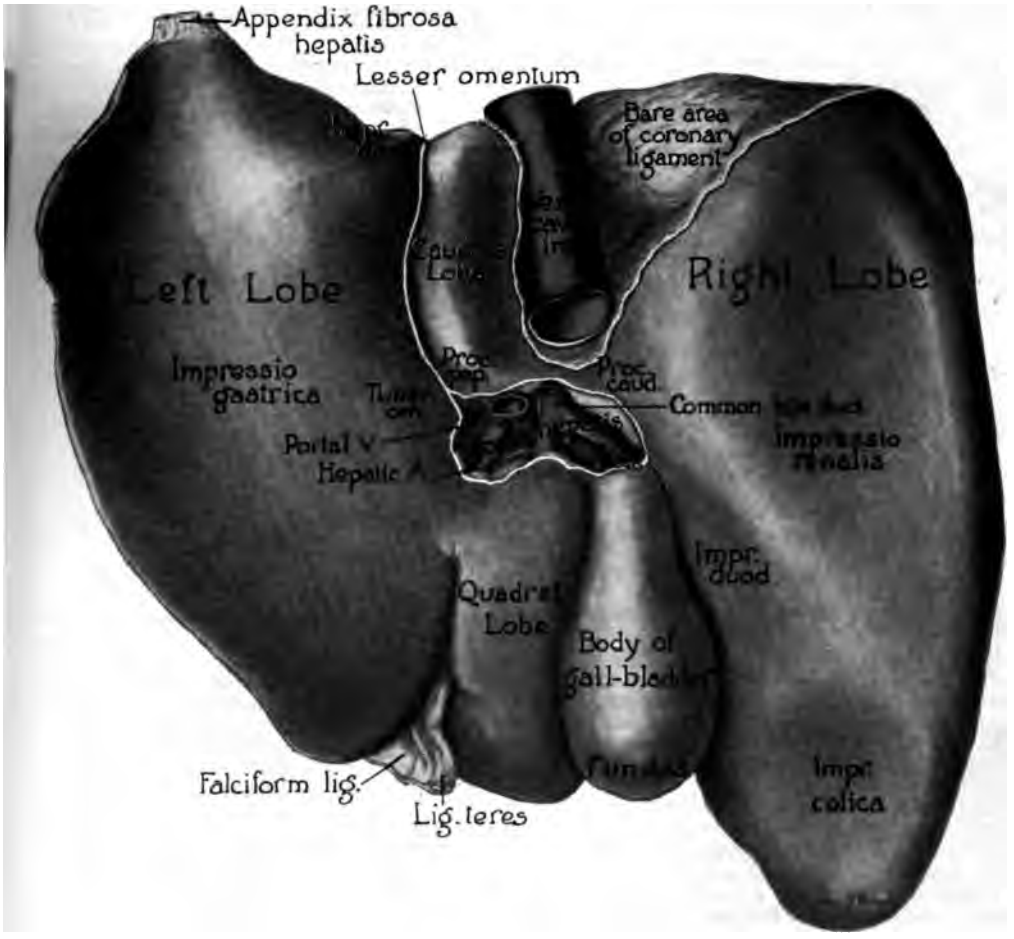
roughly comparable to a modified hemisphere occupying the upper right portion of the abdominal cavity (figs. 917, 1095). It presents a convex, rounded upper or *parietal* aspect, which is in contact with the diaphragm and adjacent body walls, and a lower, flattened *visceral* surface, in contact with the abdominal viscera. When viewed from the front, it is somewhat triangular in outline, occupying the right hypochondriac, the epigastric and (slightly) the left hypochondriac regions.

Physical characters.—In weight, the liver averages about 1500 gm. (3⅓ lbs.), but it is exceedingly variable, commonly ranging from 1000 gm. to 2000 gm. Its *relative* weight is also variable, averaging about 2.5 per cent. of the body in the adult male (somewhat higher in the female). Its *specific gravity* averages 1.056, so that the average weight of 1500 gm. would correspond to a *volume* of 1420 cc. Its *dimensions* are also quite variable. Its greatest *depth* (anteroposterior) averages about 15 cm., and its greatest *height* (vertical) is about the same. Its *width* (horizontal) is about 20 cm., while its greatest *length* (measured obliquely from side to side) averages about 25 cm. The color of the liver is a reddish-brown. It is firm in *consistency*, but friable, so that it is easily ruptured.

Surfaces and borders.—The most general division of the surface of the liver, as above stated, is into two—the parietal and the visceral. The parietal surface is again subdivided, usually into two surfaces—posterior and superior.

The **posterior surface** [facies posterior] is triangular (fig. 955). It is wide on the right, where the right lobe is in contact with the diaphragm (corresponding chiefly to the 'bare area' of the coronary ligament), and narrow on the left side, where the posterior margin of the left lobe is likewise attached to the diaphragm. Near the midline is the caudate (Spigelian) lobe, opposite the tenth and eleventh thoracic vertebral bodies, from which it is separated by the diaphragm (chiefly the right crus). On the right of the caudate lobe is the fossa lodging the vena cava

FIG. 955.—POSTERIOR VIEW (POSTERIOR AND INFERIOR SURFACES) OF THE LIVER.



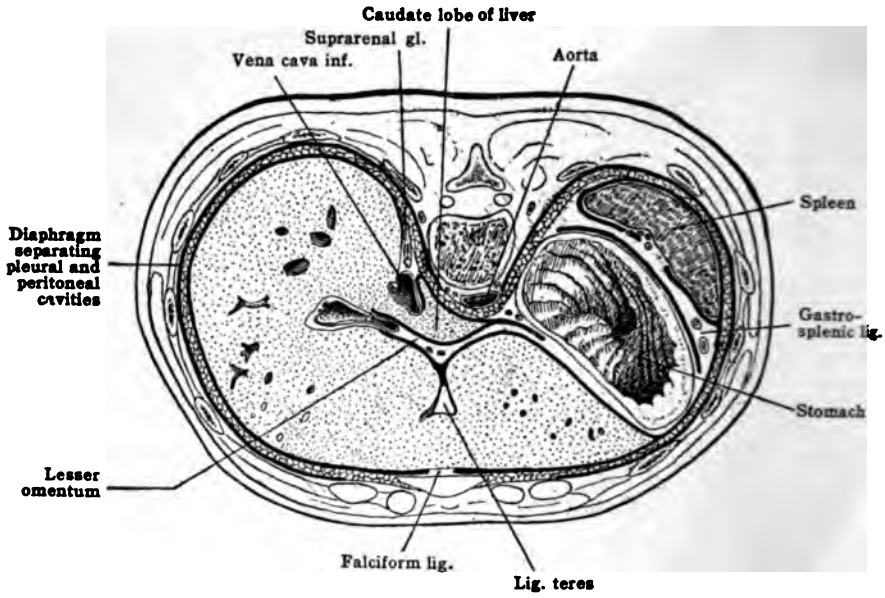
(sometimes bridged over), while to the left is the fissure of the ductus venosus, giving attachment to the upper portion of the lesser omentum (relations in cross-section shown in fig. 956).

The **superior surface** [facies superior] is in general convex and molded to the inferior surface of the diaphragm. It extends downward upon the anterior abdominal wall to a variable extent in the epigastric region, including the entire area of the liver visible from the front (fig. 954). It also presents a broad area extending downward on the right side. Symington accordingly distinguishes three surfaces corresponding to the superior surface above described, viz., right surface, anterior surface and superior surface. The superior surface is related above, through the diaphragm, with the base of the right lung, the pericardium and heart, and (on the extreme left) with the base of the left lung. Where it rests upon the liver, the heart forms a shallow fossa [impressio cardiaca].

The **inferior or visceral surface** [facies inferior] (fig. 955) faces downward and backward. It is irregularly concave, with impressions due to contact with the underlying viscera. It is divided into three lobes, right, left, and quadrate, whose relations will be described later.

Of the **borders,** the *anterior* [margo anterior] is the best marked. It forms the inferior boundary of the triangular anterior view of the liver (figs. 917, 954, 1095), and separates the superior (anterior) from the inferior surface. Slightly to the left of the midline, it usually presents a slight *umbilical notch* [incisura umbilicalis], where it is crossed by the falciform ligament. To the right of this there may also be a notch for the fundus of the gall-bladder (fig 954). The posterior surface is separated from the superior and inferior surfaces by ill-defined *posterosuperior* and *posteroinferior borders.*

FIG. 956.—CROSS-SECTION OF BODY AT LEVEL OF THE ELEVENTH THORACIC VERTEBRA (Poirier-Charpy.)



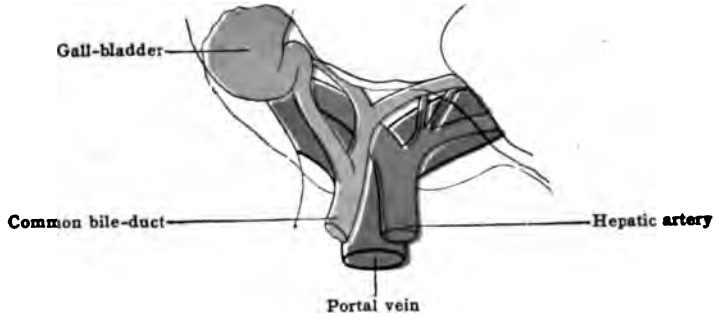
Surface-outline.—The average position of the liver may be outlined upon the anterior surface of the body as follows (fig. 1095): Locate one point on the right mammary (mid-Poupart) line opposite the fifth rib; a second point on the left mammary line about 2 cm. lower, in the fifth interspace; and a third point about 2 cm. below the costal arch (10th rib) on the right lateral wall. A line slightly concave upward, joining the first and second points, defines the uppermost aspect of the liver. A line, strongly convex laterally, joining the first and third points, defines the right side of the liver. Finally, a third line, joining the second and third points, corresponds to the anterior border and defines the lowermost portion of the liver. This line is subject to many individual variations. In general, it is usually slightly convex downward as it crosses the epigastric region. It usually presents a slight umbilical notch, as before mentioned, and frequently a notch for the fundus of the gall-bladder, which is placed near the right mammary (mid-Poupart) line. The lower and right portion of the anterior border of the liver runs somewhat parallel with the infracostal margin. In the upright position, and in livers larger than usual, it extends about 2 cm. below the hypochondrium into the right lateral abdominal (lumbar) region (fig. 1095). In the supine position however, the liver recedes about 2 cm. toward the head. The liver of course participates also in the respiratory movements of the diaphragm.

Lobes and fissures.—The superior surface is divided by the falciform ligament into two areas, corresponding to a larger right and a smaller left lobe (fig. 954). On the posterior and inferior surfaces of the liver (fig. 955), an **H-shaped arrangement** of fossæ and fissures completes the demarcation of lobes. The left upright of the H [fossa sagittalis sinistra] corresponds to the prolongation of the line of attachment of the falciform ligament. It is made up of the umbilical fissure [*fossa venæ umbilicalis*], containing the ligamentum teres, on the inferior surface; and of the *fossa ductus venosi*, containing the ligamentum venosum (obliterated ductus venosus) and the upper part of the lesser omentum, on the posterior surface of the liver. This left sagittal fossa separates the left lobe of the liver

the right lobe (in the wider sense of the term). The right lobe is further divided by the right upright and cross-bar of the H. The right upright [fossæ sagittales dextræ] is made up of the broad *fossa for the gall-bladder* [fossa vesicæ felleæ] on the inferior surface, and the broad *fossa venæ cavæ* on the posterior surface (fig. 955). These two fossæ are not continuous, but are separated by a narrow strip of liver, the caudate process of the caudate lobe. The cross-bar of the H is formed by the transverse or *portal fissure* [porta hepatis], which encloses the root structures of the liver, joining the right part of the lesser omentum (fig. 955). The area anterior to the cross-bar of the H corresponds to the quadrate lobe of the inferior surface; that posterior to the cross-bar to the caudate lobe of the posterior surface; while the remainder of the liver, to the right of the H, is the right lobe (in the narrower sense).

The right lobe [lobus hepatis dexter] makes up the greater part of the liver. Its relations on the superior and posterior surfaces have already been mentioned. On the inferior or visceral surface (fig. 955), there appears posteriorly a large concavity [impressio renalis] for the right kidney; medially a faint impression [impressio duodenalis] for the descending duodenum; and inferiorly a variable area [impressio colica] of contact with the right (hepatic) flexure of the colon. The caudate process joins the right with the caudate lobe.

FIG. 957.—RELATION OF STRUCTURES AT AND BELOW THE TRANSVERSE OR PORTAL FISSURE. ANTERIOR VIEW. (Thane.)



The left lobe [lobus hepatis sinister] lies to the left of the left sagittal fissure and the falciform ligament (fig. 955). It is flattened but variable in form and size, and makes only about one-fifth of the entire liver. In children and especially in early fetal life, it is relatively much larger. At the left extremity, there is usually found in the adult liver a variable fibrous band [appendix fibrosa hepatis] representing the atrophied remnant of the more extensive gland in earlier life. In this fibrous appendix (and in other parts of the liver) the bile-ducts of the atrophied liver substance persist as *vasa aberrantia hepatis*.

The left lobe is related *superiorly*, through the diaphragm, with the heart and the base of the left lung. *Inferiorly* (fig. 955) it presents a large concavity [impressio gastrica] which is in contact with the anterior surface of the stomach. Above and behind the gastric impression is the rounded *tuber omentale* which is placed above the lesser curvature of the stomach and related, through the lesser omentum, with a corresponding tuberosity on the pancreas. Above the gastric impression is a small inconspicuous groove [impressio œsophagea] for the abdominal part of the esophagus.

The **quadrate lobe** [lobus quadratus] lies, as before mentioned, on the inferior surface of the liver (fig. 955) in the anterior or inferior area of the H. It is in contact with the pylorus and the first part of the duodenum.

The **caudate** or **Spigelian lobe** [lobus caudatus; Spigeli] was described on the posterior surface of the liver (fig. 955). Inferiorly, the caudate lobe, behind the portal fissure, is divided by a notch into two processes. The left or *papillary process* [processus papillaris] is short and rounded, and lies opposite the tuber omentale. In the fetus it is relatively much larger and is in contact with the pancreas. The right or *caudate process* [processus caudatus] is of variable size, and joins the caudate with the right lobe of the liver. It is usually small and inconspicuous. In the fetus, however, it is relatively much larger, and extends downward to a variable extent behind the duodenum and head of the pancreas. In the adult, it forms the upper boundary of the epiploic foramen (of Winslow).

Peritoneal relations.—The liver in the adult is almost entirely surrounded by peritoneum. Although it develops together with the diaphragm in the common septum transversum (see p. 46 and fig. 963), the peritoneum soon extends in between liver and diaphragm, so that they remain in immediate contact only in the so-called 'bare area.' This is an irregular area on the posterior surface of the liver (chiefly on the right lobe), the margins of which correspond to the coronary ligament (figs. 923, 955). The posterior surface of the liver is therefore chiefly

retroperitoneal, excepting the caudate (Spigelian) lobe, which is in contact with the recessus superior of the bursa omentalis (fig. 923). The other surfaces of the liver are almost entirely covered with peritoneum, excepting the lines of attachment of the various peritoneal ligaments, and the fossa for the gall-bladder, which is usually directly in contact with the gall bladder with no intervening peritoneum.

Ligaments.—The liver is attached by five peritoneal ligaments—coronary, right and left triangular (lateral) and falciform ligaments and lesser omentum—and two accessory ligaments—teres and venosum.

The **coronary** ligament [lig. coronarium hepatis], as before mentioned, corresponds to the reflections of peritoneum from the liver to the diaphragm at the margins of the 'bare area' (figs. 923, 954, 955) on the posterior surface of the liver.

Within this uncovered area the hepatic veins join the inferior vena cava. The coronary ligament, though somewhat irregular and variable in form, is elongated laterally and roughly quadrangular. At the four angles, the peritoneal layers come together and are prolonged as four ligaments—right and left triangular (lateral) and falciform ligaments and lesser omentum. There is often also a special prolongation of the coronary ligament downward upon the right kidney, forming the *hepatorenal ligament* [lig. hepatorenale]. This lies to the right of the foramen epiploicum.

The **right triangular** (or lateral) ligament [lig. triangulare dextrum] is a short but variable prolongation of the coronary ligament to the right and downward (fig. 923). It connects the posterior surface of the right lobe of the liver with the corresponding portion of the diaphragm.

The **left triangular** (lateral) ligament [lig. triangulare sinistrum] is a longer, narrower prolongation of the coronary ligament to the left (fig. 923). It connects the posterior aspect of the left lobe of the liver with the corresponding portion of the diaphragm.

The **falciform** ligament [lig. falciforme hepatis] is a double layer of peritoneum representing (as before mentioned) the ventral portion of the primitive ventral mesogastrium (figs. 918, 923, 954).

Its upper end is continuous posteriorly with the coronary ligament. It passes forward and downward over the superior surface of the liver. From its line of attachment to the liver (between right and left lobes) it passes forward and slightly to the left to the attachment on the anterior body wall. This attachment extends downward slightly to the right of the midline to the umbilicus. The lower margin of the falciform ligament is free, and encloses the round ligament.

The **round ligament** [lig. teres hepatis] is a fibrous cord representing the obliterated fetal left umbilical vein. It extends upward from the umbilicus enclosed in the lower margin of the falciform ligament (figs. 954, 955).

At the anterior margin of the liver it passes backward on the inferior surface, enclosed in a slight peritoneal fold at the bottom of the fossa venæ umbilicalis (sometimes bridged over by liver tissue). It ends by joining the left branch of the portal vein.

The **ligamentum venosum** [lig. venosum; Arantii] similarly represents the obliterated fetal ductus venosus. It is a fibrous cord lying in the fossa ductus venosi, and extends from the left branch of the portal vein upward to the left hepatic vein near its opening into the vena cava. The ligamentum venosum lies within the hepatic attachment of the lesser omentum.

The **lesser omentum** [omentum minus] has already been discussed in connection with the peritoneum. It represents the dorsal part of the primitive ventral mesogastrium extending from the stomach to the liver. It includes two parts, as shown in fig. 924.

The upper and larger part forms the *gastrohepatic* ligament [lig. hepatogastricum], connecting the liver (fossa ductus venosi) with the lesser curvature of the stomach. The upper part of this ligament is somewhat thicker, the lower part thinner and more transparent. The relations of the lesser omentum in cross-section of the body are shown in fig. 921. The lower and right portion of the lesser omentum extends beyond the pylorus and connects the portal fissure with the duodenum, forming the *hepatoduodenal* ligament [lig. hepatoduodenale] (fig. 923). Its right free margin forms the anterior boundary of the epiploic foramen (of Winslow). Between its layers are located the root structures of the liver. A special prolongation of the hepatoduodenal ligament sometimes extends downward to the transverse colon, forming the *hepatocolic* ligament [lig. hepatocolicum].

Fixation of the liver. The liver is to a certain extent fixed in place by means of its various ligaments, and especially through the attachment of the hepatic veins to the inferior vena cava. On account of the close apposition of the liver to the diaphragm, the atmospheric pressure also helps in its support. Finally, the support of the liver, as well as of the abdominal viscera in general, is dependent to a considerable extent upon the tonic contraction of the abdominal muscles, which exerts a constant pressure upon the abdominal contents.

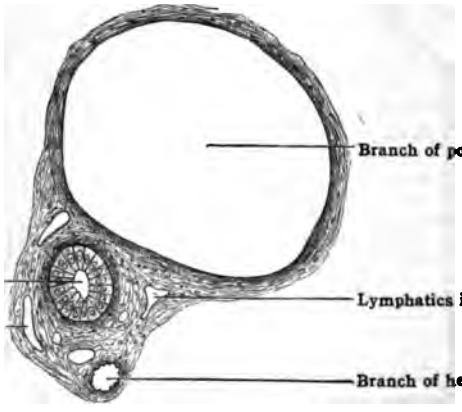
Blood-vessels.—The liver receives its *arterial* supply of blood from the hepatic artery, a branch of the celiac, which passes up between the two layers of the lesser omentum, and dividing into two branches, one for each lobe, enters the liver at the portal fissure. The right branch gives off a branch to the gall-bladder. The liver receives a much larger supply of blood from the *portal vein*, which conveys to the liver blood from the stomach, intestines, pancreas, and spleen. It enters the portal fissure, and there divides into two branches. Below this fissure the hepatic artery lies to the left, the bile-duct to the right, and the portal vein behind and between the two (fig. 957). These three structures ascend to the liver between the layers of the lesser omentum in front of the epiploic foramen. At the actual fissure the order of the three structures from before backward is—duct, artery, vein (fig. 955).

The *hepatic veins*, by which the blood of the liver passes into the inferior vena cava, open usually by two large and several small openings into that vessel on the posterior surface of the gland at the bottom of the fossa venæ cavæ.

Lymphatics.—The lymphatics are divided into a deep and a superficial set. The *deep set* runs with the branches of the portal vein, artery, and duct through the liver, leaving at the portal fissure, where they join the vessels of the superficial set. The efferent deep vessels after leaving the portal fissure pass down in the lesser omentum in front of the portal vein, through the chain of hepatic lymphatic nodes, and ultimately end in a group of nodes at the upper border of the neck of the pancreas, in which the pyloric lymphatics also terminate.

The *superficial set* begins in the subperitoneal tissue. Those of the *upper surface* consist: (1) Of vessels which pass up, principally, in the falciform ligament and right and left triangular ligaments, through the diaphragm, and so into the anterior mediastinal nodes, and finally into the right lymphatic duct. Some lymphatics of the right triangular ligament pass to the posterior mediastinal lymph-nodes and into the thoracic duct. (2) Of a set passing downward

FIG. 958.—SECTION OF A PORTAL CANAL. (Quain.)



over the anterior border of the liver to the hepatic nodes in the portal fissure, and over the posterior surface to reach the superior gastric and celiac nodes. On the lower surface, the lymphatics to the right of the gall-bladder enter the lumbar nodes. Those around the gall-bladder enter the hepatic nodes of the lesser omentum. Those to the left of the gall-bladder enter the superior gastric nodes.

Nerves.—The nerves of the liver are derived from the vagi (those from the left vagus entering from the stomach through the lesser omentum), and from the celiac plexus of the sympathetic (including right vagus branches) through a plexus accompanying the hepatic artery. The terminations, so far as known, are chiefly to the walls of the vessels and of the bile ducts.

Structure of the liver.—The liver is, for the greater part, covered by peritoneum, beneath which is found the fibroelastic layer known as Glisson's capsule. At the portal fissure, Glisson's capsule passes into the substance of the liver, accompanying the portal vessels, the branches of the hepatic artery, and the bile-ducts. The liver-substance is composed of vascular units measuring from 1 to 2 mm., and known as liver-lobules. These are in part (man) separated by a small amount of interlobular connective tissue, which is a continuation of Glisson's capsule. In this interlobular connective tissue are found the terminal branches of the portal vessels, the hepatic artery, and the bile-ducts (figs. 958, 959). The branches of the portal vessels which encircle the liver lobules are known as the interlobular veins. From these are given off hepatic capillaries, which anastomose freely, but have in general a direction toward the center of the lobule, and unite to form the central or intralobular veins, which in turn unite to form the sublobular veins, and these the hepatic veins. The intralobular branches of the hepatic arteries form capillaries which unite with the capillaries of the intralobular portal veins.

The liver is a modified compound tubular gland. The liver-cells are arranged in anastomosing cords and columns occupying the spaces formed by the hepatic capillaries. The bile-ducts have their origin in so-called bile-capillaries [ductus biliferi], situated in the columns of liver-cells; they anastomose freely and pass to the periphery of the lobules to form the primary divisions of the bile-ducts, and these unite to form the larger bile-ducts. The branches of the portal vessel are accompanied in their course through the liver by the branches of the hepatic artery and the bile-ducts, surrounded by extensions of Glisson's capsule forming the so-called

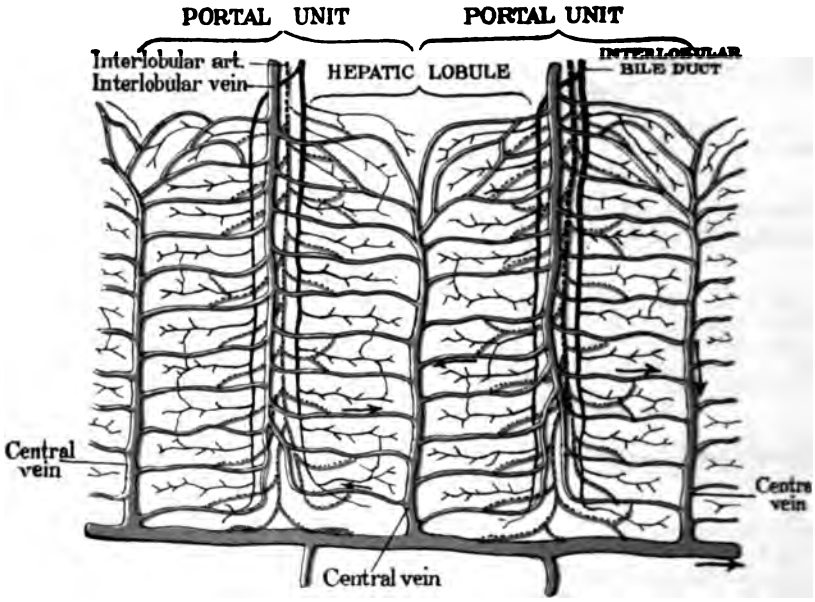
'portal canals' (fig. 958). The branches of the hepatic vein are solitary, their walls are and closely adherent to the liver substance, hence they remain wide open on sectioning liver.

While it is customary to describe thus the liver-lobules, it would be more logical to sider as the real lobules what Mall has described as the 'portal units.' Each portal unit inc the territory supplied by one interlobular branch of the portal vein, and drained by the acc panying bile-duct. The relations of the ordinary lobules and the portal units are evide fig. 959. The portal unit corresponds more nearly to the lobule of other glands, where duct is in the center of the lobule.

Bile-passages.—The bile-passages, which transmit the bile from the live the duodenum, include the gall-bladder, the cystic duct, the hepatic ducts, and common bile-duct.

The **gall-bladder** [vesica fellea], which retains the bile, is situated between right and quadrate lobes on the lower surface of the liver. It is pear-sha and (when full) is usually seen projecting beyond the anterior border of the l

FIG. 959.—DIAGRAM OF THE PORTAL UNIT AND VASCULAR RELATIONS OF THE HEPATIC LO (After Szymonowicz.)



(figs. 954, 955), coming in contact with the abdominal wall opposite the costal cartilage at the lateral margin of the right rectus muscle (fig. 109. extends back as far as the portal fissure.

It measures in length, from before backward, 7 to 10 cm. It is 2.5 to across at the widest part, and will hold about 35 cc. (1¼ oz.). The broad the sac is directed forward, downward, and to the right, and is called the The narrow end, or *neck* [collum vesicæ felleæ], which is curved first to the then to the left, lies within the lesser omentum at the portal fissure. The vening part is called the *body* [corpus vesicæ felleæ].

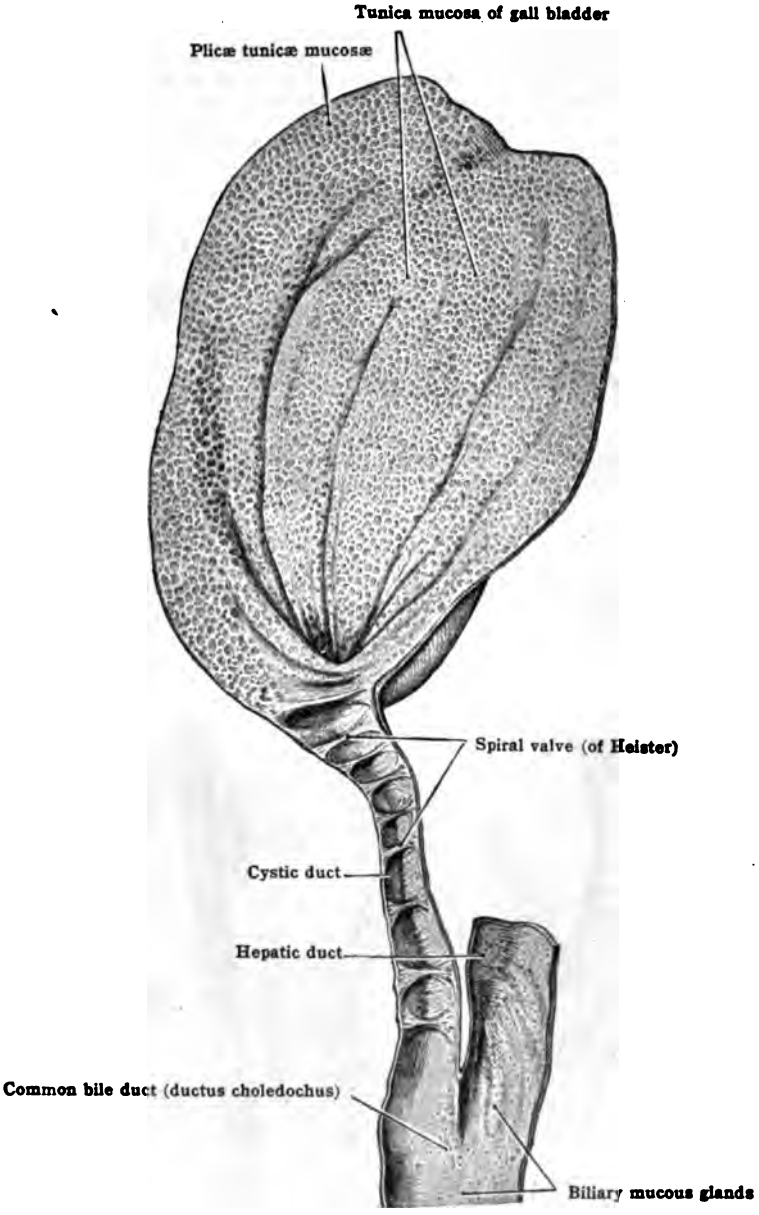
Its *upper surface* is in contact with the liver, lying in the fossa of the gall-bladde attached to the liver by fibrous connective tissue. The lower surface is covered by peri which passes over its sides and inferior surface, though occasionally it entirely surrounds bladder, forming a sort of mesentery attaching to the liver. The *lower surface* comes i tact with the first part of the duodenum and the transverse colon, and occasionally pyloric end of the stomach or small intestine, which *post mortem* are often found stai bile.

The neck of the gall-bladder opens into the *cystic duct* [ductus cy This is a tube about 3.5 cm. long and 3 mm. wide, which unites with the duct to form the ductus choledochus; it is directed backward and to th it runs in the lesser omentum, the common hepatic artery being to the l the right branch of the artery and portal vein behind (fig. 955). It jo

epatic duct at an acute angle, and is kept patent by a spiral valve [valvula piralis; Heisteri], formed by its mucous coat (fig. 960).

The *hepatic duct* [ductus hepaticus] begins with a branch from each lobe, right and left (that from the left receiving also the ducts from the caudate lobe), in the portal fissure, and is directed downward and to the right within the portal fissure and the lesser omentum (hepatoduodenal ligament), the right branch of

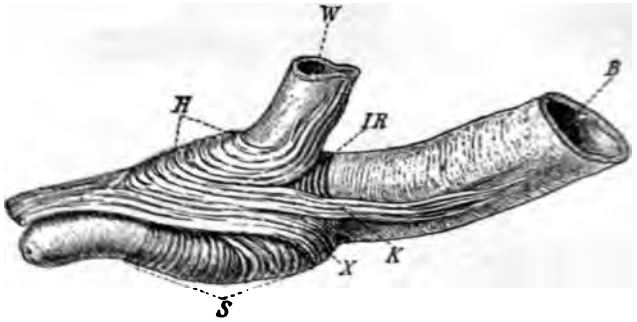
FIG. 960.—INTERIOR OF THE GALL-BLADDER AND DUCTS. (From Toldt's Atlas.)



the hepatic artery being behind and the left branch to the left. It is from 3 to 5 cm. long; its diameter is about 4 mm. Uniting with the cystic duct, it forms the *common bile-duct* [ductus choledochus].

The **ductus choledochus** or **common bile-duct** is about 7.5 cm. in length and 6 mm. in width. It passes down between the layers of the lesser omentum, in front of the portal vein, and to the right of the hepatic artery (fig. 957); it then passes behind the first part of the duodenum, then between the second part and the head of the pancreas, being almost completely embedded in the substance of

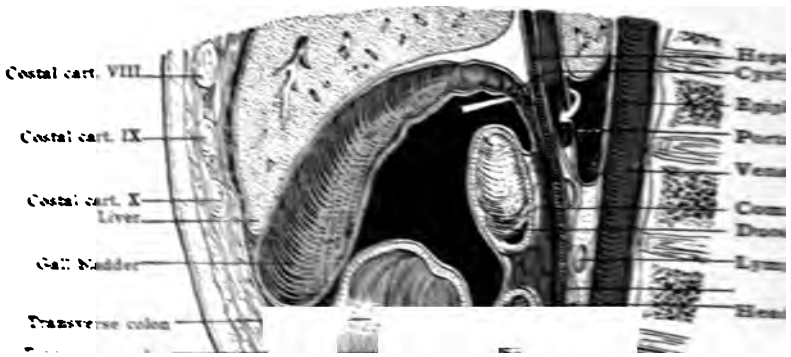
CULATURE. *B*, Common bile-duct. *W*, Pancreatic duct (of Wirsung). *S*, fibers of bile-duct. *H*, Fibers of pancreatic duct. (Hendrickson.)



In its oblique course through the duodenal wall, the common bile-duct is the pancreatic duct, the two together usually causing the plica longitudinalis du muscle fibers join with bundles of longitudinal fibers at the lower part of the sphincter around each (fig. 961). Contraction of the sphincter probably closes common bile-duct, so that except during digestion the bile is backed up into

Structure of the gall-bladder.—The wall of the gall-bladder is made up mucosa, fibromuscular and serosa.

FIG. 962. RELATIONS OF GALL-BLADDER AND BILE-DUCTS IN SAGITTAL SEC grammatic. After Testut and Jacob.)

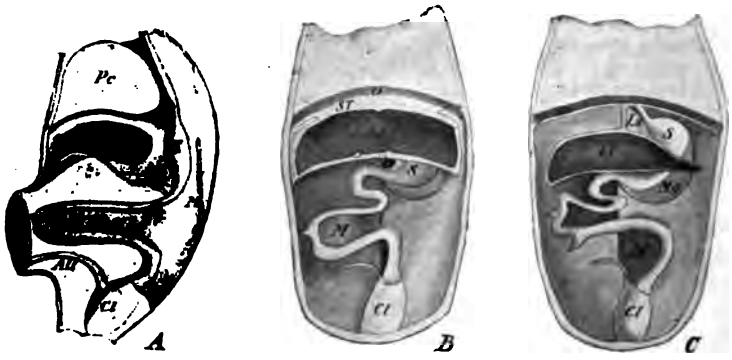


he *serosa*, formed by the peritoneum, is found only on the sides and lower surface. *ducts* consist of a fibromuscular and a mucous layer. In the fibromuscular layer are muscle-cells which are chiefly circular, together with white fibrous tissue and elastic The lining mucosa has many mucous glands. In the cystic duct the mucous membrane into folds, which are crescentic in form, and directed so obliquely as to seem to surround en of the tube in a spiral manner.

development of the liver.—For the earlier stages, see Section I, p. 46. The definite lobules are not differentiated until after birth. The process of the development of the is very complicated, the vascular arrangement being shifted repeatedly (Mall).

embryonic liver rapidly enlarges, filling the upper portion of the abdominal cavity, and ıg along its ventral wall to the region of the umbilicus. During the enlargement it 's the transverse septum (fig. 963), and there are developed grooves which result in an g of the peritoneum covering the transverse septum, and which in part separate the ing liver from that part of the septum destined to form the diaphragm, and also from the abdominal wall. These grooves appear at the sides and also ventral to the liver, but do pletely separate the liver from the diaphragm, nor do they meet in the median line. A of the liver, therefore, remains uncovered by peritoneum, and remains attached to the gm by the 'bare area' of the liver. Around this area the peritoneum of the liver is

3.—DIAGRAM: (A) A SAGITTAL SECTION OF AN EMBRYO SHOWING THE LIVER ENCLOSED THIN THE SEPTUM TRANSVERSUM; (B) A FRONTAL SECTION OF THE SAME; (C) FRONTAL TION OF A LATER STAGE WHEN THE LIVER HAS SEPARATED FROM THE DIAPHRAGM.
Allantois; *Cl*, cloaca; *D*, diaphragm; *Li*, liver; *Ls*, falciform ligament of the liver; *M*, ry; *Mg*, mesogastrium; *Pc*, pericardium; *S*, stomach; *ST*, septum transversum; *U*, ıs. (McMurrich.)



l on to the diaphragm, forming the coronary ligament, with right and left extensions, ed as the right and left triangular ligaments. Where the grooves fail to meet in the midline, there persists a fold of peritoneum, the falciform ligament, which represents the portion of the primitive ventral mesentery and attaches the liver to the ventral abdom- l. The dorsal portion of the ventral mesentery (mesogastrium) persists between the l stomach to form the lesser omentum. The developing liver early comes into intimate with the omphalomesenteric vitelline veins, and later the umbilical veins. The develop- history of these veins and their relation to the developing liver is discussed elsewhere 33). After birth the left umbilical vein forms the hepatic ligamentum teres, situated ee edge of the falciform ligament. The ductus venosus likewise atrophies to form the tum venosum. For the growth of the liver and gall-bladder, see p. 46.

ıtions of the liver and bile-passages.—Many variations of the liver have already ntioned. In *size*, both relative and absolute, it is subject to marked individual varia- well as according to age and sex (previously described). In *form*, the liver is also quite . There are two extreme types: (1) in which the liver is very wide, extending far over left hypochondrium, but relatively flattened from above downward; and (2) in which it but slightly to the left, being somewhat flattened from side to side, and elongated y. This type may occur as a result of tight lacing, in which the liver is frequently d. The part projecting below the right costal margin may form the so-called '*Riedel's* ll intermediate forms between these two types occur. Its *position and relations* will y necessarily according to differences in size and shape. For example, in the wide type in enlarged livers, the left lobe may extend over upon the spleen, a relation which is ; during prenatal life.

e may be *supernumerary fissures*, dividing the liver into additional lobes, as many as ıg been described in an extreme case (Moser). These extra fissures often correspond es which are normal in other mammals. There may also be *accessory lobes*, usually nd connected with the main gland by stalks. Any one of the normal lobes may be *l* or absent. There may also be *abnormal grooves* on the parietal surface of the liver. , there are two varieties: (1) *costal* grooves, due to impressions of the overlying ribs al cartilages; and (2) *diaphragmatic* grooves, due to wrinkles in the diaphragm. These most frequently occur in females, as a result of tight lacing. The *appendix fibrosa* ıdy been mentioned. There are numerous variations in the *vascular* arrangements, as n the *peritoneal* relations (particularly in connection with the coronary ligament).

acter becomes masked, however (in amniota, and especially in mammals), by
anastomosis between the tubules, forming what is called a 'solid' gland. The
the portal venous system are constant. The liver frequently stores large quantiti
may even undergo a complete fatty metamorphosis (lamprey). The color of the l
reddish-brown, but may be yellow, purple, green or even vermilion (due to bi
In *size*, the liver is variable, but is usually relatively larger in anamniota. Amo
there is great variation according to diet, the liver being relatively larger in carni
in herbivora, and intermediate in omnivora (including man). It is also relatively l
animals (including young and fetal stages), probably on account of their more int
lism. There are typically two lobes, right and left, in the vertebrate liver. T
quently subdivided, however, especially in mammals, which often present numer

The **gall-bladder** is typically present, as in man, but varies in form, size and
may be completely buried in the liver. In some species it is absent, in which cas
ducts open directly into the duodenum by one or more apertures. The hepat
ducts typically unite to form a common bile-duct, as in man, but there are numero
in the detailed arrangement of the ducts.

THE PANCREAS

The **pancreas** (figs. 935, 936, 964, 965, 966) is an elongated glan
transversely across the posterior abdominal wall behind the stomac
duodenum to the spleen. Through the pancreatic ducts, opening i
scending duodenum, flows its secretion [succus pancreaticus].

The pancreas is grayish-pink in color. Its average length (*in situ*) i
15 cm.; average weight about 80 gm. (extremes 60 gm. to 100 gm.
Its specific gravity, 1.047, is about the same as that of the salivary gla

In *position*, the pancreas lies in the epigastric and left hypochondri
In *form* it somewhat resembles a pistol, with the handle placed to th
the barrel to the left. The pancreas is accordingly divided into a
within the duodenal loop; a *body*, extending to the left; and a *tail*,
extremity.

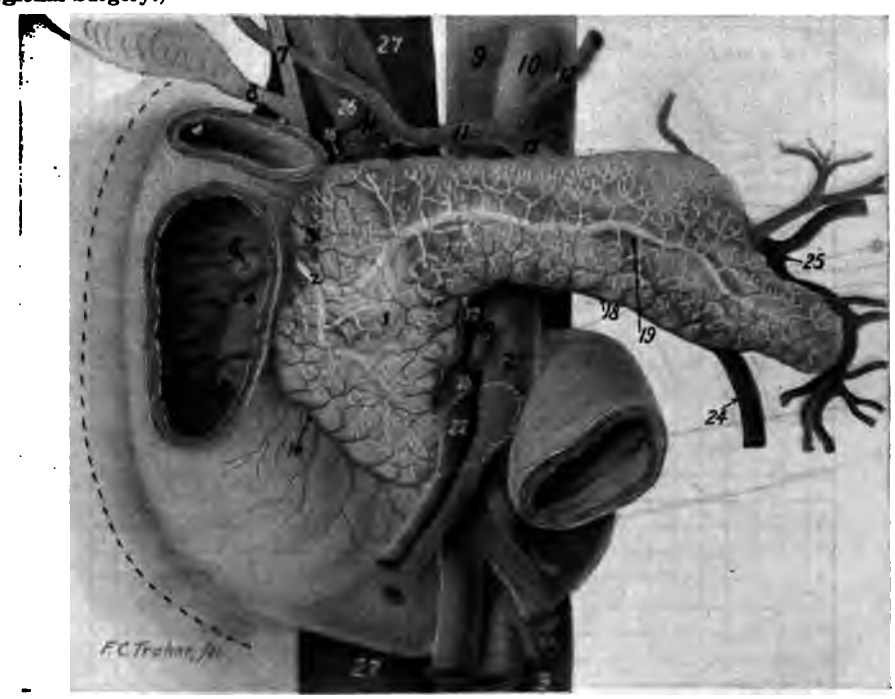
The **head** [caput pancreatis] is a discoidal mass somewhat elongated
and flattened dorsoventrally. It forms the enlarged right extremity
creas and lies within the concavity of the duodenum (figs. 935, 936,
relations are as follows: Its *posterior* surface is placed opposite the s
third lumbar vertebra, and is in contact with the aorta, the vena cava
veins and right renal artery. The common bile-duct is also partly
in this surface. Its *anterior* surface is crossed by the transverse co
which is the pyloric extremity of the stomach, and below which a
small intestine. Upon this surface are also the pancreaticoduoden
part) the superior mesenteric vessels.

The junction of the upper and left aspect of the head with the body of the pancreas is called the *neck*. This is a somewhat constricted portion grooved *posteriorly* by the superior mesenteric vessels, the vein here joining with the splenic to form the portal vein (fig. 936). *Anterior* to the neck is the pyloric portion of the stomach. The upper portion of the neck (together with a variable area on the left end of the body) projects above the lesser curvature of the stomach. This projection [*tuber omentale*] is related, through the lesser omentum, with a similar tuberosity on the left lobe of the liver. The anterior aspect of the neck is covered with peritoneum of the bursa omentalis (lesser sac), and is continuous with the anterior surface of the body of the pancreas (fig. 935).

FIG. 964.—ANATOMY AND RELATIONS OF THE PANCREAS.

1. Duct of Wirsung. 2. Duct of Santorini. 3. Common bile-duct. 4. Plica longitudinalis duodeni. 5. Papilla major. 6. Papilla minor. 7. Hepatic duct. 8. Cystic duct. 9. Abdominal aorta. 10. Celiac axis. 11. Hepatic artery. 12. Left gastric artery. 13. Splenic artery. 14. Gastroduodenal artery. 15. Right gastric artery. 16. Superior pancreatoduodenal artery. 17. Inferior pancreatoduodenal artery. 18. Inferior pancreatic artery. 19. Pancreatico magna artery. 20. Middle colic artery. 21. Superior mesenteric vein. 22. Superior mesenteric vein. 23. Middle colic vein. 24. Inferior mesenteric vein. 25. Splenic vein. 26. Portal vein. 27. Vena cava.

Black dotted line indicates site for mobilizing duodenum. White dotted line including 22 represents position of uncinate process running behind mesenteric vessels. (Coffey; in Binnie's Regional Surgery.)



The **body** [corpus pancreatis] is the triangularly prismatic portion of the pancreas extending from the neck on the right to the tail on the left. Its *direction* is transversely to the left and (usually) somewhat upward. It is therefore usually placed at a somewhat higher level than the head, opposite the first lumbar vertebra. It presents three surfaces—anterior, posterior, and inferior—and three borders—superior, anterior, and posterior.

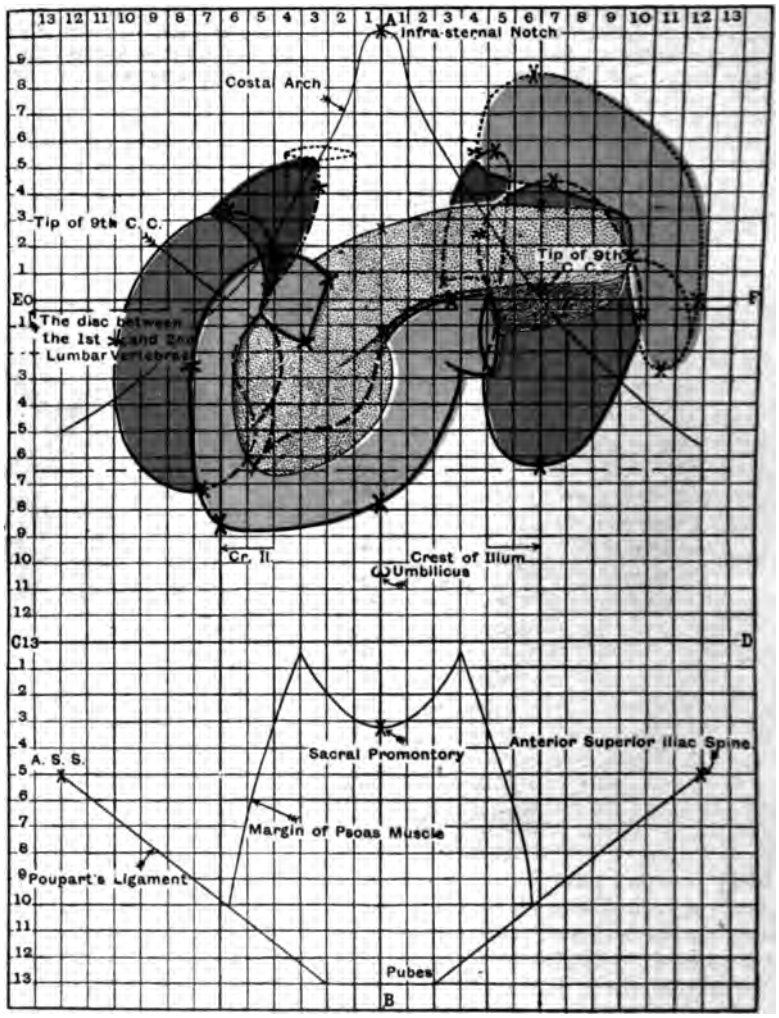
Of the **surfaces,** the **anterior** [facies anterior] faces forward and somewhat upward. It is covered with the peritoneum of the posterior wall of the bursa omentalis (lesser sac), and forms a slightly concave area which is in contact with the posterior surface of the stomach (figs. 636, 922, 924, 933). The **posterior** surface [f. posterior] of the body of the pancreas is flattened and retroperitoneal. From right to left it crosses the anterior aspect of aorta, left suprarenal body and left kidney. The splenic vessels also run along the posterior surface, the artery, which is above, corresponding more nearly with the superior border. The **inferior** surface [f. inferior] is usually the narrowest of the three. It is covered by peritoneum (continuous with the lower layer of the transverse mesocolon) and is in

contact with the duodenojejunal flexure medially and with coils of jejunu laterally.

Of the **borders,** the **superior** [margo superior] is related with the splenic arte along its whole length from its origin in the celiac, and the **posterior** [mar posterior] separates posterior and inferior surfaces. The **anterior** border [mar anterior] is sharp and prominent. It gives attachment to the transverse me colon (fig. 636), whose upper layer (belonging to the lesser sac) is continuous wi that on the anterior surface of the pancreas, and whose lower layer (belonging the greater sac) is continuous with that on the inferior surface.

The **tail** of the pancreas [cauda pancreatis] is at the left extremity of the bod It is variable in form, but usually somewhat blunted and upturned. It is almo

FIG. 965.—OUTLINE SHOWING THE AVERAGE POSITION OF THE DEEPER ABDOMINAL VISCE IN 40 BODIES, ON A CENTIMETER SCALE (reduced to 0.36 natural size). *AB*, anterior midli *EF*, 'midepigastric' line. (Addison.)



invariably in contact *laterally* with the medial aspect of the spleen, and *inferiorl* with the splenic flexure of the colon. The splenic vessels often cross from abov in front of the tail of the pancreas on their way to join the spleen.

Ducts.—The pancreas has usually two ducts, the main pancreatic duct and th accessory duct. The *main pancreatic* or *duct of Wirsung* [ductus pancreaticus Wirsungi] begins in the tail of the pancreas, and extends to the right within th body of the pancreas, about midway between upper and posterior borders, bu nearer the posterior surface (fig. 964). It runs a slightly sinuous course receivin branches all along, which enter nearly at right angles. It is largest in the hea of the pancreas (diameter about 3 mm.) where it turns obliquely downward.

As the pancreatic duct approaches the duodenum, it is joined by the common bile-duct, the two running side by side. They pass obliquely through the wall of the duodenum for a distance of about 15 mm. (usually causing a fold of the mucosa, the plica longitudinalis duodeni). They terminate finally, usually by a common aperture, but sometimes separately, on the duodenal *papilla major*, as described in connection with the interior of the duodenum. The common aperture is somewhat narrow, but just preceding this the duct is frequently dilated, forming what is called the *ampulla of Vater*.

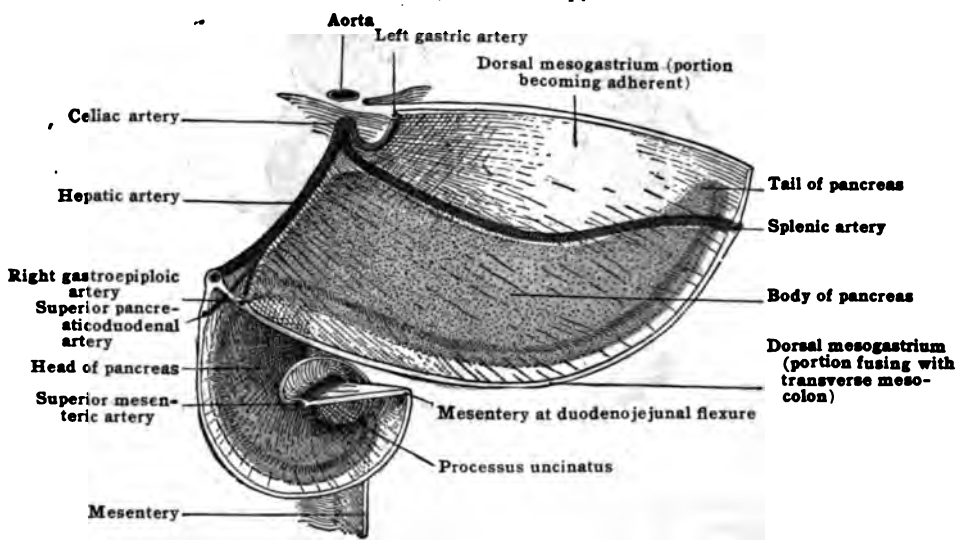
The *accessory pancreatic duct* (duct of Santorini) is usually present (fig. 964), but variable. This duct is small, and lies within the head of the pancreas.

At its left end, it usually joins the main duct in the neck of the pancreas. From here it extends nearly horizontal across to the upper part of the descending duodenum and, piercing its wall, usually ends upon the small *papilla minor*, about 2 cm. above and slightly ventral to the papilla major. The relations of the ducts are explained by its development.

Blood-vessels.—The pancreas receives blood chiefly from the splenic artery through its pancreatic branches, and from the superior mesenteric and hepatic by the inferior and superior pancreaticoduodenal arteries, which form a loop running around, below, and to the right of its head. The blood is returned into the portal vein by means of the splenic and superior mesenteric veins.

Lymphatics.—The lymphatics terminate in numerous glands which lie near the root of the superior mesenteric artery, above and below the neck of the pancreas. All the lymphatics drain ultimately into the celiac glands.

FIG. 966.—DIAGRAM SHOWING THE RELATIONS OF THE PANCREAS TO THE PRIMITIVE MESENTERY. (Poirier-Charpy.)



Nerves.—These are branches of the celiac plexus which accompany the arteries entering the gland. The main part of the celiac plexus lies behind the gland.

Minute anatomy.—In many respects, the pancreas resembles the salivary glands in structure, hence its German name 'Bauchspeicheldrüse' ('abdominal salivary gland'). The gland proper is racemose (or tubuloracemose) in structure. The thin-walled intercalary ducts, often invaginated to form centroacinar cells, are characteristic. The lobules are very loosely joined by areolar tissue, and there is no distinct fibrous capsule around the gland. The most important of the distinctive characters of the pancreas is the presence throughout the gland of numerous small interlobular cell-masses of varied form and size—the *islets of Langerhans* (fig. 967). These have no ducts, but are richly supplied with blood-vessels. They are ductless glands of great importance in sugar metabolism, and their removal or disease produces diabetes. While derived embryologically from the same entodermal anlage which gives rise to the pancreas gland proper, they apparently have no direct connections with it in the adult.

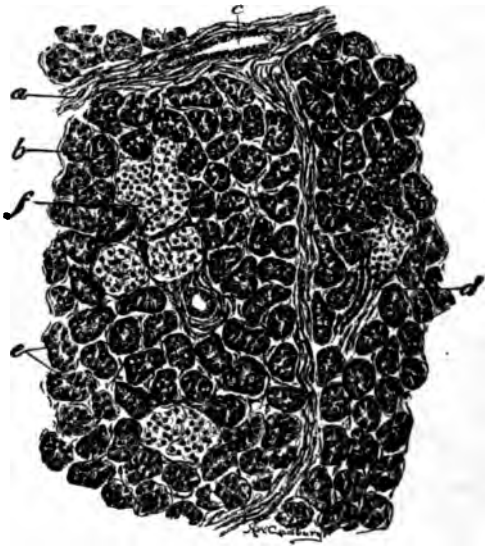
Development of the pancreas.—The earlier stages of development of the pancreas are described in Section I, p. 47. Of the adult gland, only the lower portion of the head is derived from the primitive ventral anlage, although the duct of the latter drains nearly the entire adult gland. The upper part of the head of the pancreas, and all of the body and tail are derived from the dorsal anlage; although most of its duct joins with the duct of Wirsung to form the main pancreatic duct, only a small part persisting as the accessory duct of Santorini.

During the early stages in the development of the pancreas the entodermal buds from which its forms grow into the mesoduodenum, and later the dorsal mesogastrium. With the rotation of the stomach and the consequent change in the position of the mesogastrium and its partial fusion with the abdominal wall (see *general morphogenesis*, p. 1173), the pancreas assumes a retroperitoneal position. This is illustrated by fig. 966. The head of the pancreas is involved in the rotation of the primitive intestinal loop around the superior mesenteric artery. This

accounts for the position and the hook-like form of the processus uncinatus. Following this rotation, the duodenum and the head of the pancreas become pressed backward against the posterior abdominal wall, where they become adherent, with fusion and obliteration of the primitive peritoneum. The body of the pancreas, extending into the dorsal mesogastrium (fig. 915), is similarly caught in the pouch-like downgrowth of the latter to form the bursa omentalis (lesser sac), and is thereby carried over to the left side. When the posterior layer of the primitive bursa fold becomes fused with the posterior abdominal wall, the enclosed pancreas is likewise fixed and becomes retroperitoneal. Of these obliterated peritoneal layers of the embryo, only certain layers of fascia remain as their representatives in the adult. From the lower aspect of the pancreas downward, the posterior layer of the bursa fold becomes fused with the transverse mesocolon, so that in the adult the latter appears to arise from the anterior border of the pancreas (fig. 922).

Variations.—Aside from minor fluctuations in size and form, the variations of the pancreas are chiefly congenital and of embryonic origin. Cases of *accessory or supernumerary pancreas* are not rare. They are usually of small size and have separate ducts. They may occur along the wall of the duodenum, or even in the stomach or jejunum. They are perhaps in some way connected with the numerous intestinal diverticula which occur in the embryo. *Divided pancreas*

FIG. 967.—SECTION OF HUMAN PANCREAS, MAGNIFIED, SHOWING SEVERAL ISLETS OF LANGERHANS. (Radasch.) *a*, Interlobular connective tissue, containing an interlobular duct, *c*. *b*, Capillary. *d*, Interlobular duct. *e*, Alveoli. *f*, Islet of Langerhans.



differ from the accessory in that a mass of the pancreas becomes separated from the main gland, connected only by a duct. This occurs oftenest in the region of the tail (sometimes extending into the spleen) or of the processus uncinatus, forming what is termed a 'lesser pancreas.' Sometimes a ring of glandular tissue from the head of the pancreas surrounds the descending duodenum, forming an *annular pancreas*. Variations in the *direction* of the body are numerous; it may be horizontal, ascending or bent in various ways. These are doubtless congenital variations, as similar types have been described in the fetus (Jackson). It has been experimentally demonstrated that varying degrees of distention of the stomach and intestines affect profoundly the *form of the body* of the pancreas. When the stomach alone is distended, the pancreas is flattened anteroposteriorly, the inferior surface being practically obliterated. When *both* stomach and intestines are distended, the pancreas is flattened from above downward, and extends forward like a shelf, the posterior surface being much reduced (Jackson). Numerous variations in the *ducts* are easily understood from their complicated development. The accessory duct (of Santorini) is in the fetus as large as the main duct (of Wirsung), the preponderance of the latter being established later. The accessory duct in the adult may be larger than usual, and retain its primitive drainage, or even drain the entire gland in rare cases where the duct of Wirsung is absent. Or the accessory duct may be rudimentary or (rarely) absent. Similar variations occur in the main duct of Wirsung. Rarely the pancreas may open into the duodenum by three ducts, probably representing three embryonic anlages. Abnormalities of the pancreas are often associated with duodenal diverticula.

Comparative.—The pancreas, like the liver, is constant throughout the vertebrates. It always arises by budding off from the endodermal epithelium of the intestine, closely associated with the liver. There is typically a triple anlage (rarely multiple, which is perhaps the ancestral type), with one dorsal and two ventral outgrowths. These fuse and form the adult pancreas in a variety of ways. In many of the fishes, the pancreas is very small, diffuse and inconspicuous, sometimes embedded in the liver or intestinal wall. Of the three primitive ducts, usually only two persist (as in man), but often only one, or all three (in birds). All three types occur in mammals. The islets of Langerhans arise from the epithelial pancreas anlage, and ap-

pear to be constantly present, even in the lowest vertebrates. Laguesse even considers that phylogenetically they form the most primitive part of the pancreas, but this is doubtful.

References for digestive system.—*General and Comparative:* Quain's Anatomy, 11th ed.; Poirier-Charpy, Traité d'anatomie; Rauber-Kopsch, Lehrbuch der Anatomie, 9te Aufl.; Oppel, Mikroskopische Anatomie, Bd. 1–3; also 'Verdauungsapparat' in Merkel and Bonnet's 'Ergebnisse'; Wiedersheim, Bau des Menschen; Huntington, Anatomy of the Peritoneum and Abdomen, 1903. *Topography:* (adult) Merkel, Topographische Anatomie; (developmental) Jackson, Anat. Rec., vol. 3. *Development:* Keibel and Mall's Manual. *Teeth:* Tomes, Dental Anatomy; Bean, Amer. Jour. Anat., vol. 17, 1914; James and Pitts, Proc. Roy. Soc. Med., vol. 5, 1912. *Tonsils:* (lingual) Jurisch, Anatomische Hefte, Bd. 47; (pharyngeal) Symington, Brit. Med. Jour. (Oct., 1910); (palatine) Killian, Archiv f. Laryngol., Bd. 7. *Esophagus:* Goetsch, Amer. Jour. Anat., vol. 10. *Stomach:* (structure), Bensley, Buck's Ref. Handb. Med. Sc., vol. 7 (1904); (form) Cunningham, Trans. Royal Soc. Edinb., vol. 45; (radiography) Cole, Archives Roentgen Rays, 1911; Forssell, Fortschr. auf dem Gebiete der Röntgenstr., Ergängungsband 30, 1913; Mills, Amer. Jour. Roentg., Apr. 1917. *Vermiform process:* Berry and Lack, Jour. Anat. and Phys., vol. 40. *Rectum:* Symington, Jour. Anat. and Phys., vol. 46. *Liver:* Mall, Amer. Jour. Anat., vol. 5. *Pancreas:* (islets) Bensley, Amer. Jour. Anat., vol. 12; (ducts) Baldwin, Anat. Rec., vol. 5.

SECTION XI

THE RESPIRATORY SYSTEM

REVISED FOR THE SIXTH EDITION

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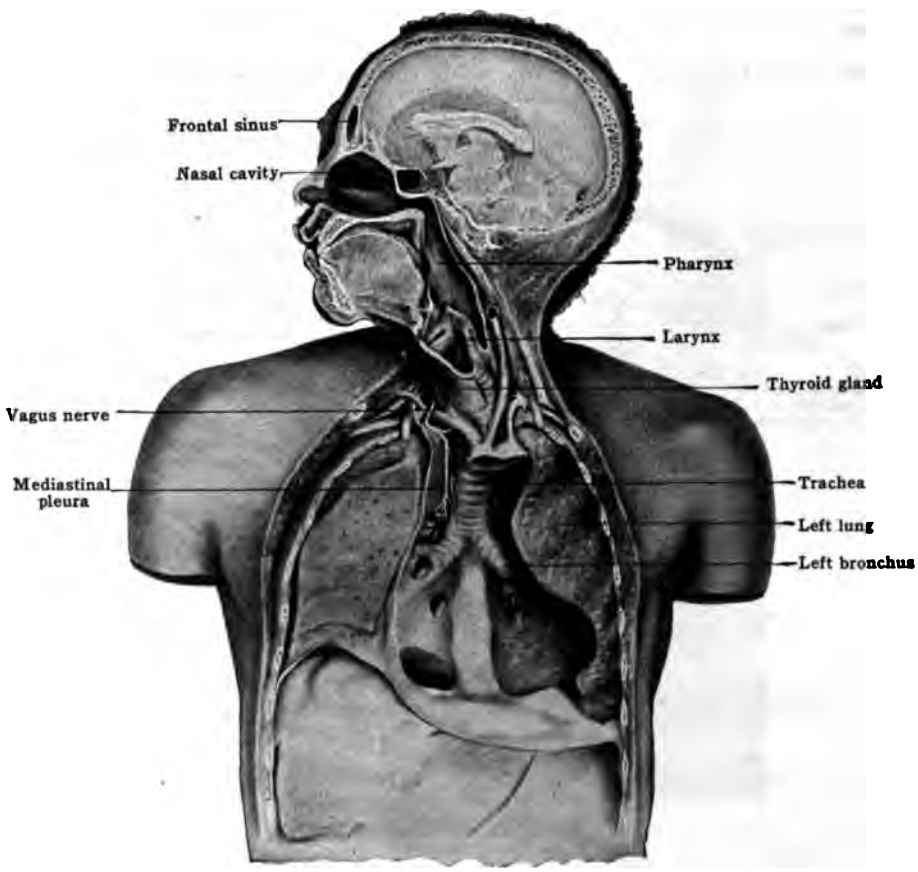
RESPIRATION in one form or another is one of the basic characteristics of living things It consists essentially in the absorption by the organism of oxygen and the discharge of a metabolic waste-product, carbon dioxide. The lungs in air-breathing vertebrates are eminently the seat of the interchange of these gases between the body and the air.

FIG. 968.—DISSECTION OF A MALE NEGRO, AGE 43 YEARS, TO SHOW THE ORGANS OF RESPIRATION IN SITU.



Among unicellular animals the oxygen is taken up directly from the medium—water or air—in which they live, and the carbon dioxide given off into it. With the cells which make up the body of higher animals the principle is the same, but the interchange of gases is indirect. The blood stands as an intermediate element between the cells of the body and the medium inhabited

pharynx and mouth in connection with alimentation, the several portion
nose functioning in the sense of smell. (For the description of the mou
pharynx see Section X; for the olfactory organ see Section IX.)

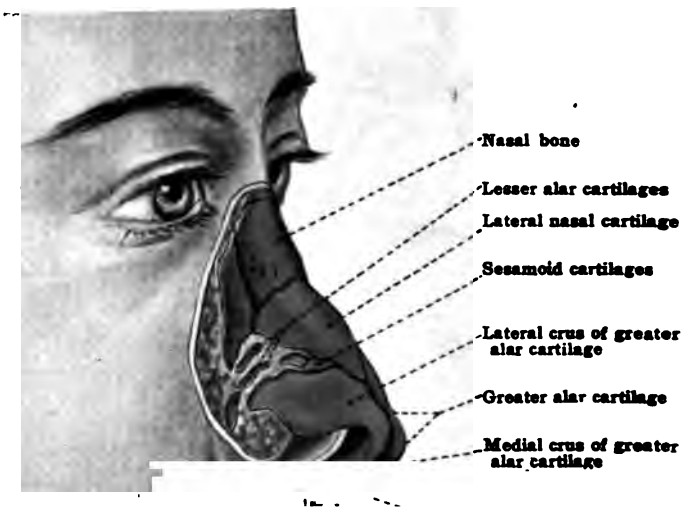
The organs of circulation are always adapted to the form of the respiratory appar
among all higher animals a connection is established between heart and lungs by the pu
artery, which carries venous blood to the latter, and by the pulmonary veins, whicl
arterial blood from the lungs to the heart, whence the aorta takes it into the general cir

In their origin and development, the respiratory organs are closely associated
differentiated from the beginnings of the digestive apparatus. Thus the processes of t
development of the nasal cavity and mouth are interdependent; the origin of the gre
of the larynx, the trachea and lungs is by outgrowth of the entodermal canal.

THE NOSE

The nose will here be described under three main heads as follows:
external nose; B, the internal nose or nasal cavity; C, the paranasal or ac
sinuses.

FIG. 969.—THE CARTILAGE OF THE EXTERNAL NOSE AS DISPLAYED (PROFILE VIEW)
THE REMOVAL OF THE SKIN AND MUSCLES. (Schaeffer.)

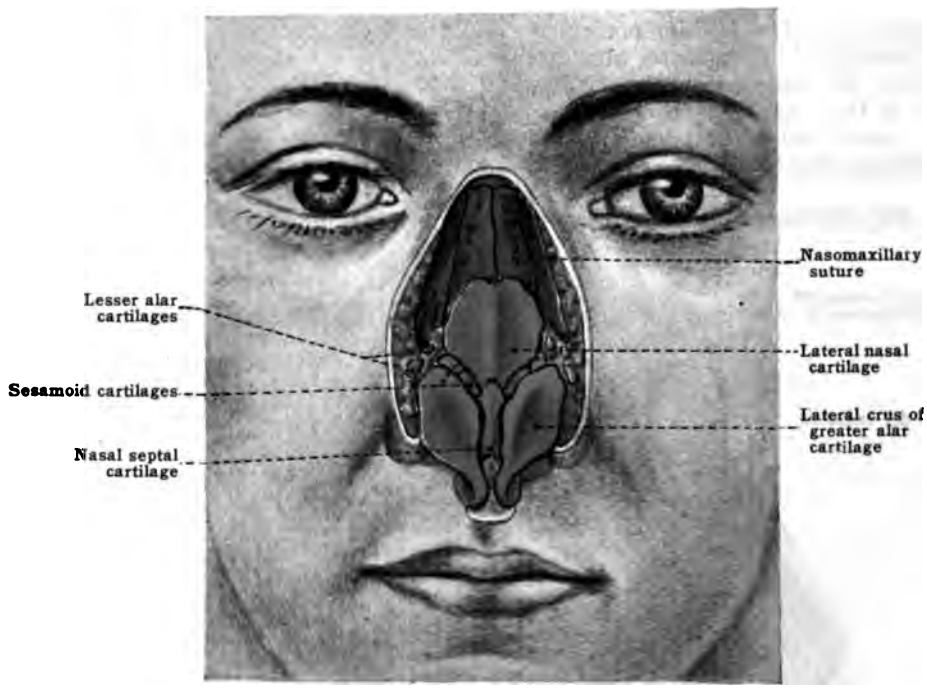


is a rounded ventral border, the **dorsum** of the nose [dorsum nasi], which may be either straight, convex, or concave, and which ends inferiorly at the **apex** of the nose [apex nasi]—the latter either in line with the dorsum nasi, depressed or upturned. The superior part of the dorsum is known as the bridge. Inferiorly, overhanging the upper lip, is the **base** of the nose [basis nasi] which presents two orifices, the **nares** or nostrils, separated from one another by the movable part of the nasal septum [septum mobile nasi].

The **sides of the nose** [partes laterales nasi] slope from the dorsum laterally and posteriorly, and below terminate on each side in the **margin** of the nose [margo nasi]; posteriorly and inferiorly the sides are expanded and more convex, forming the **alæ nasi.** Each of these is separated from the rest of the lateral surface by a sulcus, and the inferior free margin of each bounds a naris laterally.

Three types of nose, distinguished by differences in the proportion of breadth and length, are shown by the cephalometric nasal index $\left(\frac{\text{greatest breadth} \times 100}{\text{greatest length}}\right)$: the leptorrhine or long, high nose; the platyrrhine or short, low nose; the mesorrhine, a form intermediate between the other two. The leptorrhine type (index below 70) prevails among white races, the platyrrhine (index above 85) in the black peoples, and the mesorrhine (index between 70 and 85) in the red and yellow races. Minor variations in the morphology or shape of the external nose are numerous and of little significance; they represent individual and family characteristics.

FIG. 970.—THE CARTILAGES OF THE EXTERNAL NOSE AS DISPLAYED (FRONTAL VIEW) AFTER THE REMOVAL OF THE SKIN AND MUSCLES. (Schaeffer.)

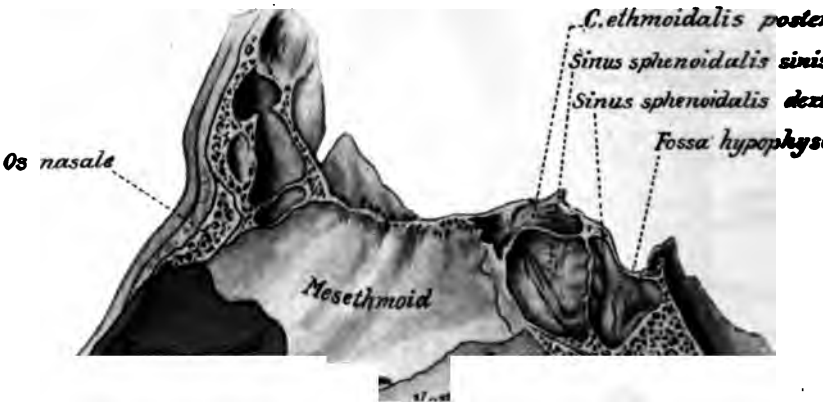


The framework of the external nose is formed partly of bone and partly of hyaline cartilage. The bones, which form only the smaller superior part, are the two nasal bones and the frontal processes and anterior nasal spines of the two maxillæ (pp. 155, 158).

The nasal cartilages [cartilagines nasi] (figs. 969–971) are located about the piriform aperture and constitute the larger part of the nasal framework. There are five principal cartilages: superiorly, the two *lateral nasal cartilages*; inferiorly the two *greater alar cartilages*, and the single median *nasal septal cartilage.* Besides these there are the *lesser alar cartilages*, the *sesamoid cartilages*, and the *vomeronasal cartilages* of Jacobson. The **lateral nasal cartilages** are triangular and nearly flat lateral expansions of the septal cartilage, placed one on each side of the nose just inferior to the nasal bone. Each presents an ental (deep) and an ectal (superficial) surface and three margins. The medial margin is continuous in its superior third with the anterior margin of the septal cartilage, and

the septum. The inferior margin is connected by fibrous tissue to the alar cartilage. The **greater alar cartilages** [cartilagines alares majores], in form, are situated one on each side of the apex of the nose (figs. 96 Each is thin, pliant, curved, and so folded that it forms a **medial and** crus, which bound and tend to hold open each naris. **The medial cr** mediale] is loosely attached to its fellow of the opposite side, **the two bei**

FIG. 972.—A DISSECTION SHOWING THE OSSEOUS AND CARTILAGINOUS SEPTUM OF TI
(Schaeffer.)



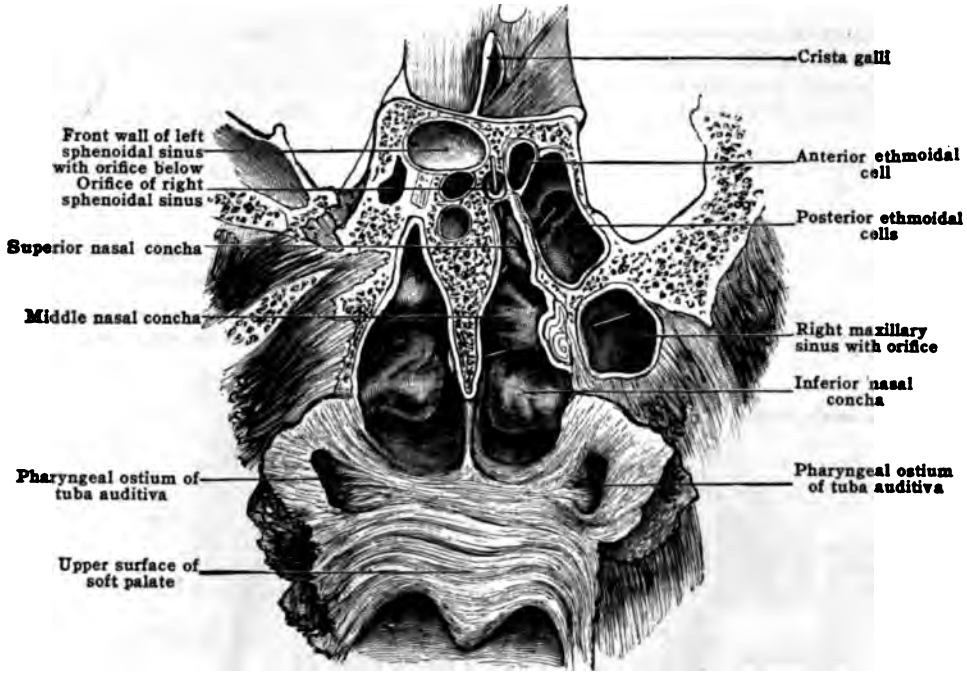
The angle formed by the crura (angulis pinnalis) varies with the shape of the nose; it averages 30°. The greater and lesser alar cartilages together form an incomplete ring around the naris.

A variable number of small cartilages, **lesser alar cartilages** [cartilagines alares minores] are found in the fibrous tissue of the ala, and in the interval between each greater alar and lateral cartilage occur one or more small plates, **sesamoid cartilages** [cartilagines sesamoideæ] (figs. 969, 970). Occasionally a posterior extension of the lateral crus of the greater alar cartilage replaces in part or in whole the lesser alar cartilages.

The **cartilaginous portion of the nasal septum** is formed by the septal cartilage, the vomeronasal cartilages and the medial crura of the greater alar cartilages (described above).

The **septal cartilage** [cartilago septi nasi] (fig. 972) forms the anterior part of the septum. It is quadrilateral in shape and fits into the triangular interval of the bony septum. Its anterosuperior margin in its upper part meets the inter-

FIG. 973.—OBLIQUE SECTION PASSING THROUGH THE NASAL CAVITY JUST IN FRONT OF THE CHOANÆ. (Seen from behind.)


Crista galli
Front wall of left sphenoidal sinus with orifice below
Orifice of right sphenoidal sinus
Anterior ethmoidal cell
Posterior ethmoidal cells
Superior nasal concha
Middle nasal concha
Right maxillary sinus with orifice
Inferior nasal concha
Pharyngeal ostium of tuba auditiva
Pharyngeal ostium of tuba auditiva
Upper surface of soft palate

nasal suture. Inferior to the nasal bone it presents a shallow groove which gradually narrows toward the tip of the nose, and whose borders are continuous superiorly with the lateral nasal cartilages, but are separated from their inferior two-thirds by a narrow slit. The most inferior part of this margin of the septal cartilage is placed between the greater alar cartilages. The anteroinferior margin extends backward from the rounded anterior angle to the anterior nasal spine. Inferiorly it is attached to the medial crus of the greater alar cartilage and to the mobile nasal septum. The posterosuperior margin is attached to the perpendicular plate of the ethmoid, and the posteroinferior margin joins the vomer and the anterior part of the nasal crest of the maxilla, the cartilage broadening out to obtain a wide though lax attachment to the nasal spine.

The *shape and size* of the septal cartilage varies with the extent of the ossification of the bony septum. Posteriorly the septal cartilage extends variously between the vomer and the perpendicular lamina of the ethmoid, thus forming the **sphenoidal process of the septal cartilage**. Indeed, the latter may be sufficiently elongated to reach the sphenoid bone—especially in children—and very frequently is the seat of a ridge-like horizontal projection into one or the other nasal fossa, causing septal asymmetry.

The **vomeronasal cartilages** [cartilagines vomeronasales, Jacobsoni] (fig. 972) are two narrow longitudinal strips, 7 to 15 mm. in length, which lie along the anterior portion of the inferior border of the septal cartilage. In this position the vomeronasal cartilages are attached to the vomer posteriorly and to the maxilla and the septal cartilage anteriorly. The vomeronasal

cartilages are not always differentiated from the septal cartilage. In man these cartilages reach their maximum development in the embryo. They are, however, always most conspicuous in animals in which the vomeronasal organ is well developed, forming a protecting and supporting framework for the organ.

Muscles.—The muscles of the external nose are grouped according to function as dilators and contractors, the latter being comparatively feeble in their action. They are described on p. 369.

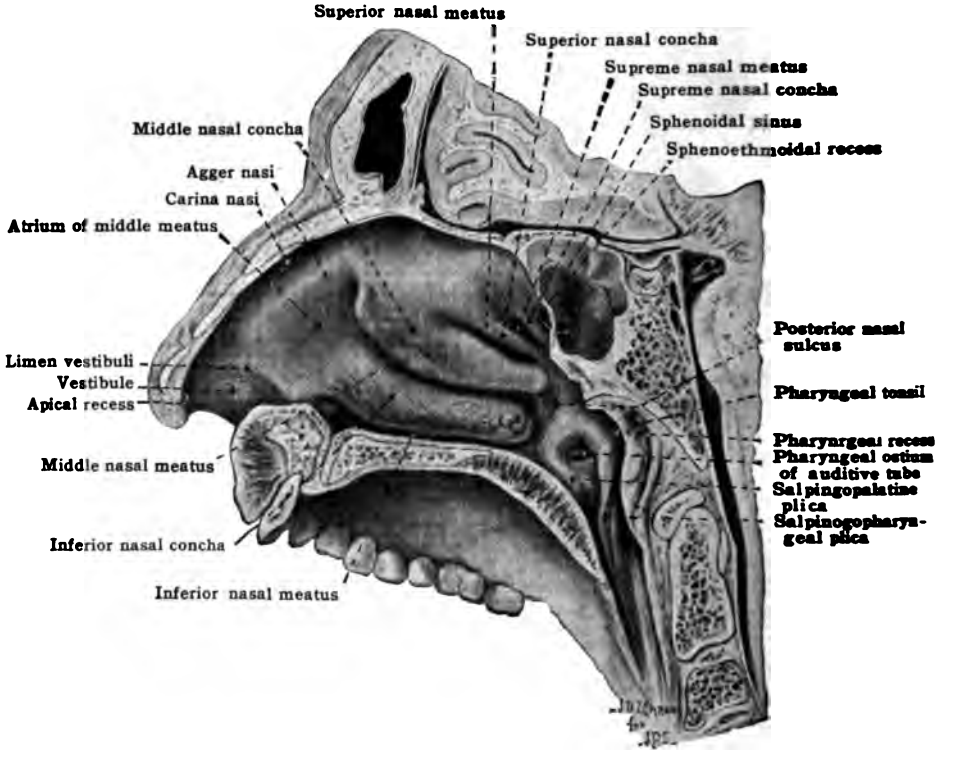
Skin.—The skin covering the external nose is thin and freely movable upon the subjacent parts, except at the tip and over the cartilages, where it is much thicker, more adherent, and furnished with numerous exceptionally large sebaceous glands. At the nares it is reflected into the nasal cavity, where it passes into the mucous membrane. The hairs on the skin of the nose are very fine, except in the nares, where they may be strongly developed.

Vessels and nerves.—The arteries of the external nose are derived from the external maxillary (facial) artery (pp. 582 and 583), the ophthalmic artery (p. 595), and the infraorbital artery (p. 590). The veins terminate in the anterior facial vein and the ophthalmic vein (p. 692). The lymphatics pass to the submaxillary and parotid lymphatic nodes (p. 742). The motor nerves are branches of the facial (p. 978). The sensory nerves are derived from the trigeminal through the frontal and nasociliary branches of the ophthalmic (p. 970) and infraorbital branch of the maxillary (p. 972).

THE INTERNAL NOSE

The **internal nose** consists of the nasal cavity and ancillary structures. The general **nasal cavity** [cavum nasi] is the roomy space situated between the floor of the cranium and the roof of the mouth, extending anteriorly into the external nose and posteriorly to the nasal part of the pharynx. The cavity is divided by a

FIG. 974.—LATERAL WALL OF THE RIGHT NASAL FOSSA AND THE NASAL PHARYNX.



median **septum** [septum nasi] into two more or less symmetrical halves—the **nasal fossæ** [fossæ nasales]. Moreover, the fossæ are further incompletely divided into **nasal meatuses** [meatus nasi] by the **nasal conchæ or turbinates** [conchæ nasales], and are extended into neighboring bones by the **paranasal** or accessory **sinuses** [sinus paranasales]. The nasal fossæ communicate freely with the exterior through the **nares** (anterior nares) and with the nasopharynx dorsally through the **choanæ** (posterior nares). With the exception of the anterior portion of the nose, where the boundaries are completed by cartilages and membranes, the walls of the nasal cavity are almost wholly of bone as described in the section on OSTEOLOGY (pp. 115–117). The walls of the nasal cavity are covered

by periosteum and mucous membrane, the latter presenting important histological differences, leading to the division of the nasal cavity into **respiratory** and **olfactory** portions [regiones respiratoria et olfactoria]. The former, the lower and greater portion of the nasal cavity, has especially to do with the function of respiration and the latter, the extreme upper portion of the nasal cavity, is primarily concerned with the function of smell and is, strictly speaking, the **peripheral olfactory organ** (see Section IX for the olfactory organ proper).

The nasal fossæ.—The paired nasal fossæ are roughly triangular in the frontal or coronal plane (fig. 975). The narrow roof of each fossa may be considered the apex of the triangle and the wider floor the base, the mesial or septal wall, normally even and approximately vertical, meeting the floor at nearly a right angle. The lateral wall, the hypotenuse of the triangle, is sloping and configured by the nasal conchæ and meatuses and the encroaching paranasal air sinuses. In sagittal section (fig. 974) each nasal fossa is quadrangular in shape, the roof being more or less parallel with the floor, the anterior side conforming to the profile of the external nose and forming with the floor at the naris an acute angle, and the posterior side passing from the anterior surface of the body of the sphenoid bone, through the choana of the respective side to the juncture between the hard and soft palates. The posterior limit of the nasal fossa is indicated on the lateral nasal wall by the *posterior nasal sulcus* (fig. 974).

While there is considerable variation in the dimensions of the nasal fossæ, the following may be taken as representative dimensions: The greatest sagittal diameter, measured from the most prominent part of the naris along the floor of the nasal fossa to the posterior border of the hard palate, is 74 mm.; the greatest sagittal diameter, measured along the roof of the fossa, is 35 mm. or less; the greatest vertical diameter, measured from the cribriform plate to the nasal floor, is from 40 to 45 mm.; the width of the roof 3 mm. or less; the width of the floor, measured at the greatest lateral expansion of the inferior meatus, varies from 12 to 23 mm.

The vestibules [vestibula nasi].—The vestibules are the dilated passage-ways leading in from the nares and may be considered antechambers to the nasal fossæ, corresponding more or less to the cartilaginous portion of the external nose and supported by the medial and lateral plates of the greater alar cartilages and adjacent portions of the nasal septum and integument.

The extension of the vestibule into the tip of the nose is often referred to as the *ventricle* of the vestibule, or the *recessus apicis* (fig. 974). On the lateral wall the vestibule is marked off from the rest of the nasal fossa by a distinct ridge, the *limen nasi* (or limen vestibuli), corresponding to the superior margin of the greater alar cartilage (fig. 974). At the limen nasi the skin lining the vestibule suffers a transition into the mucous membrane lining the nasal fossa proper. The skin lining the vestibule is beset with large hairs called vibrissæ, and contains sudoriferous and sebaceous glands.

The choanæ (posterior nares).—These are the paired communicating passage-ways between the nasal fossæ and the nasal pharynx (fig. 974). The apertures are oval in form with the vertical diameter greater than the transverse, the comparison being shown by the *choanal index*, $\frac{\text{transverse diameter} \times 100}{\text{vertical diameter}}$. They have definite osseous boundaries and are lined with mucoperiosteum continued from the nasal fossæ into the nasal pharynx. The choanæ are located at either side of the free posterior border of the nasal septum and are limited above by the body of the sphenoid and the alæ of the vomer, below by the line of junction of the hard and soft palates, laterally by the medial plates of the pterygoid processes. The osseous boundaries of the choanæ cause the apertures to stand permanently open and free for the transmission of air.

The transverse diameter of each choana varies from 12 to 17 mm. at the floor and from 7 to 10 mm. at the roof. The vertical diameter varies from 24 to 33 mm. The choanal index for the male averages approximately 61 and for the female 64.5. Posterior rhinoscopic examination reveals the choanæ, the nasopharyngeal meatus, the posterior extremities of the nasal conchæ and of the nasal meatuses beneath them.

The nasal septum (fig. 972).—The medial wall of the nasal fossa is formed by the nasal septum (fig. 972). It is supported posteriorly by a framework composed of osseous elements [septum osseum], anteriorly by cartilaginous elements (septum cartilagineum) and anteroinferiorly by integument and subcutaneous tela [septum membranaceum; septum mobile nasi]. The nasal mucous membrane covers all portions of both sides of the septum, save the vestibular part which is invested by integument continued through the nares from the exterior.

attached border of the inferior concha and below by the floor of the nose. It measures from 4.5 to 5.8 cm. in length, beginning variously from 2.5 to 3.7 cm. behind the tip of the nose. The inferior meatus is narrow anteriorly, expanding rapidly in width and height, to narrow again toward the choana.

The *ostium of the nasolacrimal duct* (fig. 976) is located on the anterior portion of the lateral wall of the inferior meatus, from 15 to 20 mm. behind the limen nasi and from 30 to 40 m. behind the naris. It is located either at the highest point of the inferior meatus or at varying distances (2 to 10 mm.) below this point. The ostium is usually a single opening, but duplication or triplication may occur. The aperture may be either located close to the attached border of the inferior concha, wide-mouthed, standing permanently open, or located lower, slit-like, collapsed and guarded by a fold of mucous membrane, the so-called valve of Hasner [plica lacrimalis, Hasneri].

The **middle nasal concha** [concha nasalis media] (figs. 974–976) is relatively large, hanging valve-like over the middle nasal meatus. It hides or operculates a number of secondary conchæ and furrows in the middle meatus. The contained osseous lamina, a part of the ethmoid bone, is covered by a thick mucous membrane, erectile in character.

FIG. 977.—ANATOMIC TYPE IN WHICH THE NASOFRONTAL DUCT AND THE INFUNDIBULUM ETHMOIDALE ARE CONTINUOUS. (After J. Parsons Schaeffer.)

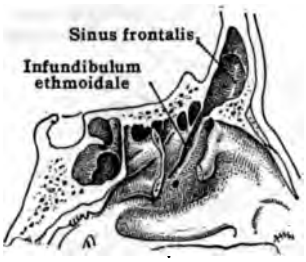
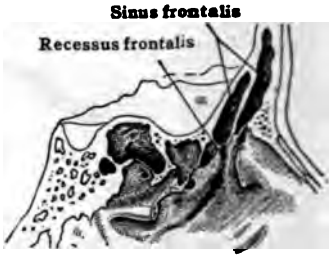


FIG. 978.—ANATOMIC TYPE IN WHICH TWO FRONTAL SINUSES ARE PRESENT, BOTH DISCONTINUOUS WITH THE INFUNDIBULUM ETHMOIDALE. (After J. Parsons Schaeffer.)



The free border of the concha presents a marked genu, giving rise to a short vertical or ascending limb and a larger horizontal or descending limb. The genu very commonly enlarges by the formation of a lobule, surmounted by a secondary nodule. Equally common is the presence of ethmoidal cells in the body of the concha media (see PARANASAL SINUSES).

The **middle nasal meatus** [meatus nasi medius] (figs. 974–976) is the most complex and important of the nasal meatuses. It is divided into an *ascending* and a *descending* ramus; the latter, spacious and arched, conforms to the contour of the middle and inferior conchæ; the former, often called the **frontal recess,** is much less roomy and is merely an extension frontalward of the middle meatus proper. On removing or turning upward the middle nasal concha one discloses on the lateral wall of the decending ramus of the middle meatus immediately below the attached border of the middle concha a conspicuous bleb-like structure—the **ethmoidal bulla,** and below the latter a sharp, crescentic lamella—the **uncinate process.** Between the free border of the uncinate process and the ethmoidal bulla is a crescentic cleft from 15 to 20 mm. long—the **semilunar hiatus,** which in turn leads from the middle nasal meatus into a crescentic groove of variable depth (from 1–12 mm.), the **ethmoidal infundibulum.**

The ethmoidal infundibulum usually ends blindly frontalward by forming one or more anterior ethmoidal air-cells (infundibular cells) (fig. 976) and ends posteriorly either in a pocket or merges gradually with the middle meatus. Occasionally it is directly continuous with the nasofrontal duct (infundibulum of the frontal sinus) or in the absence of the latter with the frontal sinus proper (fig. 977). The ethmoidal infundibulum contains in its depth the ostia or apertures of the infundibular group of anterior ethmoidal cells and the ostium of the maxillary sinus (ostium maxillare).

The groove or furrow located between the ethmoidal bulla and the attached border of the middle nasal concha is the *suprabullar furrow or recess.* It contains the apertures or ostia of most of those anterior ethmoidal cells sometimes classed as middle ethmoidal cells (bullar group of anterior ethmoidal cells).

The lateral wall of the middle nasal meatus between the attached border of the uncinate process and the inferior nasal concha is at places wholly membranous, and presents the acces-

ory maxillary ostium between the middle meatus and the maxillary sinus in from 25 to 40 per cent. of cases.

The anterosuperior portion of the middle nasal meatus, i. e., the vertical or ascending ramus (frontal recess) is a pouch-like extension communicating with the frontal group of anterior ethmoidal cells (fig. 976) and the frontal sinus. Occasionally the ethmoidal infundibulum and the duct of the frontal sinus or the frontal sinus proper are continuous channels and groove the lateral wall of the frontal recess (fig. 977); but usually the ethmoidal infundibulum and the nasofrontal duct are anatomically discontinuous channels (figs. 976, 978).

The **superior nasal concha** [concha nasalis superior] (fig. 974) is a short thin lamina of bone which projects from the lateral ethmoidal mass and slightly overhangs the superior nasal meatus. The mucous membrane covering the concha is thinner and less erectile in character than that of the middle and inferior conchæ. The **superior nasal meatus** [meatus nasi superior] (figs. 974, 976) is a narrow channel-like depression below the related concha and approximately half the length of the middle nasal meatus. Not infrequently an accessory concha molds the lateral wall of the superior meatus and divides the latter into superior and inferior recesses. The latter recesses and the anterior end of the superior meatus receive the ostia or apertures of the posterior ethmoidal cells.

The **supreme nasal concha** [concha nasalis suprema] (figs. 974, 976), found bilaterally or unilaterally in approximately 60 per cent. of bodies, is the smallest of the conchæ. It projects only slightly medialward from the posterosuperior part of the lateral nasal wall, overhanging the **supreme nasal meatus.** The latter, found in a corresponding number of bodies, is a shallow, short furrow which (in about 75 per cent. of cases) contains the ostium or aperture of a posterior ethmoidal cell (fig. 976).

Immediately above and behind the supreme concha, or the superior concha in those cases in which the former is wanting, is the **sphenoethmoidal recess** (figs. 974, 976). The latter lies in the angle between the ethmoid and the anterior surface of the body of the sphenoid bone. Posteriorly the recess receives the ostium of the sphenoidal sinus (figs. 974, 976).

The roof of the nasal fossa.—The roof of the nasal fossa (fig. 974) may be considered as a cranially arched structure with the cribriform plate forming the horizontal middle portion; the body of the sphenoid bone together with the wing of the vomer and the sphenoidal process of the palate bone, the curved posterior portion; and the frontal and nasal bones, the curved anterior portion. The entire framework is covered by nasal mucous membrane.

Anteriorly the roof of the fossa is very narrow, but it gradually widens as the choanal aperture is approached. The greatest breadth of the cribriform plate (roof proper) is approximately 5 mm. Cranially the cribriform plate supports the olfactory lobe of the brain (fig. 975) and is perforated by foramina for the passage of the olfactory nerves, etc. Anteriorly, close to the crista galli, is a longitudinal fissure (the nasal fissure) for the transmission of the anterior ethmoidal branch of the nasociliary nerve and the anterior ethmoidal vessels.

The floor of the nasal fossa.—The osseous framework of the nasal floor (figs. 974, 975) is formed by the palatal processes of the maxillæ and the horizontal processes of the palate bones. Mucous membrane covers the framework. The floor of each nasal fossa is essentially horizontal in the sagittal plane, a distinct elevation appearing just inside the limen nasi, and concave in the frontal plane.

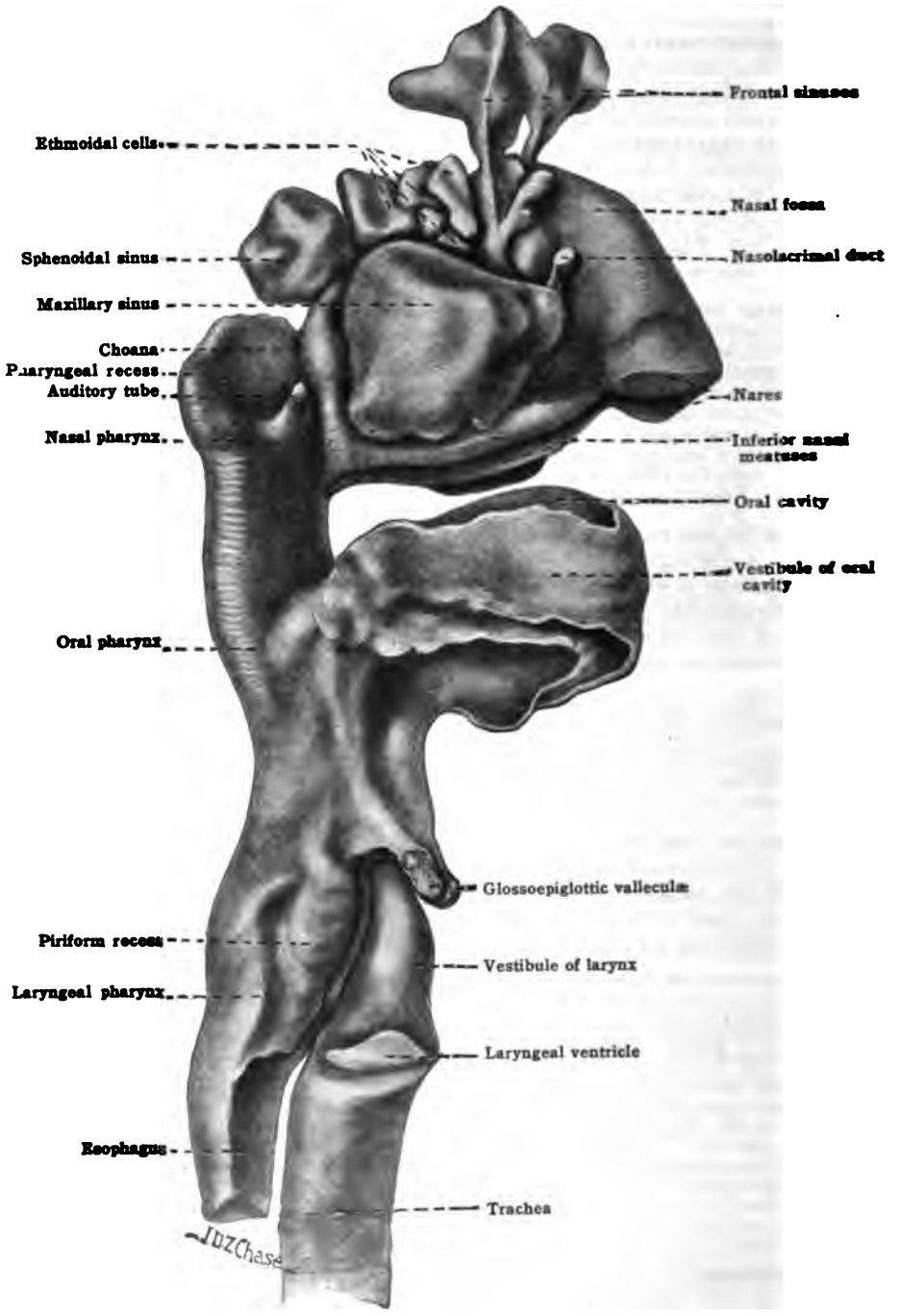
Approximately 2 cm. behind the inner margin of the nostril, each nasal fossa contains a slight depression in its floor which leads into a funnel-shaped tube of mucous membrane—the **nasopalatine canal** [canalis incisivus] or incisive canal of Stenson, located in the anterior palatine canal in the hard palate. The right and left nasopalatine canals may join and pass through the stem of the Y-shaped anterior palatine canal or incisive foramen as a common channel; however, more commonly each retains its individuality (Schæffer). The canals end in the roof of the mouth at the side of the palatine papilla. In the adult the lumina of the nasopalatine canals are usually obliterated by impervious cords of epithelial cells, but occasionally remain open (fig. 974). They are the remnants of the wide embryonic communication [ductus incisivus] between the nasal and oral cavities, which persist throughout life in many animals.

PARANASAL SINUSES

The **paranasal** (or accessory) **sinuses** [sinus paranasales] begin from the third to the fourth fetal month as evaginations from the mucosa of the nasal meatuses proper or their secondary furrows. However, the sphenoidal sinus is primarily a constriction from the posterosuperior region of the nasal fossa and is, therefore, not an outgrowth from a nasal meatus. The evaginating sacs wander into neighboring portions of the nasal walls, and by a joint growth of the sacs and an absorption of bone ultimately pneumatize large portions of the ethmoid, frontal,

maxillary and sphenoid bones in the formation of the *ethmoid cells*, *frontal sinus*, *maxillary sinus*, and *sphenoidal sinus*. respectively.

FIG. 979.—CAST OF THE NASAL FOSSÆ, PARANASAL SINUSES, ORAL CAVITY, PHARYNX AND LARYNX. Lateral view. After a cast by J. P. S. and C. H. H. in the Daniel Baugh Institute of Anatomy of the Jefferson Medical College.



Although many of the paranasal sinuses grow far from the point of initial evagination, the initial or primary points of outgrowth persist in the adult as the ostia or apertures of communication between the sinuses and the nasal fossa. The location, form and relations of the paranasal sinuses as found in the dried skull (in which the ostia may be considerably larger) have been briefly described in the section on OSTEOLOGY.

The maxillary sinus [sinus maxillaris] (antrum of Highmore).—The adult maxillary sinus is located in the body of the maxilla and is, as a rule, the largest of the pneumatic paranasal chambers (figs. 975, 979). It follows in the main the shape of the body of the maxilla and may be described as having a roof, a floor, and three walls. The *medial wall* or base forms part of the lateral wall of the nasal cavity, and the *apex* extends into the zygomatic process of the maxilla, or beyond it into the maxillary border of the zygomatic bone. The *anterior wall* of the maxillary sinus corresponds to the anterior or facial wall of the maxilla; the *posterior wall* to the infratemporal surface of the maxilla; the *roof* to the orbital surface of the maxilla, and the *floor* to the alveolar process of the maxilla. A thin mucous membrane, continuous through the aperture of the sinus with that lining the nasal fossa, lines the maxillary sinus throughout.

In very many instances the maxillary sinus is not a simple pneumatic cavity or chamber, but is incompletely divided into subcompartments and recesses by osseous and membranous septa. Sometimes a posterior ethmoidal cell grows into the body of the maxilla behind the maxillary sinus proper, the condition simulating a division of the maxillary sinus into two complete and separate compartments.

The number of teeth that bear direct relations to the floor of the maxillary sinus varies with the degree of excavation of the alveolar process of the maxilla. The teeth most constantly in intimate relationship to the maxillary sinus are the three molars and the second premolar; or, when the sinus is small, the second and third molars only. The majority of maxillary sinuses have their floors at varying distances below the level of the floor of the nasal fossa.

The maxillary sinus communicates with the deep aspect of the posterior half of the infundibulum ethmoidale by means of an oval or elongated aperture or ostium, the **ostium maxillare.** The ostium is very disadvantageously placed as a drainage opening, since it is located at the highest point in the medial wall of the cavity, and opens into the narrow infundibulum ethmoidale (described above). The ostium maxillare is sometimes double (fig. 975).

In more than one-third of specimens the maxillary sinus contains an additional aperture, the **ostium maxillare accessorium,** which communicates directly with the middle nasal meatus proper. The aperture is usually located between the posterior third of the processus uncinatus and the adjacent part of the attached border of the inferior nasal concha. It is more advantageously placed for drainage than is the constant aperture.

Measurements of 150 specimens of the adult maxillary sinus gave as the average the following (Schaeffer): posterosuperior diagonal, 38 mm.; anterosuperior diagonal, 38.5 mm.; superoinferior, 33 mm.; anteroposterior, 34 mm.; mediolateral, 23 mm. Increase in capacity of the maxillary sinus is not infrequently observed as the result of more extensive excavation of the bony processes of the maxilla, e. g., the alveolar, palatal, frontal and zygomatic. A lessened capacity may be due to unusually thick sinus walls, bulging sinusward of the facial and nasal walls, and the retention of certain teeth.

The frontal sinus [sinus frontalis].—The paired frontal sinuses (figs. 976, 979) are located between the outer and inner laminæ (tables) of the frontal bone and are extremely variable in size, shape and type (cf. pp. 131 and 1335). They develop variously as a direct extension of the whole frontal recess of the middle nasal meatus, from one or more anterior ethmoidal cells which have their points of origin in the furrows of the frontal recess, or occasionally from the anterior extremity of the ethmoidal infundibulum. The frontal sinuses are usually asymmetrical, one frequently encroaching markedly upon the confines of the other, with a corresponding displacement of the intervening septum [**septum sinuum frontalium**].

Seldom, indeed, are the frontal sinuses simple chambers, being more or less divided into subcompartments or recesses by incomplete bony partitions. Supernumerary frontal sinuses are extremely common, each with an independent connection with the nasal cavity. As many as six frontal sinuses have been observed in one skull. Rarely one or both sinuses are wholly wanting.

The typical frontal sinus may be said to be pyramidal, occupying the squama frontalis or vertical portion of the frontal bone. The pyramidal shape, however, of the sinus is very commonly greatly modified, by the extension of the cavity into the pars orbitalis of the frontal bone. Often it does not invade far into the vertical portion of the frontal bone, but grows extensively into the orbital portion. There may be a total absence in one or the other portion.

The frontal sinus usually communicates with the pouch-like **frontal recess** of the middle nasal meatus, either by means of a constricted canal, the **nasofrontal duct** (infundibulum of the frontal sinus), with proximal and distal **frontal ostia,** or by a fairly large direct single **frontal ostium** communicating between the frontal recess and the frontal sinus.

Occasionally the nasofrontal duct, or the frontal sinus proper in the absence of a duct, is directly continuous with the infundibulum ethmoidale (fig. 977). Usually, however, the infundibulum ethmoidale and the nasofrontal duct are discontinuous channels (figs. 976, 975). In approximately one-half of the latter cases the relationship is so intimate that secretions from the frontal sinus readily drain into the infundibulum ethmoidale, thence by way of the ostium maxillare into the sinus maxillaris. The efficiency of the nasofrontal duct as a drainage channel is in direct ratio to its length, diameter and directness. Often anterior ethmoidal cells encroach upon it, causing it to be constricted and sinuous in its course. Many frontal sinuses have no true nasofrontal duct, the sinus itself opening into the frontal recess by a direct single frontal ostium.

In a recent study of a large series of adult frontal sinuses average measurements were found as follows: height, 27.9 mm.; width, 23.25 mm.; depth, 19.25 mm. The combined volume of the right and left frontal sinus averaged 14 cc. (range 1–45 cc.). The frontal sinus is ethmoidal in topography before it is frontal.

One usually cannot be certain which of the potential rudiments are to develop into the frontal sinus until the latter half of the first year of postnatal life. By the end of the second year the frontal sinus has eroded into the vertical portion of the frontal bone, measuring 5 × 3 × 4 mm. and by the sixth year measures 8 × 4 × 6 mm.

The ethmoidal cells [cellulæ ethmoidales].—The ethmoidal air-cells (figs. 975, 976, 979) are primarily extensions or evaginations of the nasal mucous membrane from the middle, superior and supreme nasal meatuses, or from their secondary furrows and recesses. The ethmoidal cells by their growth ultimately honeycomb the lateral masses of the ethmoid bone and collectively form the paired *ethmoidal labyrinths* which occupy the space between the upper part of the nasal fossæ and the orbits.

Not infrequently the ethmoidal cells extend into certain of the nasal conchæ and the secondary folds of the related meatuses, forming the *conchal cells;* and into neighboring bones, forming *ethmofrontal, ethmomaxillary, ethmosphenoidal* and *ethmopalatine* cells. A very thin mucous membrane, directly continuous with that of the respiratory region of the related nasal meatuses, lines the cells. Not infrequently the osseous boundaries are deficient.

The ethmoidal cells are divided into two primary groups, the anterior and the posterior ethmoidal cells. The **anterior group,** from two to eight in number, have their ostia in communication with various parts of the middle nasal meatus. The anterior ethmoidal cells are subdivided into *secondary groups,* viz., the **frontal ethmoidal cells,** opening into the frontal recess of the middle meatus; the **infundibular ethmoidal cells,** opening into the ethmoidal infundibulum of the middle meatus; and the **bullar ethmoidal cells** (often called the middle ethmoidal cells), opening into the middle meatus, either upon or above the ethmoidal bulla, the latter being hollowed out by them (figs. 975, 976). The **posterior group,** from one to seven in number, have their ostia or apertures above the middle nasal concha and in communication with both the superior and supreme nasal meatuses.

The supreme meatus is found in about 60 per cent. of adult specimens and 75 per cent of these receive the ostium of a posterior ethmoidal cell. The superior meatus receives the apertures of posterior ethmoidal cells in practically all cases (fig. 976).

In a recent study, the number of cells composing the ethmoidal labyrinth was found to vary from 3 to 15. The fewer the cells, the larger are the individual cells, since the ethmoidal labyrinth occupies the entire ethmoidal field whether composed of few or many cells. In the newborn, the anterior group measures on the average 5 × 2 × 2 mm. and the posterior group 5 × 4 × 2 mm. In the adult the anterior group measures on the average 23.6 mm. in height, 22.6 mm. in length, and 11 mm. in width. The corresponding diameters of the posterior group are 20.8 mm., 20.5 mm. and 12 mm., respectively.

The sphenoidal sinus [sinus sphenoidalis].—The paired sphenoidal sinuses (figs. 976, 979) pneumatize the body of the sphenoid bone and not infrequently extend into the great wings, the pterygoid processes and the rostrum of the sphenoid and the basilar process of the occipital bone. Occasionally they may replace certain of the posterior ethmoidal cells, coming into immediate relationship with the maxillary sinus. The converse may occur in which one or more posterior ethmoidal cells may encroach upon the sphenoidal sinus. The sphenoidal sinuses vary greatly in size and shape and are usually asymmetrical, with corresponding asymmetry of the intervening **sphenoidal septum** [septum sinuum sphenoidalium].

Sphenoidal sinuses may be either very rudimentary or extremely large. The dimensions of the average sinus may be given as follows: height, 20 mm.; width, 18 mm.; length, 21 mm. Conforming with the variations in size, the capacity of the sphenoidal sinus varies from 0.5 cc. to 30 cc., with an approximate average of about 7.5 cc.

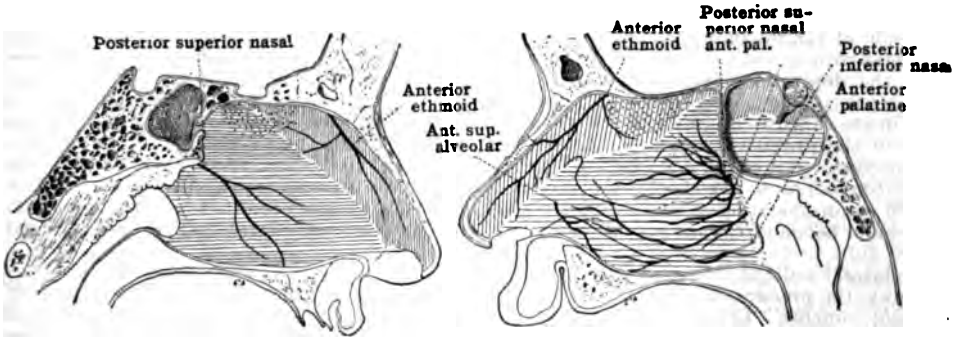
The sphenoidal sinus of each side communicates with the sphenoethmoidal recess of the nasal fossa by means of an aperture, the **sphenoidal ostium** [apertura sinus sphenoidalis]. The latter is large in the dried skull, but much reduced in the recent and living state by the respiratory mucous membrane.

The ostium sphenoidale is located in the anterior wall of the sphenoidal sinus from 3 to 20 mm. above the floor. It always opens into the posterior wall of the sphenoethmoidal recess above the uppermost nasal concha. The sphenoidal ostium is very disadvantageously placed as an efficient drainage aperture owing to its great distance from the floor of the sphenoidal sinus, averaging 14 mm.

The sphenoidal sinus arises primarily in relation with the posterior cupola of the cartilaginous nasal capsule, the wall of which gives the foundation for the sphenoidal turbinal or ossicle of Bertin. The posterior cupola or recess is, strictly speaking, the primitive sphenoidal sinus and is demonstrable as early as the fourth month of fetal life. It is only after the ossicle of Bertin fuses with the ethmoid bone, which occurs during the fourth year of infancy, that the sphenoidal sinus begins to excavate the body of the sphenoid. The average sphenoidal sinus of the term fetus has a capacity of from 6 to 8 cubic mm. By the second year the sphenoidal sinus averages 4 × 3.5 × 2 mm.; the fifth year 7 × 6.5 × 4.5 mm.; and by the ninth year 5 × 12 × 10 mm.

FIG. 980.—DIAGRAM OF THE DISTRIBUTION OF THE NERVES IN THE NASAL CAVITY. (Poirier and Charpy.)

The olfactory area is represented by dots.



Functions of the paranasal sinuses.—It is unlikely that the paranasal sinuses exert any influence upon vocalization and they supply an insignificant amount of moisture in the form of mucus to the nasal fossæ. The sinuses may, by lightening the ventral and facial part of the skull, aid in bringing about proper equipose of the head. There is some phylogenetic evidence that some of the paranasal sinuses at one time had to do with the olfactory function. However, with the marked reduction of the olfactory sense in man, the one conspicuous and probably dominant function remaining is that as an adjunct to respiration, particularly to aid in warming and humidifying the inspired air.

The mucous membrane of the nose [membrana mucosa nasi] completely lines the nasal cavity and inferiorly, at the limen nasi, blends with the skin covering the walls of the vestibule. Posteriorly it joins the mucous membrane of the pharynx and palate. It covers some of the openings which are seen in the bony walls; those apertures, however, which lead into the paranasal sinuses and into the nasolacrimal duct remain patent, although as already stated the bony openings are much reduced in size.

In the nasal cavity the bright rose-red vascular mucous membrane is tightly bound to the periosteum and perichondrium, and is covered with a ciliated columnar epithelium. Numerous large mucous **nasal glands** [glandulæ nasales] pour their more or less watery secretion over the entire surface. A very considerable venous plexus is found in many parts of the nasal mucosa. Over the inferior concha and to a less extent in the mucosa of the middle and superior conchæ, it forms the **cavernous plexuses** of the **conchæ** [plexus cavernosi concharum] contributing to build up about these bodies a true erectile tissue. The thickness which these glands and venous plexuses give to the mucous membrane of the conchæ causes the marked increase in size of these bodies over that of their bony supports. The region covered by the mucous membrane just described forms the greater part of the nasal cavity, and is known as the **respiratory region** [regio respiratoria]. The mucous membrane of a small area over the superior and supreme conchæ, a small portion of the middle concha and the adjacent septal wall (fig. 980) has a somewhat different structure. In this area the olfactory nerves are distributed, whence it is known as the **olfactory region** [regio olfactoria], and its mucous membrane, compared with that of the respiratory region, is less vascular, yellow or yellowish-brown in color, and covered by a non-ciliated epithelium. Its cells, specially modified, some of which are directly connected

with the olfactory nerve, form the **olfactory organ** [organon olfactus]. **Small mucous olfactory glands** [glandulæ olfactoriæ] occur in the region. The mucous membrane which lines the *paranasal sinuses* throughout is a continuation of the nasal mucosa; it is, however, paler, less vascular, somewhat thinner, and more loosely attached to the bones. **Mucous glands** are numerous.

Vessels and nerves.—The **arteries** of the nasal cavity are the **sphenopalatine** artery from the internal maxillary which, through its posterior lateral nasal branches, supplies a goodly portion of the nasal conchæ (p. 590), and through its posterior septal branches (**nasopalatine** artery) supplies the inferior and posterior portion of the nasal septum; the **anterior and posterior ethmoidal** arteries from the ophthalmic (p. 594) supply portions of both **medial and lateral nasal** walls; the descending palatine artery from the internal maxillary supplies small branches to the posterior portion of the nasal fossa and by its direct continuation (the **great palatine artery**) passes through the incisive foramen to the anterior portion of the floor of the **nasal fossa** (p. 590), and the superior labial branch of the external maxillary supplies the **vestibule** and adjacent parts. The **venous plexuses** of the mucous membrane are drained posteriorly by the sphenopalatine to join the pterygoid plexus, superiorly by the anterior and posterior ethmoidal veins to join the superior ophthalmic vein, and anteriorly by small branches to join the facial. The **lymphatics** form a well-developed plexus which is said to communicate indirectly, through the lymph-spaces surrounding the olfactory nerves, with the subdural and subarachnoid spaces. Posteriorly two or more well-developed trunks communicate with the **pharyngeal lymphatics**, and anteriorly the nasal lymphatics join with the lymphatics of the face. The **olfactory nerves** pass through the cribriform plate of the ethmoid bone and are distributed to the olfactory bulb (p. 962). The **trigeminal nerve** furnishes the following branches to the **nasal cavity**: branches from the nasociliary branch of the ophthalmic nerve; the posterior **superior and posterior inferior nasal**, the nasopalatine and the anterior palatine from the **sphenopalatine ganglion** (p. 995); the anterior superior alveolar from the infraorbital division of the **maxillary nerve** (p. 970). See also the terminal and vomeronasal nerves (p. 962).

The development of the nose.—The nasal cavity makes it appearance as a depression on either side of the median line, immediately above the oral fossa, with which the depressions are at first continuous. Later, by the fusion of the maxillary and medial **nasal processes** (see p. 16), the depressions or nasal pits are separated from the oral fossa. The **nasal pits** then establish a secondary connection with the roof of the primitive mouth-cavity by an attenuation and ultimate rupture (45-day embryo) of the bucconasal membranes of **Hochstetter** in the formation of the primitive choanæ or posterior nares. Later the upper portion of the mouth-cavity becomes part of the nasal cavity by the formation of the palatal processes of the maxillæ and palatine bones, so that finally the definitive hard palate is completed and the nasal cavities establish communication dorsally with the pharynx. The wide septum between the nasal pits narrows and becomes the nasal septum proper, dividing the nasal cavity into the paired nasal fossæ.

The lateral walls of the nasal fossæ, at first smooth and even, at an early time show grooves or furrows, the precursors of the nasal meatuses. The furrows delimit folds, the precursors of the nasal conchæ. Later cartilage develops within the epithelially covered mesenchymal conchæ which subsequently, together with that of the lateral nasal walls proper, undergoes ossification. The nasal mucous membrane also evaginates into neighboring bones, giving origin to the ethmoidal cells and the frontal, sphenoidal and maxillary sinuses, the initial points of outgrowth remaining as the ostia or apertures of the adult cells and sinuses.

The paranasal sinuses are preformed in the nasal meatuses and the secondary furrows that mold the lateral walls of the meatuses. This is true of all the paranasal sinuses save the sphenoidal which arises in connection with the posterior cupola of the cartilaginous nasal capsule, and in a sense is primarily a constriction of the nasal mucosa from the most dorsal and cephalic part of the nasal fossa. No paranasal sinus develops from the inferior nasal meatus. The pre-existing spaces from which paranasal sinuses and cells develop are: (1) the suprabullar recess; (2) the bullar furrow; (3) the infrabullar furrow; (4) the ethmoidal infundibulum, all of the descending ramus of the middle nasal meatus; (5) the frontal furrows; (6) the frontal recess, both of the ascending ramus of the middle nasal meatus; (7) the anterior extremity and the superior and inferior recesses of the superior nasal meatus; (8) the supreme nasal meatus; (9) the sphenoethmoidal recess.

THE LARYNX

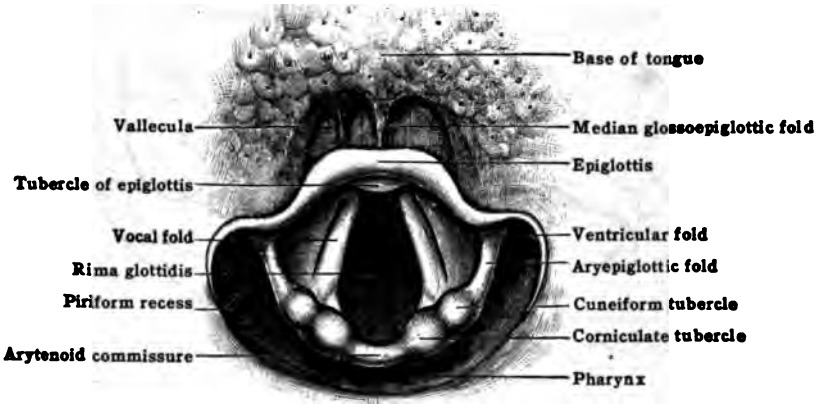
The **larynx** (figs. 968, 981, 982, 985), is a tubular organ, the framework of which consists of cartilages and elastic membranes. Its inner surface is covered by mucous membrane continuous with that of the pharynx above and the trachea below. From the membranes are formed a pair of **vocal folds** which, by the passage of air through the larynx, are thrown into vibration and so function in the generation of sound. These folds are affected in respect to their tension and in their mutual relation by the actions of a system of laryngeal muscles under the control of the vagus nerve and are made thereby, on the one hand, to produce those modifications of the sound involved in the voice and on the other hand to regulate the amount of air passing through the **cavity of the larynx.** The latter communicates above with the pharynx by means of an opening called the **laryngeal aperture,** and below with the cavity of the trachea. Figure 981 shows the laryngeal aperture with its boundaries, the epiglottis and the **aryepiglottic folds;** also the cavity of the larynx where, on the walls right and left, appear the **ven-**

tricular and the **vocal folds** with the chink called the **rima glottidis** separating **them**. The position of the larynx and some of its important parts can be well **seen** in a midsagittal section (fig. 983).

THE CARTILAGES OF THE LARYNX

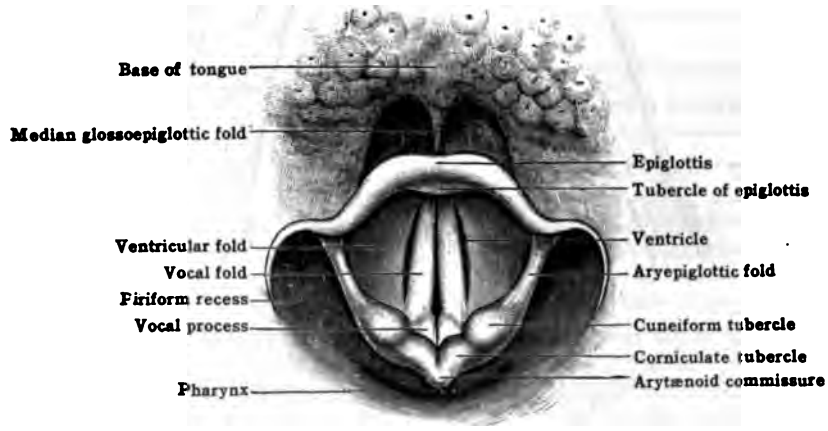
The **laryngeal cartilages** [cartilagines laryngis] are nine in number, three of **which** (cricoid, thyroid, epiglottic) are single and the rest in pairs (arytenoid, **corniculate**, cuneiform).

FIG. 981.—VIEW OF INTERIOR OF LARYNX AS SEEN FROM ABOVE DURING INSPIRATION.



The **cricoid cartilage** [cartilago cricoidea] (figs. 984, 986, 989), single, has been compared in its shape to a signet ring. Its position is at the lower end of the larynx, where it is connected with the first ring of the trachea. Posteriorly the cricoid cartilage expands into a broad **lamina**, approximately 25 mm. in height, which enters into the dorsal boundary of the laryngeal cavity, while laterally and ventrally it forms a narrow **arch** measuring but 8 mm. On either side of the upper margin of the lamina is the elliptical **arytenoid articular surface** [facies

FIG. 982.—VIEW OF INTERIOR OF LARYNX AS SEEN FROM ABOVE DURING VOCALIZATION.

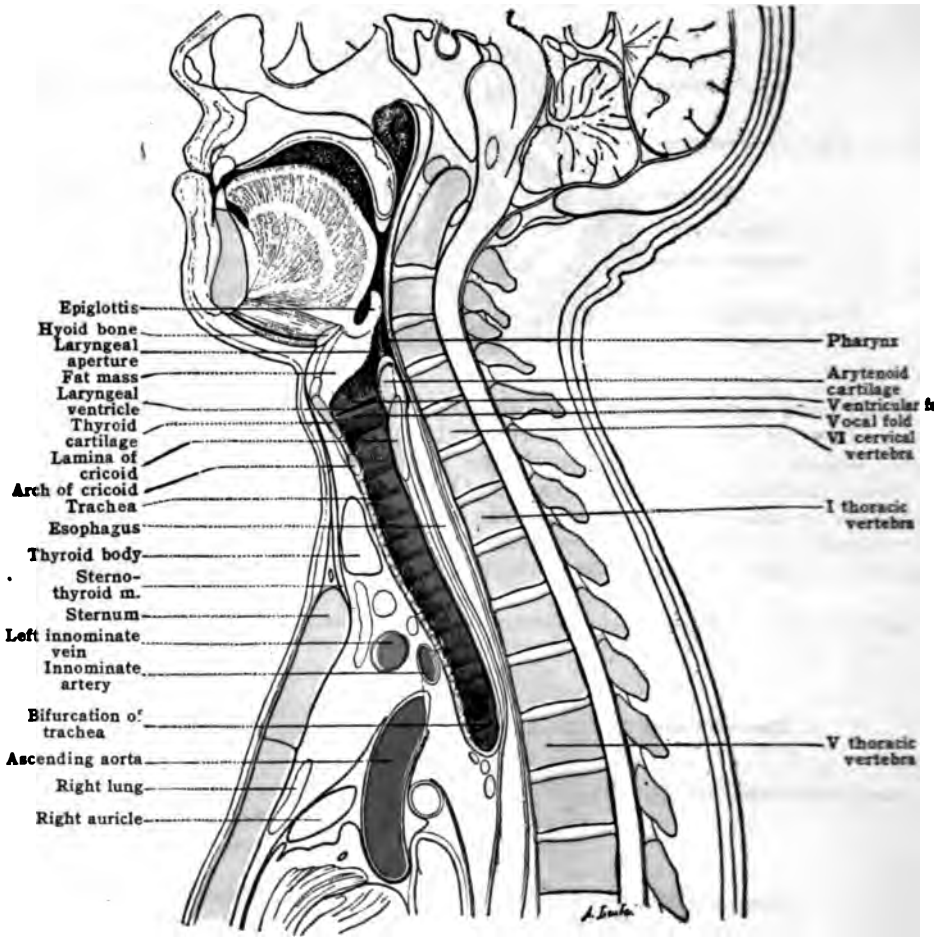


articularis arytænoidea], its long axis parallel with the margin of the cricoid, its steeply sloping surface convex for articulation with the arytenoid cartilage. The dorsal surface of the lamina presents a vertical median ridge which gives attachment to some of the longitudinal fibers of the esophagus and paired lateral impressions for the attachment of the posterior cricoarytenoid muscles. The arch, weakest in its middle part, presents concave upper and straight lower margins. A circular, elevated **thyroid articular surface** [facies articularis thy-

reoidea] for articulation with the inferior cornu of the thyroid cartilage is situated upon the side of the cricoid where arch and lamina are continuous. The internal surface is covered by the mucous membrane of the larynx.

The **thyroid cartilage** [cartilago thyreoidea] (figs. 984, 986, 988), single and the largest in the laryngeal skeleton, is composed of two broad **laminæ, right and left,** which meet and are fused ventrally in the midline, forming an angle of 90° with one another in the male and 120° in the female. The laminæ are stout, but their connection at the angle is through a weak strip of cartilage. The upper margin of each lamina is convex, and in front drops abruptly to form in the median line the **superior thyroid notch** [incisura thyreoidea superior]. The ventral edges

FIG. 983.—MEDIAN SECTION OF A MAN 21 YEARS OF AGE, SHOWING THE POSITION OF LARYNX AND TRACHEA. (After W. Braune, from Poirier and Charpy.)



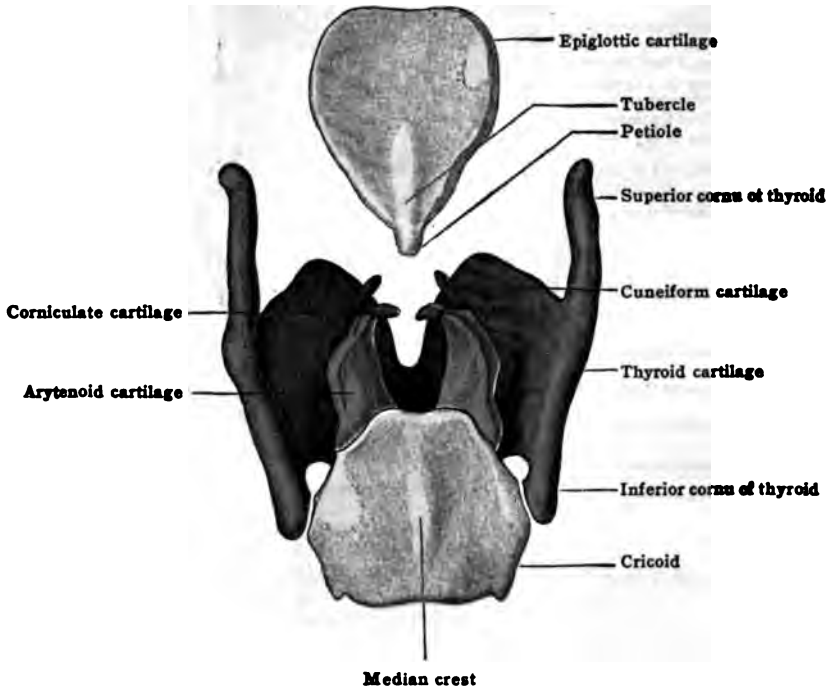
meeting in the angle produce the subcutaneous **laryngeal prominence** [prominentia laryngea] ('Adam's apple'), which is seen on the ventral aspect of the neck. The horizontal inferior margin presents near its middle the **inferior thyroid tubercle** [tuberculum thyreoideum inferius], and in the median line the **inferior thyroid notch** [incisura thyreoidea inferior]. The thick dorsal margin of each lamina is continued above the superior edge in the long **superior cornu** [cornu superius], and below the inferior margin in the short **inferior cornu** [cornu inferius]. The former is directed slightly dorsalward and medialward, and joins with the end of the greater cornu of the hyoid by a ligament. The inferior cornu, curving medialward as it descends, articulates by a flat, circular facet upon the medial side of its extremity with the thyroid articular surface of the cricoid cartilage. The external surface of the lamina affords attachment for muscles and presents in its

upper posterior part the **superior thyroid tubercle** [tuberculum thyreoideum superius]; in its lower part the **inferior thyroid tubercle.** The internal surface of the thyroid cartilage is smooth.

A thyroid foramen [foramen thyroideum], sometimes seen in the upper part of the lamina giving passage to the superior laryngeal artery, results from the incomplete union of the fourth and fifth branchial cartilages from which the laminæ are derived. The **oblique line** [linea obliqua], extending between the thyroid tubercles, is commonly present and is regarded by many anatomists as a normal feature of the external surface of the thyroid cartilage. It marks the attachment of the sternothyroid and thyrohyoid muscles. At the insertion of the vocal ligaments in the angle of the laminæ a small perichondral process is often observed.

The **arytenoid cartilages** [cartilagines arytænoideæ] (figs. 984, 988, 989, 990), paired, surmount the lamina of the cricoid cartilage and give attachment to the vocal ligaments, whose relations and state of tension are altered by the changes in position which these cartilages are almost constantly undergoing.

FIG. 984.—CARTILAGES OF THE LARYNX SEEN FROM BEHIND IN THEIR NATURAL POSITIONS. THE CUNEIFORM CARTILAGE IS SOMEWHAT HIGHER THAN NORMAL. (Merkel.)



Each cartilage is pyramidal in form, and molded for the attachment of several muscles. The **apex,** which is above, is bent dorsalward and medialward and is connected with a corniculate cartilage. The **base,** somewhat triangular in shape, presents at the lateral and dorsal part an oval or circular concave **articular surface,** directed medialward and caudalward to meet the arytenoid articular surface of the cricoid cartilage. The lateral angle of the base is prolonged into a stout **muscular process** for the insertion of the cricoarytenoid muscles, while the anterior angle is extended as a sharp projection, the **vocal process** [processus vocalis], which serves for the attachment of the vocal ligament. The surfaces of the arytenoid are medial, dorsal, and ventrolateral. The narrow **medial surface,** covered by the mucosa of the larynx, is nearly vertical, and faces the corresponding side of the opposite arytenoid, from which it is separated by a small space. The **dorsal surface** is concave for muscular attachment. The **ventrolateral surface** is the largest, and presents an irregular contour.

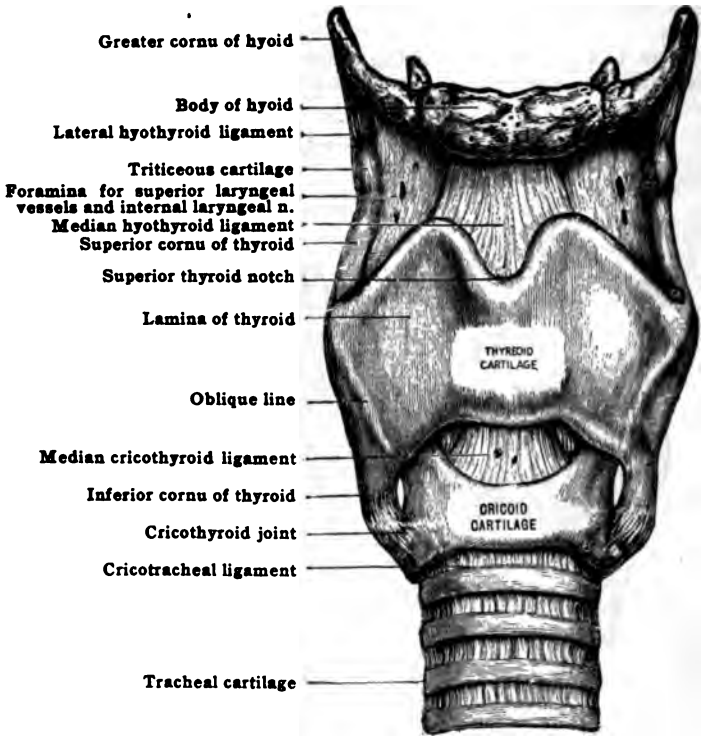
On this surface a ridge, the **arcuate crest** [crista arcuata], extends horizontally between two hollows—the **triangular fovea** [fovea triangularis] above, which lodges some mucous glands, and a larger depression below, the **oblong fovea** [fovea oblonga] for the vocal muscle. The **colliculus** is a small eminence found upon the ventral margin and ventrolateral surface.

The corniculate cartilages (of Santorini) [cartilagines corniculatæ (Santorini)] (figs. 984, 986, 988).—This pair of small conical cartilages is set upon the bent apices of the arytenoids, continuing their curves dorsalward and medialward.

The corniculate cartilage is not an independent structure in many lower animals, and its continuity with the arytenoid is sometimes met with in man where the two cartilages are normally developed in a continuous mass of tissue.

The **epiglottic cartilage** [cartilago epiglottica] (figs. 984, 988, 992, 998), unpaired, invested by mucosa behind and partly in front, thin and leaf-shaped, stands behind the root of the tongue and the body of the hyoid. It lies above the thyroid cartilage, in front of the entrance of the larynx. The free upper margin

FIG. 985.—FRONT VIEW OF THE LARYNGEAL SKELETON. (Modified from Bougery and Jacob.)



is convex, or notched; the lower end tapers to a short stalk, **the petiole** of the epiglottis [petiolus epiglottidis], to which the thyroepiglottic ligament is attached. The ventral surface is free above and covered by mucosa; in its lower part it is bound to the body of the hyoid, and is separated by a mass of fat from the hyothyroid ligament. Its dorsal surface above is saddle-shaped; below, it is convex, presenting the **epiglottic tubercle** [tuberculum epiglotticum]. To the margins are attached the aryepiglottic folds. The epiglottic cartilage presents numerous small holes and depressions for the accommodation of glands.

The **cuneiform cartilages (of Wrisberg)** [cartilagines cuneiformes (Wrisbergi)] (fig. 984) lie as small, rod-like bodies in the aryepiglottic folds anterior to the corniculate cartilages. They are variable in form and size and not rarely absent altogether.

These cartilages are parts of the epiglottic cartilage in some mammals where, as in man, they lie in the aryepiglottic folds. Their relations to the arytenoids are regarded as secondary. Sutton has shown that in the ant-eater a continuous rim of yellow elastic cartilage extends from the sides of the epiglottic cartilage to the summits of the arytenoids. A minute unpaired *interarytenoid* or *precricoid cartilage* is rarely present imbedded in the cricopharyngeal ligament and covered by the pharyngeal mucosa. It is a constant structure in certain mammals. A pair of small *sesamoid cartilages*, also constantly present in some mammals, is occasionally found in man at the lateral margins of the arytenoids, connected with them and with the corniculate cartilages by elastic ligaments.

Structure of the cartilages.—The thyroid, cricoid, and greater part of the arytenoid are composed of hyaline cartilage; the epiglottic, corniculate, and cuneiform cartilages, as well as the apex and vocal process of the arytenoid, are of elastic cartilage. Certain parts of the laryngeal skeleton normally undergo calcification and subsequent ossification. Calcification begins at about twenty years of age in the thyroid and cricoid cartilages, and later in the arytenoid. The process begins a little later in the female than in the male, and does not extend so rapidly. The extent to which the cartilages are ossified and the time occupied in the process vary considerably. The elastic elements are not involved in the process.

FIG. 986.—CRICOID AND ARYTENOID CARTILAGES, VENTRAL VIEW. (Rauber-Kopsch.)

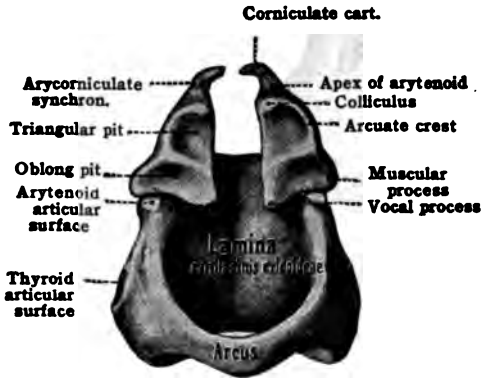
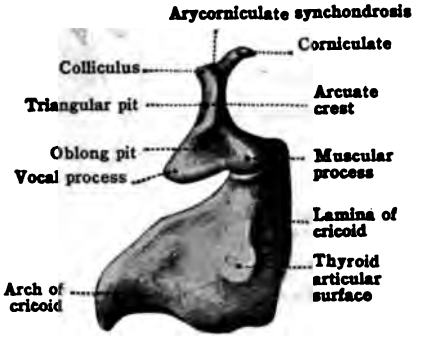


FIG. 987.—CRICOID AND ARYTENOID CARTILAGES SEEN FROM THE LEFT. (Rauber-Kopsch.)



THE JOINTS AND MEMBRANES OF THE LARYNX

(A) THE ARTICULATIONS OF THE LARYNGEAL CARTILAGES

The cricothyroid articulation (figs. 984, 986).—The articular surfaces concerned are the thyroid articular surface on the lateral aspect of the cricoid and the articular surface on the inferior cornu of the thyroid cartilage. The **cricothyroid articular capsule** attached around the margins of these surfaces and certain accessory bands serve to bind the cartilages together. The capsule is lined by synovial membrane, forming a typical arthrodial joint.

The accessory bands, **ceratocricoid ligaments,** fall into three groups radiating from the inferior cornu: the **ligamenta ceratocricoidea posteriora** upward and medialward to the superior margin of the cricoid; the **ligamenta ceratocricoidea lateralia** downward at the side and back of the capsule; the **ligamentum ceratocricoideum anterius** downward and forward.

A rotary movement about a transverse axis of the cricoid upon the thyroid or *vice versa* and a slight backward and forward gliding are permitted at this joint.

The cricoarytenoid articulation (figs. 984, 988, 989).—The articular surface of the cricoid cartilage and the articular surface of the arytenoid which enter into this articulation are so disposed that at no time do they meet in complete apposition. A loose capsule [capsula articularis cricoarytænoidea] of fibrous and synovial strata attached around the edges of the joint surfaces unites the cartilages and encloses a cavity, forming a typical arthrodial joint.

The **posterior cricoarytenoid ligament,** attached above to the medial surface of the base and muscular process of the arytenoid, and below to the lamina of the cricoid, is important in helping to fix the former cartilage in place upon the sloping arytenoid articular surface of the cricoid and in limiting its movements. Motion at this articulation is very free. The following simple movements of the arytenoid are best understood: (1) gliding of the arytenoid toward or away from its fellow; (2) inclining ventrally and dorsally; (3) rotating on a vertical axis, so that the vocal process sweeps medialward or lateralward and also a little caudalward or cephalad.

The arycorniculate articulation [synchondrosis arycorniculata] is the union of the apex of the arytenoid cartilage with the corniculate cartilage. It is usually formed by connective tissue; rarely is there a joint cavity.

The thyroepiglottic union is accomplished by the strong, elastic **thyroepiglottic ligament** (fig. 988) connecting the petiole of the epiglottic cartilage with the thyroid cartilage, caudal and dorsal to the superior notch.

(B) The Elastic Membrane of the Larynx

The elastic membrane of the larynx [membrana elastica laryngis] **is a name** given to a more or less continuous sheet of elastic fibers connected **with the**

Fig. 988.—The Laryngeal Skeleton, Dorsal View. (Modified from Poirier and Charpy.)

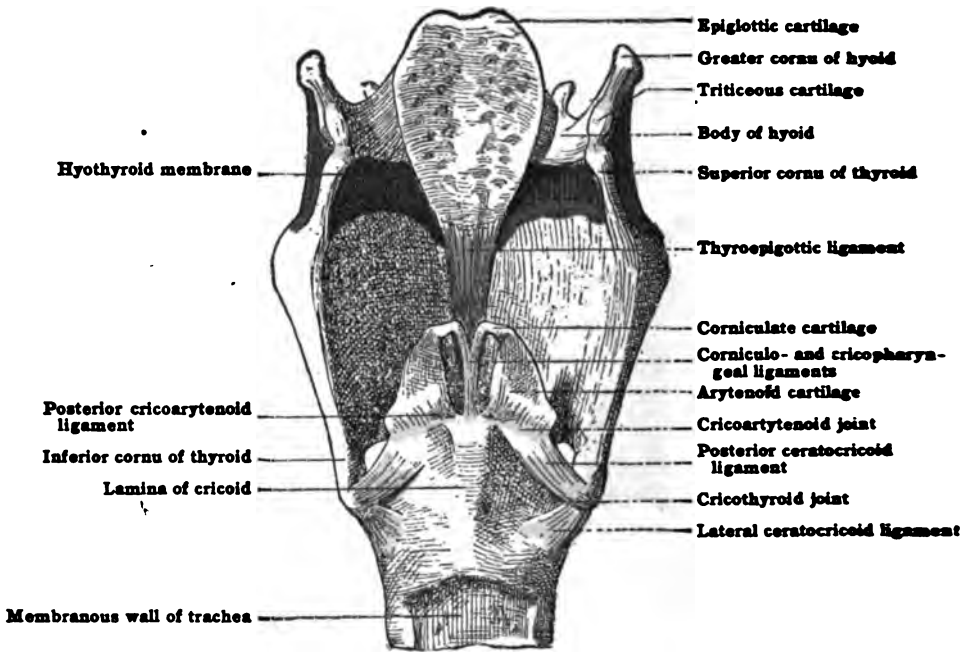
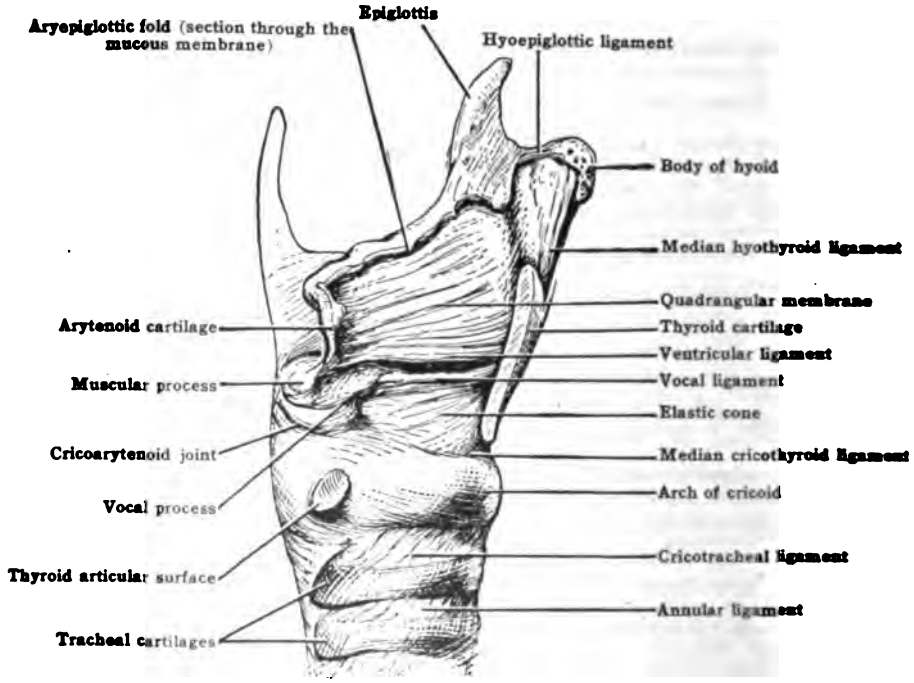


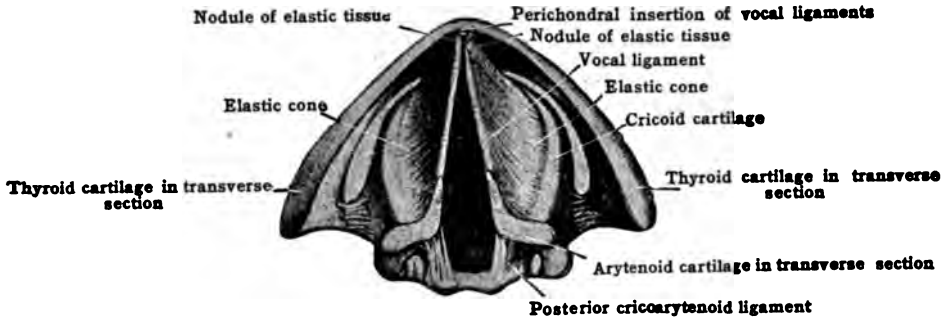
Fig. 989.—The Larynx with its Ligaments, Viewed from the Right. (The right lamina of the thyroid cartilage has been removed.) (Spalteholz.)



deeper parts of the laryngeal mucosa. Its upper part is known as the *quadrangular membrane,* the lower part as the *elastic cone.* A middle region of the elastic membrane lies opposite the ventricle of the larynx.

The quadrangular membrane (figs. 989, 992) extends from the aryepiglottic folds above to the level of the ventricular folds (false vocal cords) below. The lateral parts of this membrane are widely separated cephalically, but they converge toward the middle line as they descend. Ventrally, the membrane is fixed in the angle of the thyroid laminæ and to the sides of the epiglottic cartilage; dorsally, to the corniculate cartilages and to the arytenoids. The cephalic edge on either side lies within the aryepiglottic fold, which it supports; it slopes caudalward and dorsalward and includes the cuneiform cartilage. The caudal edge, horizontal and in a sagittal plane, is best developed ventrally, where it is attached in the angle of the thyroid a little way from the middle line; dorsally, it is fixed to the medial margin of the triangular fovea of the arytenoid. This caudal free margin, differentiated as the **ventricular ligament** [lig. ventriculare], is enclosed within, and is the support for the ventricular fold.

FIG. 990.—THE ELASTIC CONE SEEN FROM ABOVE. (Modified from Luschka.)



The elastic cone [conus elasticus] (figs. 989, 990) extends from the level of the vocal folds to the cephalic margin of the cricoid cartilage. Its component fibers are attached in the re-entrant angle and adjacent caudal margin of the thyroid cartilage, whence they spread caudalward and dorsalward to the cephalic edge of the cricoid arch and to the arytenoid cartilages. The strong ventral portion, perforated by vessels, is the **median cricothyroid ligament** (figs. 985, 986). The lateral parts (lateral portions of the cricothyroid membrane) present cephalic free edges, somewhat thickened, which, running horizontally near the middle line from the thyroid angle to the vocal processes, constitute the **vocal ligaments.** These are inserted ventrally into a perichondral process in the thyroid angle; dorsally, they have a wide area of attachment to the cephalic and medial surfaces of the vocal processes of the arytenoids with the elastic fibers of which they are in part continuous. A yellowish, cellular nodule (sometimes cartilage) occurs in the ventral end of each ligament. The vocal ligaments enter into the formation of the vocal folds (true vocal cords).

(C) CONNECTIONS BETWEEN THE LARYNX AND NEIGHBORING STRUCTURES

The **hyothyroid membrane** [membrana hyothyreoidea] (figs. 988, 991, 992) is a loose, fibrous, elastic sheet, binding together the thyroid cartilage and hyoid bone. It extends from the cephalic margin of the former to the greater cornua and cephalic margin of the body of the latter. The superior laryngeal artery and vein and the internal laryngeal nerve pass through it from the side. Its dorsal and lateral edge is cord-like, consisting of elastic fibers which stretch as the **lateral hyothyroid ligament** from the superior cornu of the thyroid to the greater cornu of the hyoid. A small **cartilago triticea** is sometimes present in this band. The middle part, **median hyothyroid ligament,** thick and elastic, extends from the superior thyroid notch upward behind the body of the hyoid to be attached to its cephalic margin, the *hyoid bursa* being interposed between the bone and the membrane.

The cartilago triticea is the remains of a connection between the thyroid and hyoid present in the embryo. It persists in adult life in some lower animals.

The **hyoepiglottic ligament** [lig. hyoepiglotticum] (figs. 989, 992) connect ventral surface of the epiglottic cartilage with the cephalic margin of the body the greater cornua of the hyoid. It is a broad sheet, lying above a mass

FIG. 991.—THE LARYNX SEEN FROM THE LEFT SIDE. (Modified from Luschka

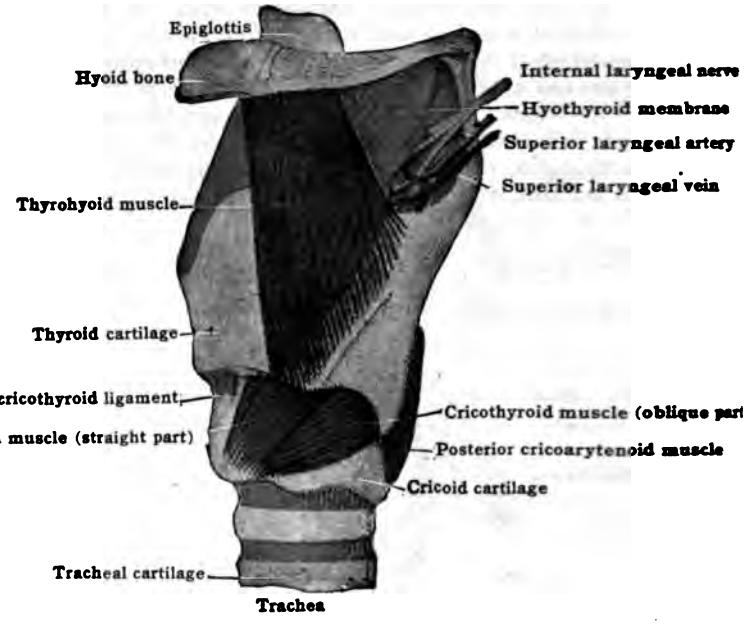
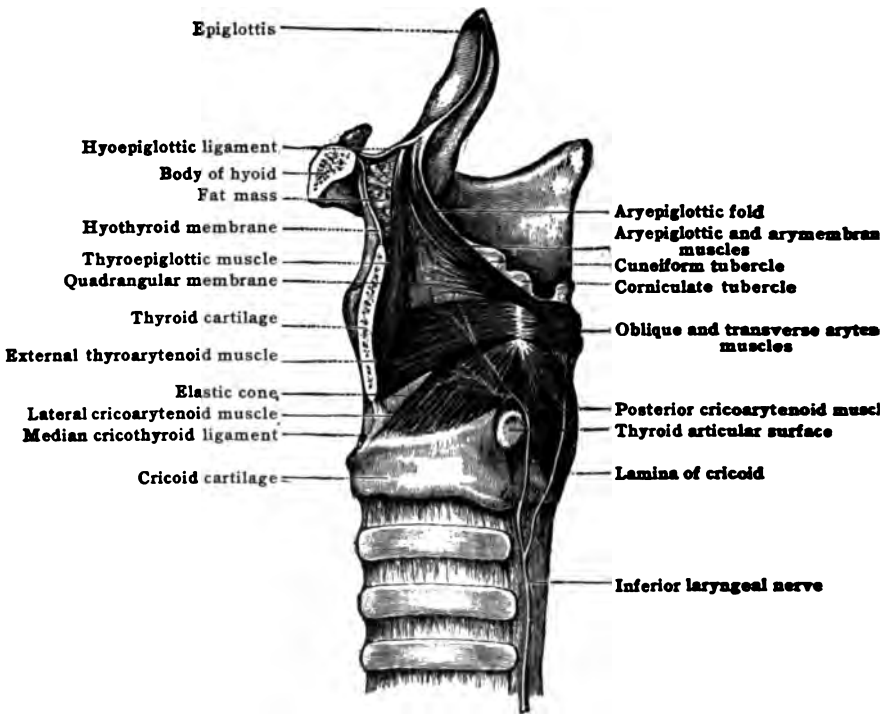


FIG. 992.—THE MUSCLES AND LIGAMENTS OF THE LARYNX SEEN FROM THE SIDE. (T lamina of the thyroid cartilage has been removed.)



which stands between the median hyothyroid membrane and the epig and spreading laterally to join the pharyngeal aponeurosis in the region piriform recess.

The name *glossoepiglottic ligament* is given to the elastic fibers extending between the root of the tongue and the epiglottis within the median glossoepiglottic fold.

The **corniculopharyngeal ligament** (fig. 988) extends from the corniculate cartilage caudalward and toward the median line, attaching to the mucosa of the pharynx and joining its

FIG. 993.—SCHEME OF RIMA, SHOWING ACTION OF POSTERIOR CRICOARYTENOID MUSCLE WHICH DRAWS THE ARYTENOID CARTILAGE FROM I TO II. (Modified from Stirling.)

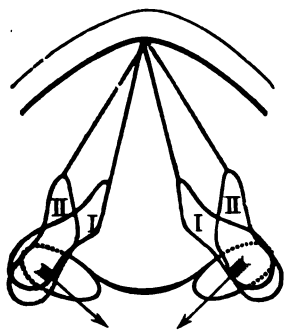


FIG. 994.—SCHEME SHOWING ACTION OF THE TRANSVERSE ARYTENOID DRAWING ARYTENOID CARTILAGE FROM NEUTRAL POSITION I TO II. (Modified from Stirling.)

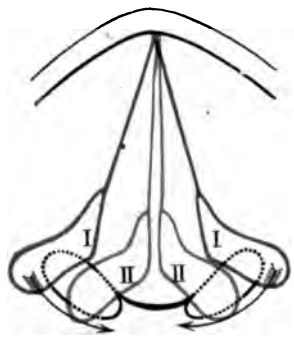
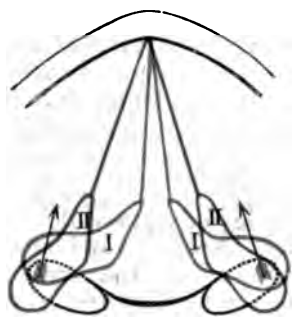
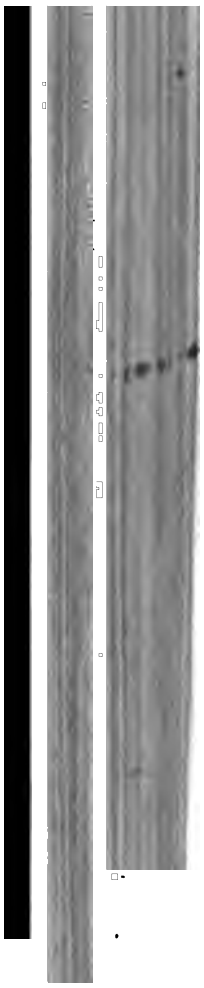


FIG. 995.—SCHEME SHOWING ACTION OF THYROARYTENOID DRAWING THE VOCAL PROCESSES AND THE VOCAL LIGAMENTS FROM II TO I. (Modified from Stirling.)



fellow behind the arytenoid muscle. From this point a single band, the **cricopharyngeal ligament**, which may enclose a nodule of cartilage (**the interarytenoid cartilage**), descends in the middle line, to be fixed to the cricoid lamina and into the pharyngeal mucosa.

The larynx and trachea are united by fibrous membrane, the **cricotracheal ligament** [lig. cricotracheale] (figs. 985, 989), between the inferior margin of the cricoid cartilage and the cephalic margin of the first tracheal ring. Dorsally the ligament is continued into the membranous wall of the trachea.



fibers and are supplied by the vagus nerve through its laryngeal br
principal intrinsic laryngeal muscles are (1) the *cricothyroid*, (2
cricoarytenoid, (3) the *arytenoid* (transverse and oblique), (4) the *la*
tenoid, (5) the *thyrcoarytenoid* (external and internal or vocal : all
the transverse arytenoid, are in pairs.

The **cricothyroid** muscles [m. cricothyreoideus] (fig. 991) are
either side of the outer surface of the larynx in its lower part. E
partially separated into a ventral **straight** [pars recta] and a
portion [pars obliqua], which together arise from the arch of the
fibers of the straight part ascend steeply and are inserted into the
of the thyroid cartilage. The oblique portion is inserted into the
and into the caudal margin and inner surface of the thyroid cartil

The straight part elevates the arch of the cricoid, causing the lamina
arytenoid cartilages, to sink, while the oblique part draws forward the thyr
ligaments are made tense. The muscle is supplied by the external branch of
geal nerve. A connection between the dorsal part of this muscle and the
of the pharynx together with their common nerve-supply indicate their

The **posterior cricoarytenoid** muscle [m. cricoarytaenoideus p
991, 993), paired, is situated at the back of the larynx, covered
cous coat of the pharynx. It is a thick, triangular mass which fa
the posterior surface of the cricoid lamina, the two muscles being
by the median crest of the cartilage. The lower fibers ascend and
pass horizontally lateralward and are inserted into the muscular
arytenoid cartilage on its dorsal surface at its

W

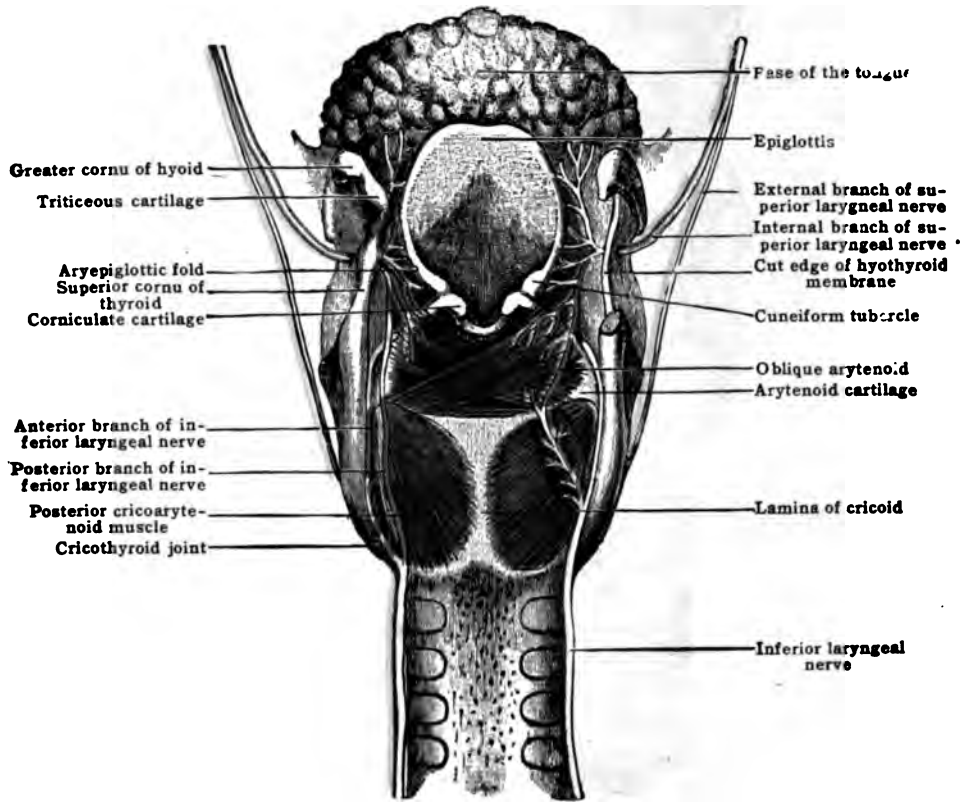
transverse arytenoid

The **lateral cricoarytenoid** muscle [m. cricoarytænoideus lateralis] (fig. 992) arises from the upper margin and outer surface of the cricoid arch and from the elastic cone, whence the fibers extend backward and upward to an insertion on the anterior surface of the muscular process of the arytenoid cartilage. This muscle is inseparable from the thyroarytenoid in about half the cases.

The lateral cricoarytenoids by their contraction cause the vocal processes to move toward the median line and a little downward, so that the vocal ligaments are approximated and slightly stretched. They antagonize the posterior cricoarytenoids. The anterior branch of the inferior laryngeal nerve supplies these muscles.

The **external thyroarytenoid** muscle [m. thyreoarytænoideus (externus)] (figs. 992, 995, 999), variable in form and in the disposition of its fibers, is closely connected with the preceding. It lies under cover of the thyroid lamina lateral

FIG. 996.—THE MUSCLES AND NERVES OF THE LARYNX. DORSAL VIEW.



to the laryngeal saccule (ventricular appendix) and elastic cone. Arising within the angle of the thyroid laminæ, the muscle extends upward and backward to its insertion on the lateral margin of the arytenoid cartilage.

It draws forward the arytenoid cartilage (and also tilts the cricoid), and rotates it so that the vocal process passes forward, medialward and downward, relaxing the vocal ligament. It is the antagonist of the cricothyroid (fig. 995). Its nerve-supply is the anterior branch of the inferior laryngeal.

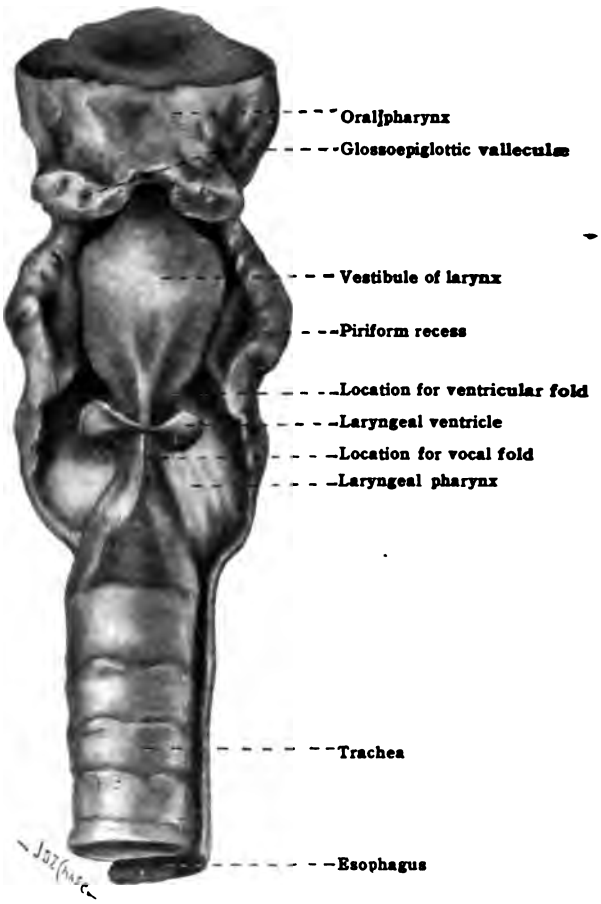
The **vocal muscle** [m. vocalis], (fig. 999), prismatic in form, is the inner constant part of the thyroarytenoid. It lies in the vocal lip lateral to the vocal ligament. Its fibers run from their origin in the angle of the thyroid laminæ to their insertion in the vocal process and oblong fovea of the arytenoid cartilage.

It draws forward the vocal process, relaxing the vocal ligament. Its nerve comes from the anterior branch of the inferior laryngeal. The insertion of certain fibers of this muscle into the elastic vocal ligament has been observed (aryvocalis muscle of Ludwig). D. Lewis has shown that some of the elastic fibers in the vocal ligament are derived from the perimysium of the vocal muscle.

The **ventricular muscle** [m. ventricularis] consists of a few fibers derived from the th arytenoid which reach the back of the laryngeal saccule and enter the ventricular fold. small *thyroarytenoideus superior* extends from the angle of the thyroid to the muscular pr of the arytenoid upon the lateral surface of the main muscle.

The **thyroepiglottic** muscle [m. thyrœpiglotticus] is a fairly constant p muscle closely connected with the thyroarytenoid (fig. 992). It originates the inner surface of the thyroid lamina and proceeds upward and backwa end in the quadrangular membrane and in an insertion on the lateral bor the epiglottis.

FIG. 997.—CAST OF LARYNX, PHARYNX, ETC. VENTRAL ASPECT. From a cast by J. I the Daniel Baugh Institute of Anatomy of the Jefferson Medical College.



SUMMARY OF THE ACTIONS OF THE LARYNGEAL MUSCLES

According to their actions, the laryngeal muscles may be divided into—(*a*) those w effect the tension of the vocal folds; (*b*) those which control the rima glottidis; (*c*) those w effect the closure of the laryngeal aperture and vestibule.

(*a* The vocal ligaments are made tense by the action of the cricothyroid, the lateral posterior cricoarytenoid and the transverse arytenoid muscles. The vocal ligaments ar laxed at the result of the action of the external thyroarytenoid and vocal muscles.

(*b*) The rima glottidis is widened by the posterior cricoarytenoid and made narrow by contraction of the transverse and oblique arytenoids. The lateral cricoarytenoideus assists in closing the rima glottidis by rotating the vocal processes medialward, and if the terior cricoarytenoid contracts simultaneously, it aids in the closure. The vocal ligament approximated also by the thyroarytenoideus (externus).

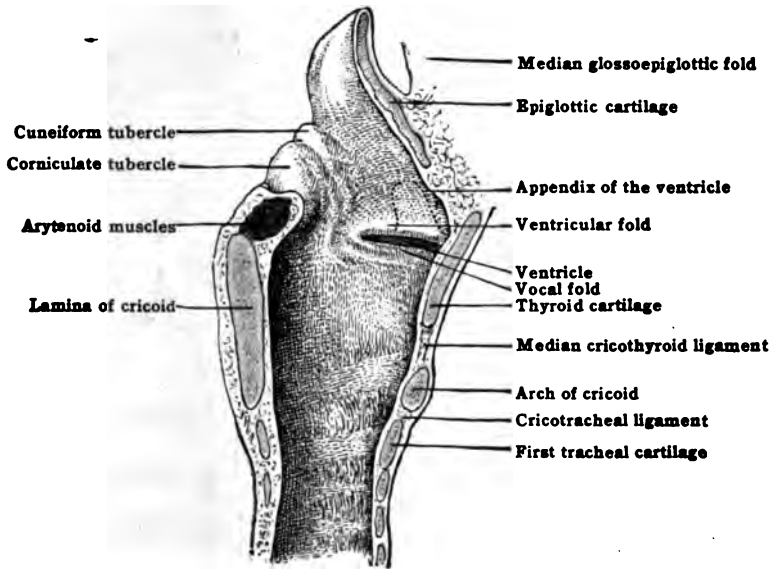
(*c*) The superior laryngeal aperture (aditus) and vestibule are closed mainly by the t verse arytenoid and thyroarytenoid (externus), by which the arytenoid cartilages are bro into apposition and drawn toward the epiglottis. Together these muscles form a sphinct the laryngeal vestibule. Other muscles derived from the constrictor group, the oblique a noid and aryepiglottic, assist in closing the laryngeal aperture.

CAVITY OF THE LARYNX AND LARYNGEAL MUCOSA

The **cavity of the larynx** [cavum laryngis] is relatively narrow and does not correspond in shape with the outer surface of the organ. Its form is shown in figs. 979 and 997 taken from casts of the laryngeal cavity and the spaces continuous with it. Its walls are covered throughout by the **mucous membrane** of the larynx (figs. 998, 999). The mucosa of the larynx is continuous above with the mucous membrane of the pharynx, below with that of the trachea (figs. 981, 982). At the root of the tongue the pharyngeal mucosa is reflected backward to the anterior surface of the epiglottis, presenting the **median** and **lateral glossoepiglottic folds** [plica glossoepiglottica mediana; lateralis]. From the sides of the pharynx it passes medialward, first sinking between the thyroid cartilage laterally and the arytenoid and cricoid medially, lining the walls of the *piriform recess;* then passing over the margin of the aryepiglottic fold to enter the vestibule of the larynx.

At the medial side of the piriform recess a slight fold of the mucosa [plica nervi laryngei] corresponds to the superior laryngeal nerve. Between the root of the tongue and the epiglottis is a depression on either side of the middle line and limited by the median and lateral

FIG. 998.—MEDIAN SECTION OF THE LARYNX. (Merkel).



glossoepiglottic folds; this is the **epiglottic vallecula** [vallecula epiglottica]. The piriform recess and the epiglottic vallecula are favorite sites for the lodgment of foreign bodies. The **aryepiglottic fold** [plica aryepiglottica] extends from the side of the epiglottis to the apex of the arytenoid cartilage; within it are fibers of the aryepiglottic and thyroepiglottic muscles and the cuneiform and corniculate cartilages. These cartilages correspond to two rounded eminences on each side of the laryngeal entrance, the **cuneiform** and **corniculate tubercles** [tuberculum cuneiforme (Wrisbergi); tuberculum corniculatum (Santorini)], respectively. Of these, the former is often small and inconspicuous, the latter usually well developed and prominent (fig. 998).

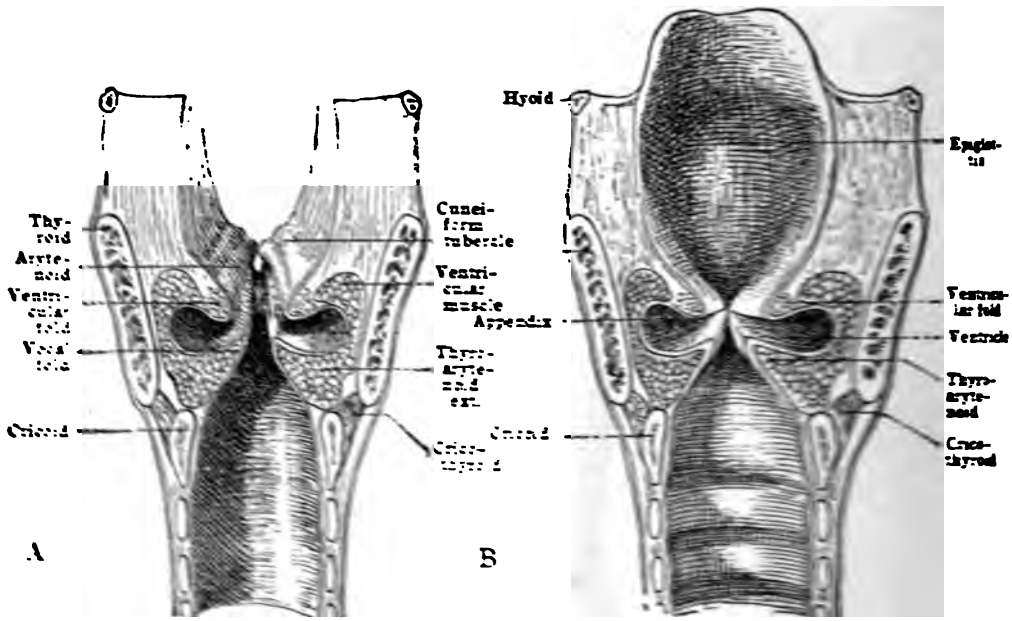
The cavity of the larynx above the level of the ventricular folds (false vocal cords) is known as the **vestibule** [vestibulum laryngis]. This is wide in its cephalic part, but the sides incline toward the median line in descending, and the cavity becomes narrow transversely in approaching the region of the glottis. Here the cavity is termed the **superior entrance to the glottis** [aditus glottidis superior]. The parts of the framework of the larynx which enter into the walls of the vestibule are: ventrally, the epiglottic and thyroid cartilages with the thyroepiglottic ligament; laterally, the quadrangular membrane, the cuneiform and corniculate cartilages, and the medial surface of the arytenoid cartilage; dorsally, the anterior surface of the transverse arytenoid muscle. The vestibule communicates with the pharynx by the **laryngeal aperture** [aditus laryngis] (figs. 981, 982, 983, 998), which looks cephalically and dorsally. The form of the aperture is oval or triangular, with the base directed ventrally; here it is bounded

by the epiglottis; laterally by the aryepiglottic fold, of the mucosa. Dorsally the laryngeal aperture is prolonged as a little notch between the corniculate cartilages and the apices of the arytenoids [**incisura interarytænoidea**], limited behind by a commissure of the mucosa.

The high ventral wall of the vestibule presents a marked convexity, the **tubercle of the epiglottis** [tuberculum epiglotticum], over the thyroepiglottic ligament. The lateral walls, higher ventrally than dorsally, show two slight ridges, separated by a shallow groove, extending caudalward from the cuneiform and corniculate tubercles. The dorsal wall, very low, corresponds to the commissure connecting the arytenoid cartilages.

The **ventricular folds** [plicæ ventriculares] or 'false vocal cords' are prominent rounded folds of mucous membrane extending ventrodorsally, one on each side of the rima vestibuli (figs. 981, 982, 998, 999). The folds are most prominent in their ventral half, reaching the angle between the laminæ of the thyroid cartilage. They gradually fade away dorsally, but fall short of the dorsal laryngeal wall.

FIG. 999.—FRONTAL SECTION OF A LARYNX HARDENED IN ALCOHOL. A Posterior segment. B. Anterior segment. Poirier and Charpy.



correspond in the ventrodorsal extent to the vocal ligaments, and stand nearer the median line than the ventricular folds. In color the vocal folds are pearly white, excepting the ventral end of each, where there is a **yellow spot** [macula flava] produced by a little mass of elastic tissue (sometimes cartilage) in the ligament. The **vocal lip** [labium vocale] on each side forms the floor of the related laryngeal ventricle and contains the upper part of the elastic cone, whose thickened free edge, the vocal ligament, lies in the vocal fold and along the vocal muscle. The two vocal lips with the vocal folds and the intervening space, the rima glottidis, together constitute the sound-producing apparatus, the **glottis.**

The **rima glottidis** (figs. 981, 982, 999) the narrowest part of the laryngeal cavity, is an elongated slit between the vocal folds and the medial surfaces of the arytenoid cartilages, extending from the transverse arytenoid muscle dorsally to the thyroid cartilage ventrally. The portion of the rima between the vocal folds is known as the **pars intermembranacea,** that between the arytenoids the **pars intercartilaginea.** The rima glottidis in easy respiration is narrow and has the form of a long triangle; in labored breathing it is widely open and lozenge-shaped.

Below the level of the vocal folds is the space called the **inferior entrance to the glottis** [aditus glottidis inferior] (fig. 999), which is narrow from side to side above, wide and circular in section below—altogether somewhat funnel-shaped. Its walls are formed by the elastic cone and by the arch and lamina of the cricoid cartilage. The lining mucosa is separated from the elastic cone by numerous glands and loosé connective tissue, a condition favorable to the development of edema; below it is continuous with the mucosa of the trachea.

By means of the **laryngoscope** a more or less complete picture of the laryngeal aperture and the cavity of the larynx can be obtained (figs. 981, 982). Cranialward there appear the root of the tongue with the epiglottic valleculæ and glossoepiglottic folds leading dorsalward to the epiglottis; dorsal to the latter, the triangular aperture of the larynx, bounded laterally by the aryepiglottic folds. Farther lateralward appear the piriform recesses, as transverse fissures behind the laryngeal aperture. Within the aryepiglottic folds are seen the prominent corniculate tubercles on either side of the interarytenoid commissure and just ventral, the variable cuneiform tubercles. Within the vestibule the epiglottic tubercle rises upon the ventral wall, while laterally appear the ventricular folds overhanging the slit-like openings of the laryngeal ventricles. Below this level the vocal folds stand out on either side approaching nearer the median plane than do the ventricular folds and conspicuous by their pearly whiteness. The form and extent of the rima glottidis and of its divisions, the intermembranous and intercartilaginous parts, can be inspected. Far down, the cricoid cartilage and ventral wall of the trachea may appear and under favorable conditions a glimpse of the bifurcation of the latter can be obtained.

The **mucous coat of the larynx** [tunica mucosa laryngis] in general is covered by a ciliated epithelium; the vocal lips, and, exceptionally, small areas of the mucosa of the laryngeal surface of the epiglottis and the ventricular folds possess a covering of flat, non-ciliated cells. The attachment of the mucosa to the underlying parts is very firm about the vocal folds and dorsal side of the epiglottis, but loose in the aryepiglottic folds, where much areolar tissues is present. In general the mucosa is pink in color becoming bright red over the epiglottic tubercle and edges of the epiglottis and fading over the vocal folds, which appear almost white.

Numerous **mucous glands** [glandulæ laryngeæ] occur about the larynx and are aggregated into groups in certain places. One cluster of **anterior glands** is found in front of and on the posterior side of the epiglottis; another, the **middle glands,** is in the ventricular fold, in the triangular fovea of the arytenoid cartilage and clustered about the cuneiform cartilage, while a third set, the **posterior glands,** is disposed about the transverse arytenoid muscle. Many glands pour their secretion into the appendix of the laryngeal ventricle, but there are none on or about the vocal folds. **Lymph-nodules** of the larynx occur in the mucosa of the ventricle and on the posterior surface of the epiglottis.

Position and relations.—The larynx opens above into the pharynx by the aditus and in this region is connected with the hyoid bone. Below, its cavity leads into the trachea. Its position in the neck is indicated on the surface by the laryngeal prominence (Adam's apple). It stands ventral to the fourth, fifth, and sixth cervical vertebræ; from these it is separated by the prevertebral muscles and fascia and the laryngeal portion of the pharynx. The integument and cervical fascia cover the larynx ventrally in the middle line, while toward the side are the sternohyoid, sternothryoid, and thyrohyoid muscles. The lateral lobe of the thyroid gland and the inferior constrictor of the pharynx are in relation to it laterally, while further removed are the great vessels and nerves of the neck.

Peculiarities of age and sex. Position.—The larynx is placed high in the neck in fetal and infantile life and descends in later life. In a six-months fetus the organ is two vertebræ higher than in the adult. (Symington.) The descent of the larynx has been attributed to the vertical growth of the facial part of the skull, but this cause is questioned by Cunningham, who points out the high position of the larynx in the anthropoid apes, where the facial growth is more striking than in man; it appears also that the larynx follows the thoracic viscera in their subsidence, which, according to Mehnert, continues until old age. At birth the interval be-

tween the hyoid bone and thyroid cartilage is relatively very small and increases but little during early life.

Growth and form (cf. p. 47).—The larynx of the newborn is relatively large and in contour more rounded than that of the adult. The organ continues to grow until the third year, when a resting period begins, lasting until about twelve years of age, during which time there appears to be no difference between the larynx of the male and that of the female. At puberty, while no marked change is observable in the larynx of the female, rapid growth accompanied by modification of form of the larynx is initiated in the male. The laryngeal cavity is enlarged, the ventrodorsal diameter markedly increased; the whole framework becomes stronger; the thyroid cartilage especially increases greatly in its dimensions, giving rise to the laryngeal prominence; the vocal folds are lengthened and thickened, the voice changing in quality and pitch. These changes are, for the most part, effected in about two years, but complete development is not attained before twenty to twenty-five years of age. Castration is known to influence the development of the larynx, for in the eunuch it has been found to resemble that of a young woman. The changes in the structure of the cartilages have already been described.

Dimensions.—In the male the distance from the upper edge of the epiglottis to the lower margin of the cricoid is 70 mm.; in the female, 48 mm. The transverse diameter is 40 mm. in the male, 35 mm. in the female. The greatest sagittal diameter is 40 mm. in the male, 37 mm. in the female. The *vocal folds* in the male measure relaxed about 15 mm., in the female but 11 mm.; when stretched, about 20 mm. and 15 mm. respectively.

The length of the *rima glottidis* in the quiescent state is on the average 23 mm. in the male, 17 mm. in the female. In the male the *pars intermembranacea* measures 15.5 mm., the *pars intercartilaginea*, 7.5 mm. In the female these are 11.5 mm. and 5.5. mm. respectively. The rima may be lengthened by stretching of the vocal folds to 27.5 mm. in the male and 20 mm. in the female. (Moura.) In the male the width of the rima glottidis is 6–8 mm. in its widest part, but may be increased nearly to 12 mm.

Vessels and nerves (figs. 991, 996).—The *arteries* supplying the larynx are the superior and inferior laryngeal, which accompany the internal and inferior largyneal nerves respectively, and the cricothyroid arteries (see pp. 580, 604). The superior and inferior laryngeal veins join the superior and inferior thyroid veins respectively. The *lymph* vascular system is well developed throughout the larynx generally, but in the vocal folds where the mucosa is thin and tightly bound down the vessels are scarce and small in size (see p. 751).

The *nerves* of the larynx are the superior and inferior laryngeal branches of the vagus and also certain branches of the sympathetic. Taste-buds occur and are abundant in the mucosa of the posterior surface of the epiglottis. The innervation of the muscles has already been indicated, and the description of the course and relations of these nerves will be found in the chapter on the PERIPHERAL NERVOUS SYSTEM. It should be mentioned here, however, that the idea of sharply limited territories of innervation, not only for the mucosa, but for the muscles as well, has been brought into question by the researches of Semon and Horsley, Exner, and others, which show that the distribution and functions of the laryngeal nerves are extremely complex.

The development of the larynx.—The larynx is developed partly from the lower portion of the embryonic pharynx and partly from the upper portion of the trachea (see p. 471). The cricoid cartilage represents the uppermost tracheal cartilage, while the thyroid is formed by the fusion of four cartilages representing the ventral portions of the cartilages of the fourth and fifth branchial arches. The laryngeal muscles are derived from the musculature of these arches and consequently their nerve-supply is from the vagus. Whether or not the arytenoid and epiglottic cartilages are also derivatives of the branchial arches is uncertain, although it seems probable that they are.

THE TRACHEA AND BRONCHI

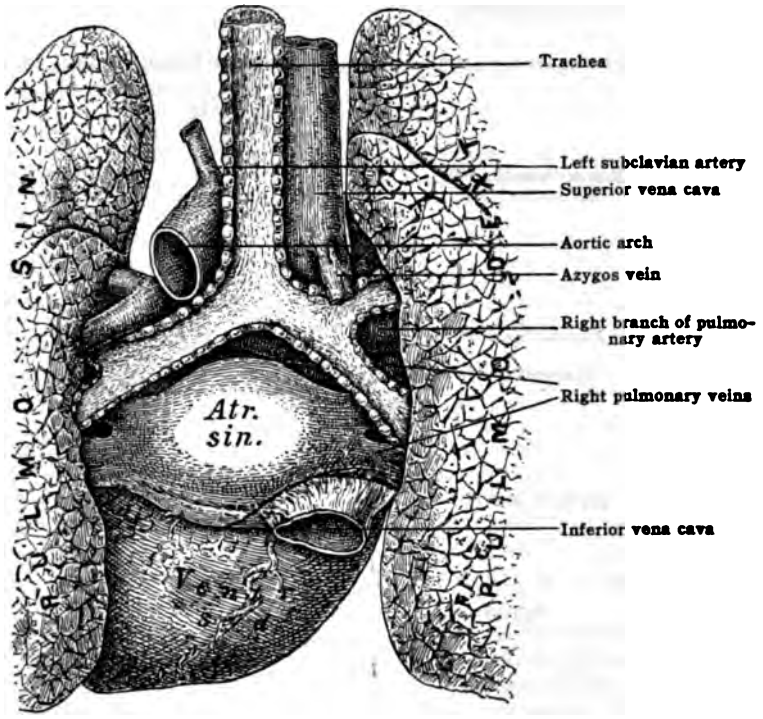
The tubular **trachea** (figs. 968, 983, 1000), or windpipe, extends from the larynx downward through the neck and into the thorax to end by dividing into two branches, the **right** and **left bronchi** [bronchus (dexter et sinister)], which lead to the lungs. These tubes are simple transmitters of the respiratory air. Their walls are, for the most part, stiff and elastic, consisting in large part of cartilage. While the general form of these tubes is cylindrical, a rounded contour is presented by their walls only in front and at the sides, the posterior surface being flat. The inner surface of the walls of the tubes presents a succession of slight annular projections caused by the cartilaginous rings which enter into their structure (fig. 997). The caliber of the trachea varies at different levels, a cast of the lumen being in general spindle-shaped. Its sectional area is less than the combined sectional areas of the two bronchi. When the **bifurcation of the trachea** [bifurcatio trachеæ] is viewed by looking down into its cavity, a sagitally directed keel, the *carina trachеæ* (fig. 1001), is seen between the openings which lead into the bronchi.

Position and relations (figs. 983, 1000, 1004).—The trachea lies in the median plane, extending from the level of the sixth cervical vertebra caudalward and dorsalward, receding from the surface in following the curve of the vertebral column, and deviating a little to the right, reaches the level of the fourth or fifth thoracic vertebra, where it divides. Its caudal end is fixed so that with elevation and descent of the larynx the tube is stretched and contracted, changes in length

which also result from extension and flexion of the head and neck. The mobility of the trachea is favored by its loose investment of connective tissue.

About half of the trachea lies in the neck, but the extent varies with the length of the neck, the position of the head and with age; the trachea holds a lower position in adult life than in childhood and a still lower one in old age when the bifurcation may be as low as the sixth or seventh thoracic vertebra. Ventrally and closely connected with the trachea is the isthmus of the thyroid gland, covering usually the second to fourth cartilages; ventral to this the cervical

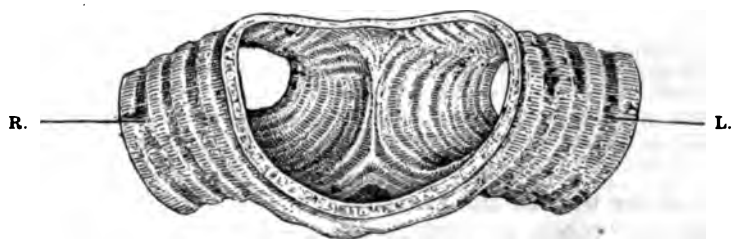
FIG. 1000.—TRACHEA AND BRONCHI IN THEIR RELATIONS TO THE GREAT VESSELS AS SEEN FROM BEHIND. (After Gegenbaur.)



fascia and integument. More caudally, the trachea is related ventrally to the inferior thyroid veins and some tracheal lymph-glands, and sometimes a thyroidea ima artery. The innominate artery occasionally crosses the trachea obliquely in the root of the neck. Dorsal to the trachea, in its whole length, lies the esophagus, which in this part of its course inclines to the left. On either side are the great vessels and nerves of the neck, and the lobes of the thyroid gland. The inferior laryngeal nerve lies in the angle between the esophagus and trachea.

Within the thorax the trachea lies in the mediastinum, enveloped in loose areolar tissue and fixed through strong fibrous connections with the central tendon of the diaphragm. The

FIG. 1001.—BIFURCATION OF THE TRACHEA SHOWING THE TRACHEAL KEEL. R. L., Right and left bronchi. (Heller and von Schroetter, from Poirier and Charpy.)

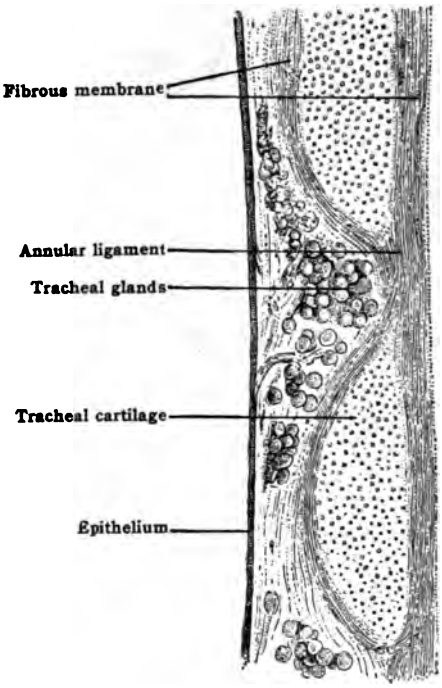


innominate artery and the left common carotid are at first ventral and then lateral as they ascend, while the left innominate vein and the remains of the thymus are further ventralward. The aortic arch is in contact with the ventral surface of the trachea near the bifurcation. On the right side are the vagus nerve, the arch of the vena azygos, the superior vena cava, and the mediastinal pleura; on the left, the arch of the aorta, the left subclavian artery, and the inferoir laryngeal nerve. A large group of **bronchial lymph-glands** [lymphoglandulæ bronchiales] lies caudal to the angle of bifurcation. The esophagus is dorsal and to the left.

The bronchi take an oblique course to the hilus of the lung, where they branch. The right bronchus is nearer to the vertical in its course than is the left; it is also shorter and broader. These conditions explain the more frequent entrance of foreign bodies into the right than into the left bronchus. The asymmetrical course of the two bronchi is probably genetically associated with the position of the heart and aorta.

The azygos vein arches over the right bronchus, the vagus passes dorsally, and the right branch of the pulmonary artery crosses ventrally below the level of the first (eparterial) branch of the bronchus. The aorta arches over the left bronchus and gains its dorsal surface along with the esophagus; the left branch of the pulmonary artery passes at first ventrad and then cephalad to the bronchus.

FIG. 1002.—SCHEMATIC LONGITUDINAL SECTION OF THE WALL OF THE TRACHEA. (Gegenbaur.)



Dimensions.—On account of their elasticity considerable difficulty is met with in obtaining accurate measurements of the air-tubes. The length of the trachea is given at 95–122 mm.; its transverse diameter 20–27 mm.; the sagittal diameter 16–20 mm. The right bronchus has a length of 25–34 mm.; the left, 41–47 mm. The transverse diameter of the right is 18 mm.; of the left, 16 mm. The angle of bifurcation of the trachea varies from 56° to 90°, the mean being 70.4°; a wide angle corresponding to the breadth of the thorax of man. The right bronchus makes an angle of 24.8° with the median plane; the left, 45.6°.

According to Tillaux the length of that portion of the trachea between the superior edge of the sternum and the cricoid cartilage varies with age and sex as follows:

Adult male,	from 4.5 to 8.5 cm	average, 6.5 cm.
Adult female,	from 5 to 7.5 cm	average, 6.4 cm.
Boys $2\frac{1}{2}$ to 10 years,	from 2.7 to 6.5 cm	average, 4.4 cm.
Girls $3\frac{1}{2}$ to $10\frac{1}{2}$ years,	from 4 to 6.5 cm	average, 5.1 cm.

The diameter of the lumen of the trachea when distended to a cylindrical form has been measured by Sée as follows: newborn, 4.12 to 5.6 mm.; infant 2 years, 7.5 to 8 mm.; infant 4 to 7 years, 8 to 10.5 mm.; over 20 years, male, 16 to 22.5 mm.; over 20 years, female, 13 to 16 mm.

Structure of the trachea and bronchi (figs. 989, 999, 1000, 1002).—The walls of the trachea and bronchi are composed of a series of cartilages having the form of incomplete rings, held together and enclosed by a strong and elastic fibrous membrane. Dorsally, where the rings are deficient, this membrane remains as the membranous wall [paries membranaceus]; between the cartilages it constitutes the annular ligaments [ligg. annularia (trachealia)].

A tracheal cartilage [cartilago trachealis] comprises a little more than two-thirds of a circle. Its ends are rounded, its outer surface flat, while the inner surface is convex from above downward; the upper and lower margins are nearly parallel. The cartilages are from sixteen to

twenty in number. The first is usually broader than the type, and is connected by the cricotracheal ligament with the cricoid cartilage. Sometimes these two cartilages are in part continuous. The last cartilage is adapted to the bifurcation of the trachea and presents at the middle of its lower margin a hook-like process. This turns backward between the origins of the bronchi, and in the majority of cases gives a cartilaginous basis to the tracheal carina. Some of the tracheal cartilages vary from the type by bifurcating at one end. The cartilages keep the lumen of the trachea patent for the free passage of the air. Calcification occurs as with the laryngeal cartilages, but much later in life.

A **mucous coat** [tunica mucosa], soft and pinkish-white in color, covers the inner surface of the trachea (fig. 1002); posteriorly it is thrown into longitudinal folds. Mucous **tracheal glands** [gl. tracheales] are present in the elastic **submucous coat** [tela submucosa] between the cartilages and at the dorsum of the trachea. A thin layer of transversely disposed smooth muscle-fibers, stretching between the ends of the cartilages in the dorsal wall, constitutes the **muscular coat** [tunica muscularis]. Contraction of this *trachealis muscle*, as it is more properly named, causes the ends of the tracheal cartilages to be approximated and the lumen of the windpipe to be diminished.

The structure of the walls of the bronchi is similar to that of the trachea. The right bronchus possesses six to eight cartilages; the left, nine to twelve.

An inconstant *bronchoesophageal* muscle may connect the back of the left bronchus with the gullet.

Vessels and nerves.—The *arteries* supplying these air-tubes come from the inferior thyroid and from the internal mammary by its anterior mediastinal or bronchial branches. *Venous radicles* come together in the annular ligaments and join lateral veins on either side, which empty the blood into the plexuses of the neighboring thyroid veins.

Lymph-vessels are abundant, and are disposed in two sets, one in the mucosa, another in the submucosa. They drain into the tracheal, bronchial and esophageal lymph-glands. The lymphatics of the tracheal submucosa establish a direct pathway of infection to the lung by anastomosing with periarterial and peribronchial lymphatics at the bifurcation of the trachea (Winternitz). *Nerves* are provided by the vagus direct, by the inferior laryngeal, and by the sympathetic.

THORACIC CAVITY

Thoracic cavity [cavum thoracis] is the term used to denote the space included by the walls of the thorax and occupied by the thoracic viscera. These are, on each side, the lung, the pleura with its cavity, and in the middle the thymus gland or its remains, the pericardium and heart, great vessels, nerves, trachea, thoracic duct and esophagus, all closely associated and surrounded by connective tissue, forming a dividing wall, the mediastinal septum, standing between the right and left sides of the thoracic space.

The **limits** of the thoracic space are given by the skeletal parts of the thorax together with the ligaments involved in the articulations and the muscles and membranes interposed between the bones. The arched diaphragm forms the inferior limit; and the barrier presented by the scalene muscles and the cervical fascia makes the superior boundary, which, it is to be observed, lies above the plane of the superior aperture of the thorax and therefore in the base of the neck (fig. 1003). These boundaries are approached by the extension of the pleural cavities; yet there intervenes the parietal layer of the pleural sac which is connected with the thoracic walls by loose connective tissue, the **endothoracic fascia.**

The **form** of the thoracic space departs from the external contour of the thorax chiefly through the projection into it of the ridge made by the succession of the thoracic vertebral centra, and by the presence on either side of the latter of the broad, deep pulmonary sulcus. On account of these features a transverse section of the thoracic space is somewhat heart-shaped, however, much compressed ventrodorsally (fig. 1009).

The arch of the diaphragm on the right side rises to the level of the spinous process of the seventh thoracic vertebra; on the left, to the level of the eighth thoracic spinous process. At its circumference the diaphragm is in contact to a variable extent above its origin with the inner surfaces of the costal arches. In the lower part of this zone a connection exists between the muscle and the thoracic wall through a continuation of the endothoracic fascia; in the upper part, the phrenicocostal sinus (see p. 1260) intervenes. The level reached by this deepest part of the pleural cavity is lower than the summit of the peritoneal cavity, so they overlap to a considerable extent.

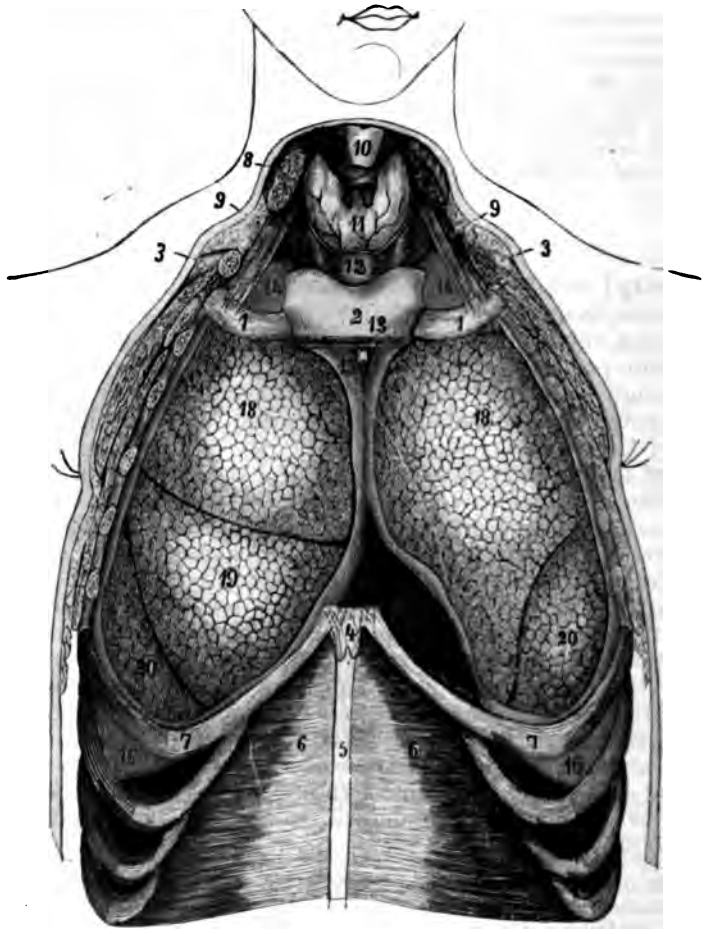
THE PLEURÆ

The **pleuræ** (figs. 1003, 1009) are the paired, closed serous sacs which invest nearly the whole surface of the lungs forming the **pulmonary pleuræ**, and in large measure line the inner surface of the thoracic walls, forming the **parietal pleuræ.** Strictly speaking, however, the *endothoracic fascia* lines the thoracic cavity, and

the pleuræ together with other structures are contents of the thoracic cavity. The right and left pleural sacs are completely separated one from another by a sagittal partition, the *mediastinal septum* (see p. 1261). The walls of the sacs enclose paired spaces or cavities known as the **pleural cavities**, which in the normal state are merely potential or capillary spaces containing a small amount of serous fluid for lubrication of the apposed surfaces of the pulmonary and parietal pleuræ. The right and left pleural cavities, as the pleural sacs, are absolutely independent of each other, are lined by endothelium and present a smooth glistening appearance.

FIG. 1003.—PLEURAL CAVITY OPENED FROM IN FRONT.

1, first rib; 2, manubrium sterni; 3, acromial extremity of clavicle; 4, xiphoid process; 5, linea alba; 6, m. transversus abdominis; 7, seventh rib; 8, sternocleidomastoid m.; 9, anterior scalene m.; 10, larynx; 11, thyroid gland; 12, deep layer of cervical fascia in front of the trachea; 13, superior mediastinum; 14, pleural cupola; 15, mediastinal pleura (costomediastinal sinus) 16, lower margin of costal pleura (phrenicostal sinus); 17, pericardium; 18, superior lobe of lung; 19, middle lobe of right lung; 20, inferior lobe of lung; 21, diaphragm. (Rauber-Kopsch.)

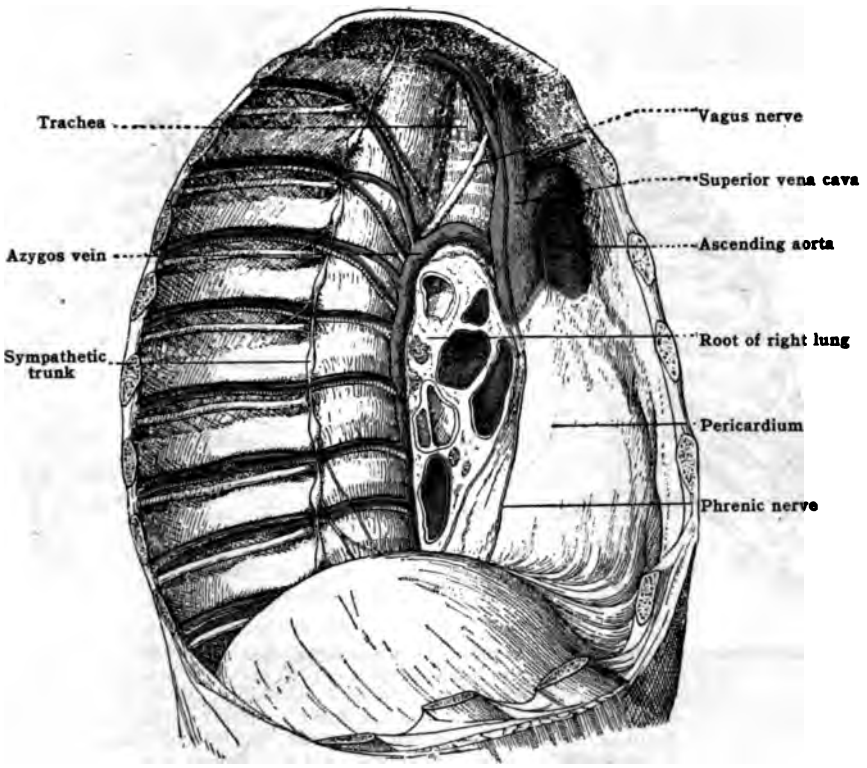


The paired **pulmonary pleura** covers the outer surface of the lung, with which it is inseparably connected. It follows all irregularities of the lung surface and dips into the fissures of the lung so as to separate the lobes. At the hilus the pulmonary pleura passes from the mediastinal surface of the lung to cover the root above, in front, and behind, then continues medialward as the mediastinal portion of the parietal pleura, forming caudal to (below) the root of the lung a double layer of mediastinal pleura which is directed caudalward and medialward as the **pulmonary ligament** (fig. 1010). The portion of the lung occupied by the hilus and the very limited space of the lung surface between the layers of the pulmonary ligament caudal to the hilus have no pleural investment.

The paired **parietal pleura** is divided, according to the regions of the chest with which it is associated, into the *costal*, *diaphragmatic*, and *mediastinal pleuræ;* moreover, the parietal pleura extends into the root of the neck, forming the *cervical pleura* [*cupula pleuræ*]. It must be kept in mind that the subdivision of the parietal pleura as indicated is more or less arbitrary and that the several divisions are directly continuous with each other.

The **costal pleura** lines the thoracic wall, to which it is loosely bound by the *endothoracic fascia;* dorsally where the pleura is reflected from the ribs to the vertebral column, it is more firmly atached. It covers incompletely the deep surface of the sternum and extends laterally upon the inner surfaces of the ribs and intercostal muscles. Dorsally beyond the angles of the ribs it passes over the anterior rami of the thoracic nerves and intercostal vessels, the heads of the ribs, and the sympathetic trunk to the vertebral column; here it becomes continuous with the mediastinal pleura. Above (cranialward), the costal pleura reaches beyond the superior aperture of the thorax into the root of the neck, and in the form of a dome, the **cupola** of the pleura,

FIG. 1004.—RIGHT LATERAL SURFACE OF THE MEDIASTINUM AFTER REMOVAL OF THE PLEURA. (Poirier and Charpy.)



is adapted to the apex of the lung. It is supported by processes of the deep cervical fascia, and by a fibrous aponeurosis known as *Sibson's fascia*, coming from the scalenus minimus muscle and connected with the inner margin of the first rib. In relation to the pleural cupola are those structures grouped about the lung apex: the brachial plexus, subclavian artery, anterior scalene muscle, and the subclavian vein, and, on the left side, in addition, the thoracic duct. The highest point dorsally of the cervical pleural dome reaches the neck of the first rib; ventrally from 3 to 6 cm. above the sternal end of the first rib, and from 1 to 4 cm. above the clavicle. Below (caudalward), the costal pleura is continuous with the **diaphragmatic pleura** [pleura diaphragmatica], which is bound closely by a very sparse endothoracic fascia to the thoracic surface of the diaphragm and covers it, excepting the pericardial area and where the diaphragm and thoracic wall are in contact.

The **mediastinal pleuræ** are reflected from the costal pleuræ on the deep surface of the sternum, at the right and left sides of the mediastinum as the **laminæ mediastinales,** covering the pericardium [pleura pericardiaca], to which they are closely adherent, and also the other structures of the mediastinum, with which the two layers are less firmly connected. Above (cephalad to) the lung root each mediastinal pleura stretches directly from the sternum to the vertebral column; at the level of the root it is reflected laterally to the pulmonary pleura covering the root ventrally and dorsally, while caudal to the root the mediastinal pleura forms a double layer—the *pulmonary ligament.* The right mediastinal lamina covers (fig. 1004) the right innominate vein, the superior vena cava, the vena azygos, the trachea, the innominate artery,

the description of the reflections of the parietal pleuræ, the ventral mediastinal space is narrow cephalically, due to the close approximation in the midline of the right and left mediastinal pleuræ. This takes place on the ventral aspect of the pericardium from the sternal angle to the fourth costal cartilages. Owing to the receding of the left mediastinal pleura from the midplane and from its fellow, the ventral mediastinum is of considerable but variable breadth in its lower or caudal half. The components of the ventral mediastinum are the caudal portion of the thymus, a few lymph-nodes, lymph-vessels, adipose and areolar tissue, and small branches from the internal mammary arteries.

The **middle mediastinum** is the expanded central portion of the caudal segment of the mediastinal septum. It is, generally speaking, coextensive with the pericardium and in addition to the latter consists of the heart, the ascending aorta, the trunk of the pulmonary artery, the cardiac end of the superior vena cava, the arch of the azygos vein, the phrenic nerves and accompanying vessels, the bronchial lymph-nodes, and a large portion of the roots of the lungs.

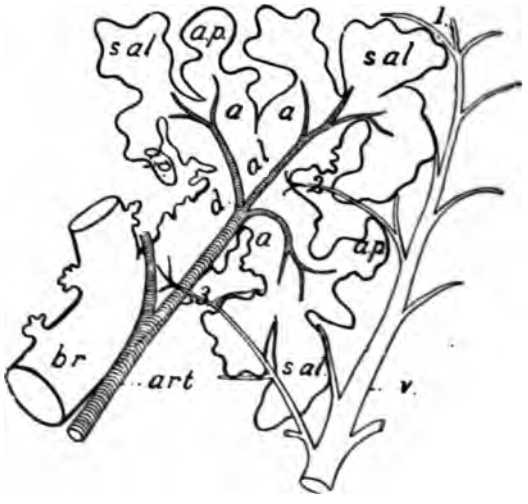
The **posterior** (dorsal) **mediastinum** (fig. 1009) occupies the interval bounded by the lower eight thoracic vertebræ dorsally; the pericardium and the roots of the lungs ventrally; the mediastinal pleuræ laterally. It extends from the fourth thoracic vertebra to the diaphragm. It may be thought of as a caudal extension of the more dorsal portion of the superior mediastinum, many of the component structures of the latter being prolonged into the dorsal mediastinum on their way to the abdominal cavity. The dorsal mediastinum includes the esophagus, the descending thoracic aorta and its right intercostal branches, the azygos and hemiazygos veins and tributaries, the thoracic duct, the vagi and splanchnic nerves, and the dorsal mediastinal lymph-nodes; all surrounded and supported by connective tissue.

THE LUNGS

The **lungs** [pulmones], the essential organs of respiration, are constructed in such a way as to permit the blood to come into close relation with the air (fig. 1008). In plan of structure the lung has been compared with a gland, since it is

FIG. 1008.—SCHEMATIC SECTION OF A LOBULE OF THE LUNG SHOWING THE RELATION OF THE BLOOD-VESSELS TO THE AIR-SPACES. (After Miller, from the 'Reference Handbook of the Medical Sciences.')

b.r. Respiratory bronchiole. *d.al.* Alveolar duct; a second alveolar duct is shown cut off. *a.a.* Atria. *s.al.* Alveolar saccule. *a.p.* Alveolus. *art.* Pulmonary artery with its branches to the atria and saccules. *v.* Pulmonary vein with its tributaries from the pleura (1), the alveolar duct (2), and the place where the respiratory bronchiole divides into the two alveolar ducts (3).

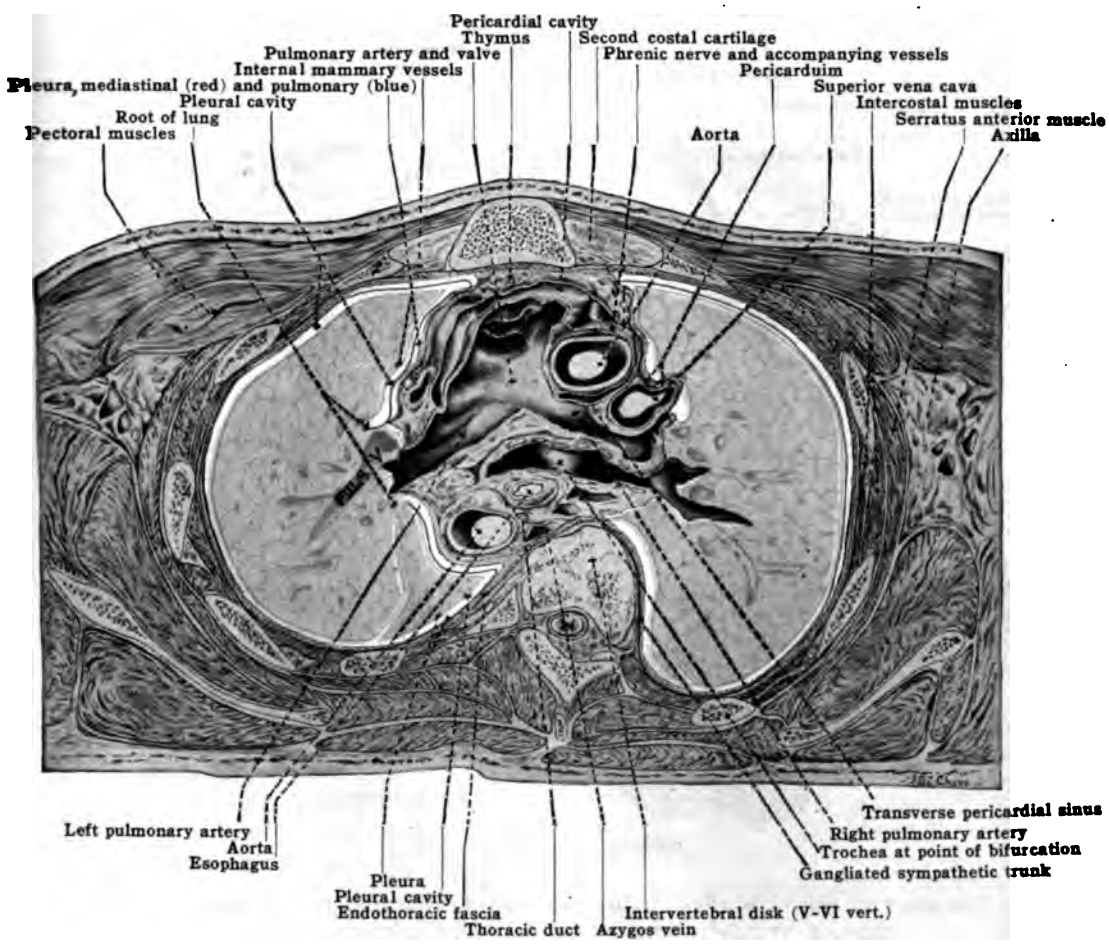


composed of a tree-like system of tubes terminating in expanded spaces. Closely associated with the system of tubes are certain blood-vessels, some nutritive but most of them respiratory in character.

The lungs are two in number, and lie one on either side of the thoracic cavity separated by the mediastinal partition (figs. 968, 1009). Serous membranes covering the latter right and left are parts of two closed sacs, the **pleuræ**, each of which is to be regarded as lining one lung and the neighboring chest-wall after the manner of serous membranes in general. The spaces enclosed within the sac-walls are the **pleural cavities**, potentially subdivisions of the cœlom. It must be kept clearly in mind that the lungs are not contained within the pleural cavities (p. 1258), but lie in pleural cavities containing a small amount of serous fluid.

Form of the lungs (figs. 1009, 1010).—Each lung is pyramidal or conical in form, with the **base** [basis pulmonis] caudal and resting on the diaphragm, and with **apex** [apex pulmonis] cephalic, in the root of the neck. Three surfaces, costal, mediastinal and diaphragmatic are described. The broad convex **costal surface** [facies costalis] is directed against the thoracic wall ventrally, laterally and dorsally, and is marked by grooves corresponding to the ribs. The **mediastinal surface** [facies mediastinalis] is concave and presents a contour adapted to structures of the mediastinum (fig. 1010). A special concavity on this surface, known as the **cardiac fossa,** corresponds to the prominence of the heart and is deeper in the left lung than in the right. Above and behind the cardiac fossa

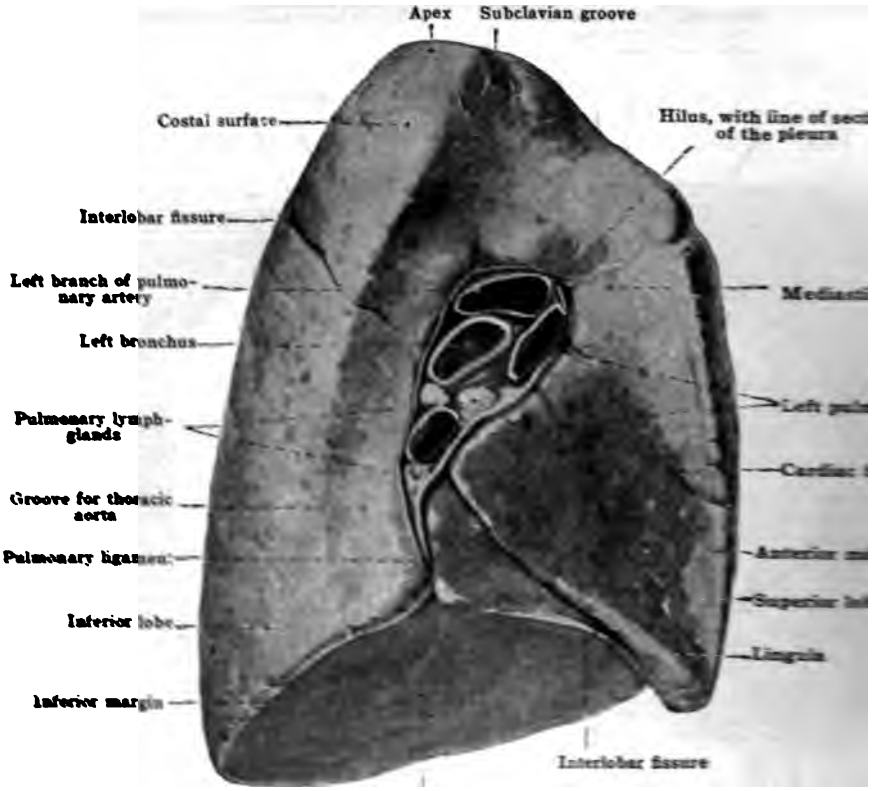
FIG. 1009.—HORIZONTAL SECTION OF THE THORAX THROUGH THE ROOTS OF THE LUNGS.



is a depression, the **hilus** of the lung [hilus pulmonis], where the bronchus, pulmonary vessels, lymphatics and nerves, together constituting the **root** of the lung [radix pulmonis], enter and leave. Near the dorsal edge of the mediastinal surface is a groove, which ascends and turns forward over the hilus. The groove of the left lung is adapted to the cylindrical surface of the aorta; that of the right, the vena azygos. A well-marked **subclavian sulcus** extends upward on this surface to the apex, corresponding on the right side to the lower part of the trachea and right subclavian artery, on the left to the left subclavian artery alone. Further forward is a groove adapted in the right lung to the superior cava; in the left to the left innominate vein. The lung with its visceral pleura is not in actual contact with these several structures, but is separated from them by the pleural cavity and the mediastinal pleura. The mediastinal surface passes gradually into the costal surface dorsally, there being no proper dorsal edge. Where the mediastinal and costal surfaces meet ventrally, a sharp ventral or **anterior margin**

phragm and thoracic wall.

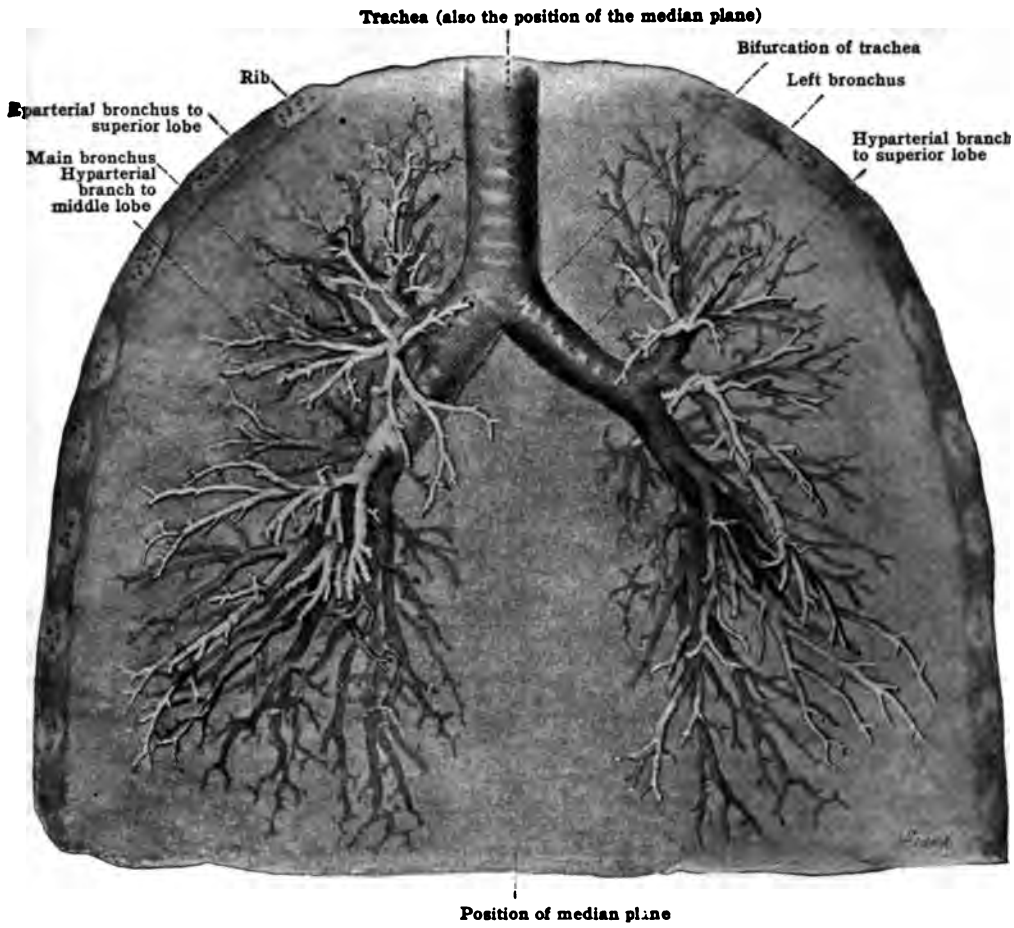
FIG. 1010.—LEFT LUNG, VIEWED FROM THE MEDIASTINAL SURFACE. (Spalteh



The **apex** of the lung [illegible] is rounded and points

inferior lobe [lobus inferior]. The interlobar fissure runs caudally and ventrally beginning a short distance below the apex, and reaching the base near the anterior margin in the left lung, somewhat further back in the right lung. From the obliquity of the plane of the fissure it will be noticed that the inferior lobe reaches dorsally to within a short distance of the apex, and includes the greater part of the back and base of the lung, while the superior lobe takes in the anterior margin and apex. The presence of a **middle lobe** [lobus medius] disturbs the symmetry of the right lung. This results from a deep, nearly horizontal **secondary fissure** cutting through the lung somewhat below its middle, and extending along the plane of the fourth rib between the anterior margin of the lung and the main interlobar fissure, which it reaches at about the level of the midaxillary line.

FIG. 1011.—CAST OF THE AIR-TUBES AND THEIR BRANCHES, VIEWED FROM IN FRONT. (Spalteholz.)



Besides possessing the individual peculiarities mentioned, the two lungs further differ from each other in general form and weight, the right lung being considerably broader and heavier than the left. The difference in length maintained by some anatomists, even if it prove constant, must be slight and of little practical importance. These differences seem to follow the asymmetry of the vault of the diaphragm and the position of the heart.

Topography of the lungs.—The **apices** of the lungs extend upward as high as the first thoracic vertebra, a level considerably higher than the superior margin of the sternum (figs. 1013, 1014). The subclavian vein and artery and the brachial plexus, together with the anterior scalene muscle, control to a certain degree the height reached. There seems to be no constant difference between the levels attained by the apices of the two lungs. The extent to which the apex rises above the clavicle is rarely more than 3.5 cm. (Merkel), and will, of course, vary with individual differences in the position and form of this bone. The average is not over 2.5 cm. (1 in.).

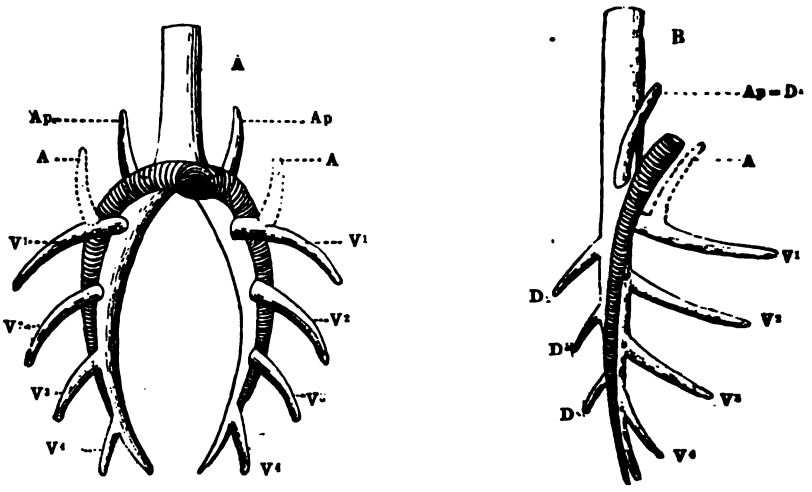
The **base** of the lung, resting on the diaphragm, is separated by that thin partition from the underlying abdominal viscera: thus beneath the base of the right lung is the right lobe of the

liver, while under the left lung are the left lobe of the liver, the fundus of the stomach, and the spleen. The position of the apex changes very little in respiration, and the same holds true for the dorsal bulky part of the lung. In deep inspiration the thin inferior (caudal) and anterior (ventral) margins of the lung migrate into and partially obliterate the phrenicocostal and the costomediastinal sinuses of the pleura, respectively. The dorsal part of the lung rests against the side of the vertebral column in the deep hollow of the angles of the ribs, and reaches below to the level of the eleventh costovertebral joint (fig. 1014).

The anterior margins (fig. 1013) descend in curves from behind the sternoclavicular joints and run near together a little to the left of the median line. At the level of the sixth costosternal junction the anterior margin of the right lung turns lateralward to follow the sixth costal cartilage. The anterior margin of the left lung turns lateralward along the fourth costal cartilage as far as the parasternal line, descending in a curve to the lingula and thus forming the cardiac incisure. The positions of the inferior margins (figs. 1013. 1014) of the two lungs are practically alike in their positions. Each extends in a curve convex downward, behind the sixth costal cartilage in its entire length, crosses the costochondral junction of the sixth rib to

FIG. 1012.—SCHEME OF THE BRONCHIAL TREE ACCORDING TO NARATH. A. Anterior view. B. Right lateral view. (Poirier and Charpy.)

A. Apical bronchus, collateral of the first ventral and susceptible of becoming eparterial. Ap. in migrating to the bronchial trunk.



the superior margin of the eighth rib in the axillary line, and so to the ninth or tenth rib in the scapular line, whence they run horizontally medialward to the eleventh costovertebral joint. These relations are the mean between the conditions observed in the cadaver and as found by physical examination of the living. In old age the inferior margins of the lungs reach a level one or two intercostal spaces lower than is the case in adult life (Mehnert).

The chief or interlobar fissure (fig. 1014) begins dorsally about 6 cm. below the apex of the lung at the level of the head of the third rib. With the arm hanging at the side, a line drawn across the back from the third thoracic spine to the root of the scapular spine would indicate the course of the upper part of this fissure. (Merkel.) Thence it passes caudalward and around the chest to the end of the sixth rib in the midclavicular (mammillary) line. Merkel points out the use of the root of the scapular spine as a landmark for finding the limits of the lobes dorsally: with the arm hanging at the side all above this spot is superior lobe; all below it the inferior. The secondary fissure of the right lung begins at the main interlobar fissure in the midaxillary line, about the level of the fourth rib or fourth interspace, and passes nearly horizontally to the anterior margin of the lung at the level of the fourth rib.

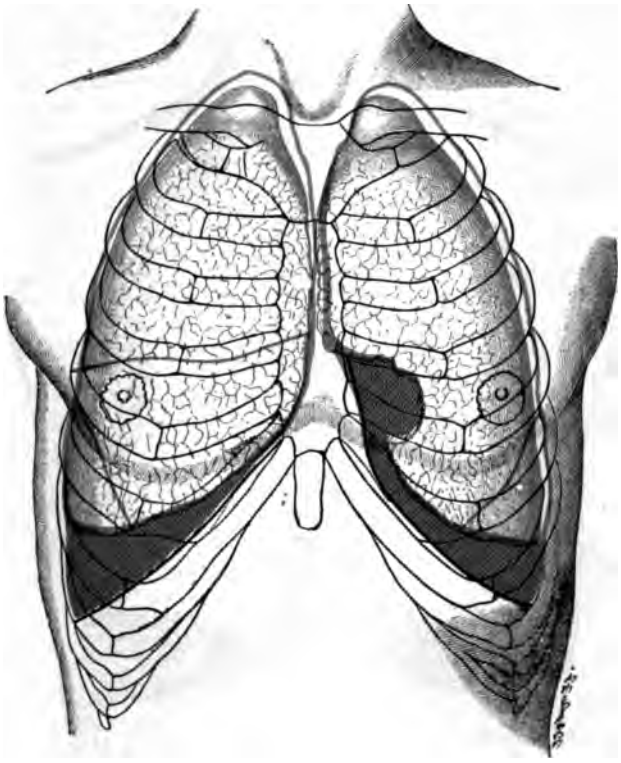
The roots of the lungs are placed opposite the fifth, sixth, and seventh thoracic vertebræ. The right root lies dorsal to the superior vena cava and under the arch of the azygos vein; the left root is beneath the aortic arch and ventral to the thoracic aorta. The phrenic nerve passes ventrad to each root, the vagus dorsad. The pulmonary plexuses occupy ventral and dorsal positions, respectively. The pulmonary ligament of the pleura goes from the caudal edge of the root (see p. 1260).

Branching of the bronchial tubes (figs. 1000, 1011).—Each bronchus, from its origin at the bifurcation of the trachea, takes an oblique course to the hilus, and then continues in the lung as a main tube, extending toward the posterior part of the base. These stem-bronchi are curved, probably in adaptation to the heart, the right like the letter C and the left like an S. Throughout their course the stem-bronchi give off in monopodic fashion collateral branches, the bronchial rami [rami bronchiales], and these, branching in a similar way, reach all parts of the lung.

The first bronchial ramus of the right stem-bronchus arises above the place where the latter is crossed by the pulmonary artery and is named the **eparterial bronchial ramus** [ramus bronchialis eparterialis]; it supplies the superior lobe of the right lung, sending a special branch to the apex. All other bronchial rami, whether in the right or left lung, take origin from the stem-bronchi below the level of the crossing of the pulmonary artery and are called **hyparterial bronchial rami** [rami bronchiales hyparteriales]. The second bronchial branch of the right lung goes to supply the middle lobe, while several bronchial branches enter the inferior lobe. On the left side, the first bronchial branch arises below the crossing of the pulmonary artery, and goes to supply the superior lobe, providing it with an apical ramus. The other branches are given to the inferior lobe.

Structure of the bronchial rami.—The larger bronchial rami contain in their walls both C-shaped and irregular plates of cartilage, the latter gradually replacing the former as the branches become smaller. The membranous wall is lost and plates of cartilage are disposed on all sides. The mucosa,with ciliated epithelium, is thrown into longitudinal folds covering

FIG. 1013.—VENTRAL TOPOGRAPHY OF THE LUNGS AND PLEURA. (After Merkel.)



bundles of elastic fibers of the membrana propria. Next to the latter is a continuous layer of smooth muscle-fibers circularly arranged. Mucous secreting **bronchial glands** [gl. bronchiales] are present as far as tubes of 1 mm. diameter; here the cartilages also disappear.

To W. S. Miller is due the credit of having greatly increased our knowledge of the finer structure of the lung and for having presented the conception of the primary lung lobule now generally accepted by anatomists. Some of the chief results of Miller's work are embodied in the following descriptions pertaining to the termination of the air-tubes and to the blood and lymph vascular systems of the lungs and pleura.

Through further branching of the bronchial rami a great number of very fine **bronchioles** [bronchioli] are reached, whose walls possess a weak muscle layer and are lined by mucosa having an epithelium of flattened non-ciliated cells. These, subdividing, give rise to the **respiratory bronchioles** [bronchioli respiratorii], the walls of which are beset with alveoli (fig. 1008). From the respiratory bronchioles arise the **alveolar ducts** [ductuli alveolares], or terminal bronchi, each of which leads to a group of air-spaces, called *atria*, each of which again communicates with a second series of air-spaces, the *air-sacs* (alveolar sacs or infundibula), whose walls are pouched out to form numerous **pulmonary alveoli** [alveoli pulmonum].

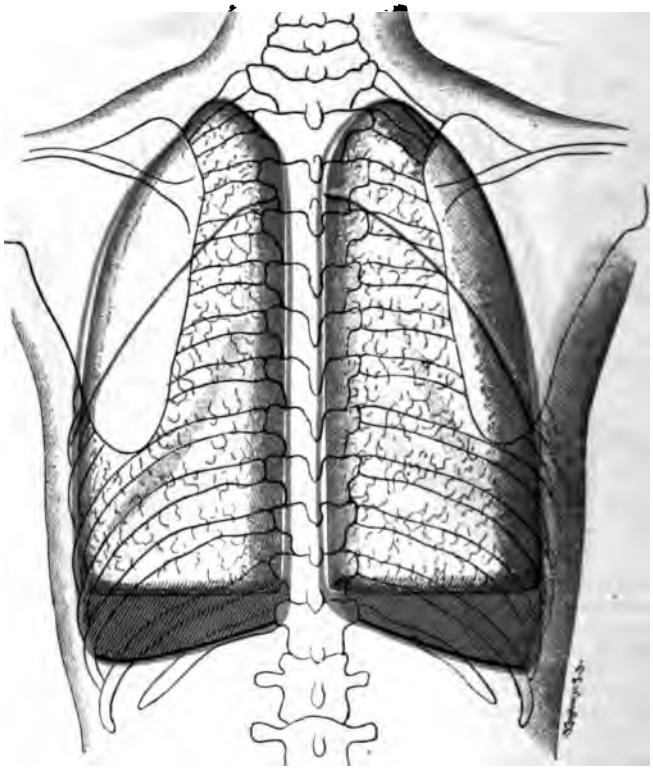
A terminal bronchus with its air-spaces and blood-vessels, lymphatics and nerves, together form a **pulmonary lobule** [lobulus pulmonum], the unit of lung structure.

Aeby divided the bronchial branches into two sets, according to their relation to the pulmonary artery. The branch arising above the place where the pulmonary artery crosses the stem-bronchus he named the **eparterial bronchus,** and those arising below the crossing he called **hyparterial.** An eparterial bronchus exists only on the right side; all other branches are hyparterial. Since the eparterial supplies the superior lobe of the right lung and no eparterial

branch is present on the left side, Aeby concluded that the left lung had no lobe homologous with the superior lobe of the right lung. He compared the middle lobe of the right with the superior lobe of the left lung. The collateral branches of the stem-bronchi arise in a dorsal and ventral series in the lower mammals, and the same arrangement, though less obvious, obtains in man. According to the views of Aeby and Hasse, the first ventral branch of the right side is distributed to the middle lobe, while the remaining three ventral and all the dorsal lateral branches are given to the inferior lobe. On the left side, the first ventral branch is given to the superior lobe; the other ventral branches and the dorsal branches are distributed to the inferior lobe.

Narath is not in accord with Aeby and considers the division of bronchial branches in accordance with their relation to the pulmonary artery as of no great morphological significance. He attributes the apparent differences on the two sides to a shifting in position of homologous branches. Thus, Narath considers that the eparterial bronchus of Aeby has become the first dorsal lateral branch by displacement above the pulmonary artery and that it is homologous

FIG. 1014.—DORSAL TOPOGRAPHY OF THE LUNGS AND PLEURA. (After Merkel.)
The parietal pleura is in green, visceral pleura and lungs in red, lung fissures in blue.



with an apical branch of the left side, which retains its primitive origin from the first ventral branch (fig. 1012). Huntington in extensive studies of the bronchial tree in mammals supports the conclusions of Narath, believing that the eparterial bronchus is a secondary branch which has migrated cephalically on the main stem. Since the designation 'epiarterial' connotes a faulty morphology Huntington argues that, except for purposes of topography, we should abandon the distinction between eparterial and hyparterial bronchi.

The physical properties of the lungs.—The average *dimensions* in the adult male are as follows: Height of the lung is given at 25–27 cm., the greatest sagittal diameter at 16–17 cm., and the greatest transverse measurement as 10 cm. for the right and 7 cm. for the left. The *volume* of the lungs when well expanded is 6500 c.c. (Merkel.) The *weight* of the lungs can be found only approximately on account of the presence of blood and mucus. In the adult male the weight of both lungs is given as 1300 gm.; female, 1023 gm. The weight of the right lung compared with the left is as 11 is to 10. Ried and Hutchinson found the weight of the lungs compared with that of the body as 1 : 37 (male), 1 : 43 (female); in the fetus at term, 1 : 70. After respiration has been established, the lung, if placed in water, will float. Its *specific gravity* is between 0.345 and 0.746. (Rauber.) The fetal lung contains no air and is heavier than water. Its specific gravity is 1.045 to 1.056. (Krause.) Lung tissue, free of air, with vessels moderately filled, has likewise a specific gravity of 1.045 to 1.056. (Vierordt.)

The color of the lung results from the presence of blood, pigment, and the air in the alveoli. It varies, therefore, as these constituents are all or in part present and with differences in their proportions. Thus the general color is red in the fetus, pink in the infant, and gray mottled

with black in the adult. The dark color is traceable to the carbonaceous matter carried into the lungs from the atmosphere.

In consistence the lung is soft and spongy, and when compressed between the fingers, emits a crackling sound. Among the physical properties the elasticity of the lung is quite remarkable. Under ordinary conditions the pressure of the air in the lung keeps the alveoli and the organ as a whole distended, but when the pleura has been opened and the air pressure equalized without and within, the lung collapses.

Vessels and nerves of the lungs.—The **bronchial arteries** (see p. 624), belonging to the systemic system, carry blood for the nourishment of the lungs. They arise from the aorta or from an intercostal artery, two for the left lung and one for the right, and, entering at the hilus, reach the dorsal wall of the main bronchus. The bronchial arteries accompany the bronchi, whose walls they supply, as far as the distal ends of the alveolar ducts, beyond which they do not go. These vessels also supply the lymph-glands of the hilus, the walls of the large pulmonary vessels, and the connective-tissue septa of the lung. **Bronchial veins** (see p. 699), anterior and posterior, arise from the walls of the first two or three divisions of the bronchi and end in the innominate and the azygos or in one of the intercostal veins; those arising from the walls of the smaller tubes, including the alveolar ducts, join the pulmonary veins. The **pulmonary artery** (see p. 570), entering the hilus in a plane anterior to the bronchus (fig. 1009), turns to the posterior aspect of the main-stem, following its branches and their subdivisions of the lobules. Entering the lobule, the last branch of the vessel gives off as many twigs as there are atria (fig. 1008), and these twigs end in dense capillary nets in the walls of the alveoli. Here the venous blood brought by the pulmonary artery, separated from the air in the alveolus only by a thin septum, is changed to arterial blood in the respiratory process. According to Miller, anastomosis between the branches of the pulmonary artery is exceptional. Anastomosis between the bronchial and pulmonary arteries has been claimed, but the connection apparently existing between these vessels is through the radicles of the bronchial veins which join the pulmonary veins. The pulmonary venous radicles begin at the capillary networks and drain the arterial blood into the pulmonary veins, which run between adjacent lobules and which receive also blood coming from the capillary network of the pulmonary pleura and from the capillary network of the bronchi (fig. 1008). Thus it will be seen that while the pulmonary vein carries mainly arterial blood, it carries also some venous blood. The **pulmonary veins** (see p. 570) follow the bronchial tree on the side opposite the arteries to the hilus, where, having converged to two large trunks located in the root of the lung below the plane of the artery, they pass to the left atrium. The pulmonary veins have no valves.

Lymphatics.—Miller has found the lymphatic vessels forming a closed tube system in the walls of the bronchi, in the pleura, and along the branches of the pulmonary artery and veins. Within the lung numerous **pulmonary lymph-glands** [lymphoglandulæ pulmonales] are found chiefly at the places of branching of the larger bronchi [lymphoglandulæ bronchiales]. Scattered along the latter, as well as associated with the branches of the pulmonary artery and vein, are found nodules of lymphoid tissue. Deposits of carbonaceous matter in the lymphoid structures of the lung are present, except in early infancy; the amount increases with age.

Nerves.—The vagus and sympathetic contribute to form the pulmonary plexuses in front and behind the root of the lung, from which branches go to accompany bronchial arteries; a smaller number accompany the air-tubes (see p. 1073).

Variations.—Congenital absence of one or both lungs has been observed. Variations in the lobes are not uncommon—four for the right and three for the left lung has been recorded. An *infracardiac lobe*, as found in certain mammals, sometimes occurs; an infracardiac bronchus is, however, constant in man. More or less complete fusion of the middle and upper lobes of the right lung is not rare.. The lungs may be symmetrical, with two lobes each, the apical bronchus of the right springing from the first ventral bronchus, as is normal for the left lung (Waldeyer, Narath); or the lungs may have three lobes each, the apical bronchus of the left arising from the main bronchus. The apical bronchus of the right lung may arise from the trachea, an origin that is normal in the hog and other artiodactyls.

Development of the lungs and trachea.—The first indication of the trachea and lungs appears in embryos of the third week as a trough-like groove in the ventral wall of the upper part of the esophagus, communicating above with the pharynx. Later the groove becomes constricted off from the esophagus, the constriction extending from below upward, so that a tube is formed which opens into the pharynx above. For further details, see DEVELOPMENTAL ANATOMY, p. 47.

References for respiratory system. A. **External nose** and **nasal cavity.** Kallius, in von Bardeleben's Handbuch; Zuckerhandl, Normale u. path. Anatomie d. Nasenhöhle, Bd. 1, Wien, 1893; Schaeffer, The Nose and Olfactory Organ, Phila., 1920; (*Development*) His, Archiv f. Anat. u. Phys., 1892; Killian, Arch. f. Laryngol., Bd. 4, 1896; Schaffer, Jour. Morphol., vol, 21, 1910; (*Conchæ*) Peter, Arch. f. mikr. Anat., Bd. 60, 1902; (*Paranasal sinuses*) Bartels, Zeitschr. f. Morph. u. Anthrop., Bd. 8; Turner, Accessory Sinuses of the Nose, Edinburgh, 1901, Schaeffer, The Paranasal Sinuses, in the Nose and Olfactory Organ, *loc. cit.*; Davis, Nasal Accessory Sinuses, Phila., 1914; (*Anthropology*) Hoyer, Morph. Arbeiten, vol. 4, 1894. B. **Larynx.** Gerlach, Anat. Hefte, H. 56; (*Development*) Lisser, Amer. Jour. Anat., vol 12; (*Ossification*) Scheier, Arch. f. mikr. Anat., Bd. 59. C. **Lungs.** (*Structure; vascular supply*) Miller, Arch. f Anat. u. Entw., 1900, Amer. Rev. Tuberculosis, Vols. 2 and 3, 1919; Amer. Jour. Anat., vol.7: Schultze, Sitzb. Akad. Wiss., Berlin, 1906; Winternitz et al, Bul. Johns Hopkins Hosp., 1920; (*Development*) Aeby, Der Bronchialbraum der Säugethiere und des Menschen, 1808; Narath, Der Bronchialbaum der Säugethiere und des Menschen, 1892, 1901; Flint, Amer. Jour. Anat., vol. 6; Huntington, Amer. Jour. Anat., vol. 27, 1920; (*Topographical*) Mehnert, Topogr. Altersveränderungen d. Atmungsapparatus, Jena, 1901. D. **Pleura.** Ruge, Morph. Jahrb. Bd. 41.

SECTION XII

UROGENITAL SYSTEM

REVISED FOR THE SIXTH EDITION

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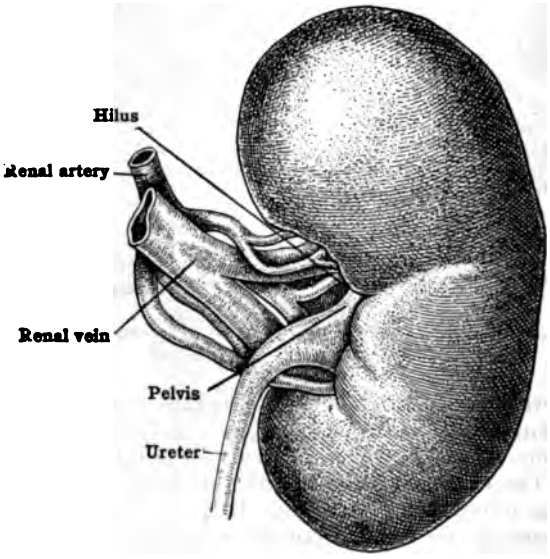
The **urogenital system** [apparatus urogenitalis] includes (A) the **urinary organs** [organa uropoëtica] and (B) the **reproductive organs** [organa genitalia].

A. THE URINARY ORGANS

THE organs forming the urinary apparatus are the **kidneys,** by which the urine is produced; a duct, the **ureter,** proceeding from each kidney and conveying the urine to the **bladder,** which serves as a reservoir for the urine and from which, by a single duct, the **urethra,** the urine is carried to the exterior.

FIG. 1015.—POSTEROMEDIAL ASPECT OF THE RIGHT KIDNEY.



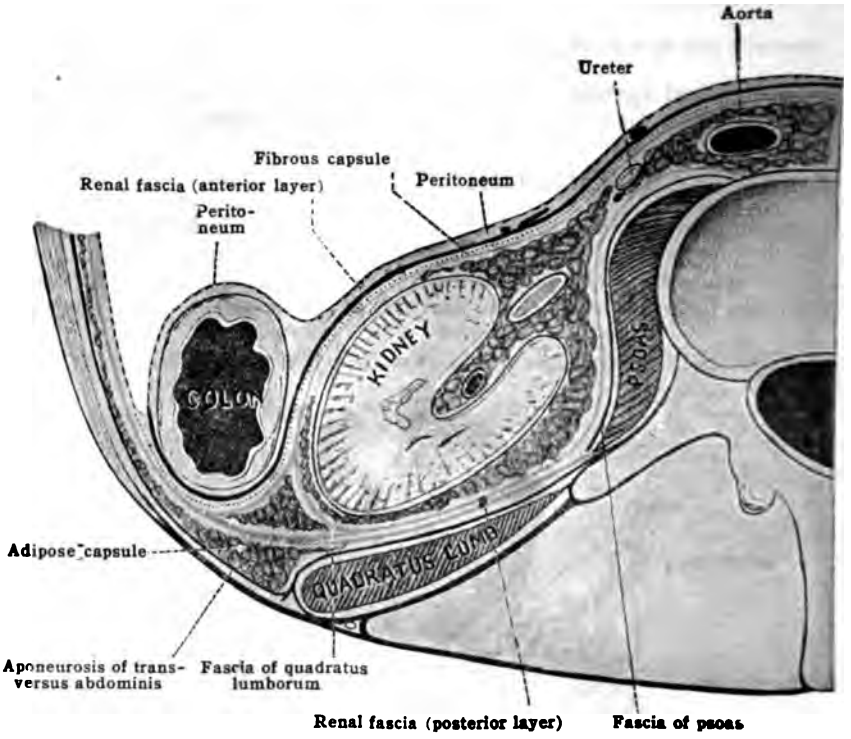
THE KIDNEYS

The **kidneys** [renes] are paired organs situated in the posterior part of the abdomen, on either side of the vertebral column and behind the peritoneum. The right kidney is as a rule, lower than the left. Each kidney is somewhat bean-shaped (fig. 1015) and is situated in such a way that the *ventral* or *visceral surface* [facies anterior] which is convex, looks obliquely ventrally and laterally, while the *dorsal* or *parietal surface* [facies posterior], usually less convex, looks dorsally and somewhat medially (fig. 1016). The *upper extremity* [extremitas superior] is usually larger than the *lower extremity* [extremitas inferior], and is about 1 cm. nearer the vertebral column. The *lateral border* [margo lateralis] is narrow and convex, and the *medial border* [margo medialis], which looks medially and ventrally, is concave, its middle third presenting a slit-like aperture, the **hilus.** This opens

into a cavity, called the **sinus** (fig. 1017), which is about 2.5 cm. in depth and is occupied mainly by the dilated upper extremity of the ureter, known as the renal pelvis, the interval between this and the actual kidney substance containing adipose tissue in which are imbedded the renal vessels and nerves.

Size.—The length of the kidney in the male averages 10–12 cm., its breadth about 5.5 cm. and its thickness 3 cm.; it weighs 115–150 grams. The dimensions of the female kidney are nearly as great, but its weight is from one-seventh to one-fifth less. In the child the organ is relatively large, its weight compared with that of the entire body being about 1 : 133 at birth; but its permanent relation, which is about 1 : 217, is usually attained at the end of the tenth year.

FIG. 1016.—DIAGRAM SHOWING RELATION OF KIDNEY TO CAPSULE AND ADJACENT STRUCTURES. (Gerota.)



Investment and fixation.—The surface of the kidney is covered by a thin but strong *fibrous capsule* [tunica fibrosa]. The capsule divides in the region of the hilus into two layers, one of which turns inward at the hilus to line the walls of the sinus (fig. 1017). The other forms a sheath covering the vessels and nerves before they pass into the hilus. It may readily be peeled off from a healthy kidney, except at the bottom of the sinus, where it is adherent to the blood-vessels entering the kidney substance and to the terminal portions of the pelvis. External to the capsule is a quantity of fat tissue, the **adipose capsule** [capsula adiposa], which forms a complete investment for the organ and is prolonged through the hilus into the sinus.

The *peritoneum*, which covers the ventral surface of the adipose capsule, has usually been regarded as the principal means of fixation of the kidney, but in reality this is accomplished by means of a special **renal fascia** (fig. 1016), developed from the subperitoneal areolar tissue (Gerota).

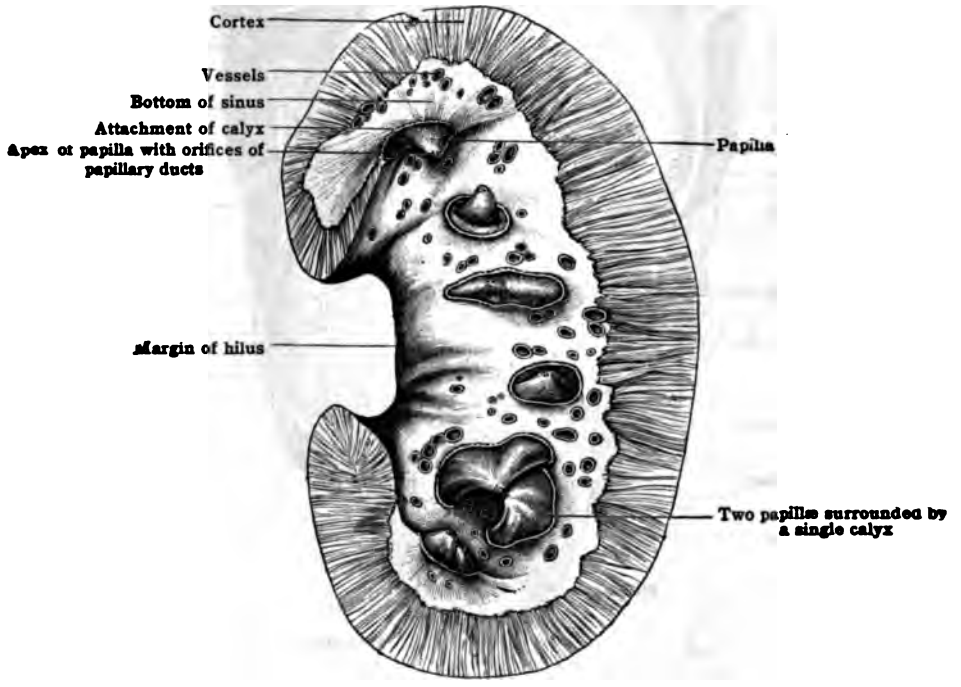
Renal fascia.—Lateral to the kidney there occurs between the transversalis fascia and the peritoneum a subperitoneal fascia, which, as it approaches the convex border of the kidney, divides into two layers, one of which passes in front of and the other behind the kidney, enclosing the adipose capsule. Traced medially, the anterior layer of the renal fascia passes in front of the renal vessels, and, over the aorta, becomes continuous with the corresponding layer of the opposite side; upward, it passes over the suprarenal gland and at the upper border of that organ becomes continuous with the posterior layer; and downward, it is lost in the adipose tissue intervening between the iliac fascia and muscle. The posterior layer, which is the thicker

of the two, passes medially behind the renal vessels and is lost in the connective tissue in front of the vertebral column, and below it is lost, like the anterior layer, in the iliac region. Behind the posterior layer, between it and the quadratus lumborum, is a mass of adipose tissue, the **pararenal adipose body**, and both layers are united to the fibrous capsule of the kidney by strands of connective tissue which traverse the adipose capsule.

Each kidney is, accordingly, supported by these strands in a space bounded laterally and above by the layers of the renal fascia, and open medially and below. Should these strands become atrophied by wasting disease or ruptured by the pressure of the pregnant uterus, by the improper use of corsets, or by any other cause, the phenomenon of movable or wandering kidney may be set up by slight external violence, the organ tending to shift its place as far as the attachment of its vessels to the main trunks and the arrangement of the renal fascia will permit.

Position and relations.—The kidney is said to lie in the lumbar region. It is, however, intersected by the horizontal and vertical planes which separate the hypochondriac, lumbar, epigastric and umbilical regions from each other, and hence belongs to all these segments of the abdominal space (see fig. 965). Its vertical extent may be said to correspond to the last thoracic and upper two or three lumbar vertebræ, the right lying in most cases from 8 to 12 mm. (⅓ to ½ in.) lower than the left; but exceptions to this rule are not infrequent.

FIG. 1017.—SECTION OF KIDNEY SHOWING THE SINUS. (After Henle.)

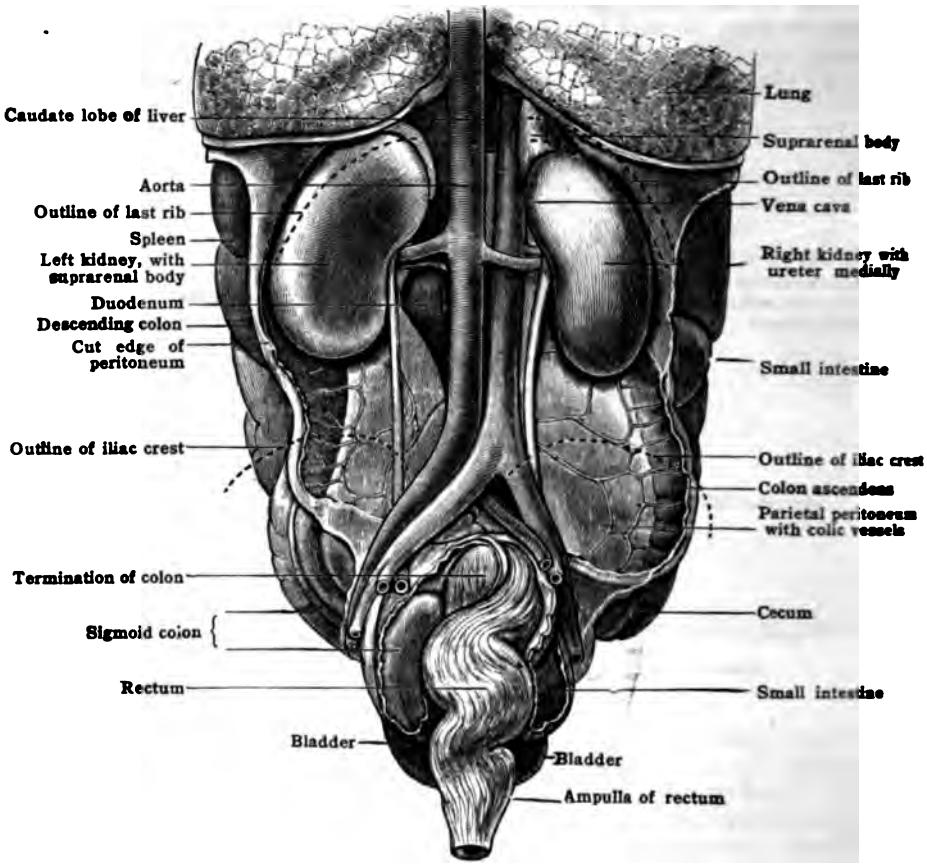


The **posterior surface** (figs. 1018, 1019), rests against the posterior abdominal wall extending upward in front of the eleventh and twelfth ribs, and medialward to overlap the tips of the transverse processes of the first and second lumbar vertebræ; the left kidney usually reaches as high as the upper border of the eleventh rib, the right only to its lower border. The parietal relations of the posterior surface (fig. 1019) on both sides are as follows: (1) the diaphragm; the left kidney, on account of its higher position, entering more extensively into this relation than the right; (2) the 'transversalis area,' corresponding to the portion of the transversalis fascia covering the ventral surface of the quadratus lumborum and adjacent part of the transversus abdominis muscle; (3) the lateral aspect of the psoas; and (4) the last thoracic, iliohypogastric and ilioinguinal nerves and the anterior divisions of the subcostal and first lumbar vessels, all of which run obliquely downward and laterally in front of the quadratus lumborum.

The **upper extremity** of each kidney is crowned by the suprarenal gland (figs. 1018, 1021), which encroaches also upon its ventral surface and medial border and is fixed to it by fibers derived from the subperitoneal tissue.

The anterior surface (fig. 1020) of each kidney was originally completely covered by peritoneum that separated it from neighboring viscera, but, owing to secondary changes whereby the ascending and descending colons, the duodenum and the pancreas become retroperitoneal organs, these come into direct relation with one or the other of the kidneys and separate portions of them from actual contact with the peritoneum. Thus, in the case of the right kidney (figs. 965, 1021), the portion of the anterior surface immediately adjacent to the medial border has the descending portion of the duodenum in direct contact with it, and throughout a zone extending downward and laterally from the middle of the

FIG. 1018.—THE ABDOMINAL VISCERA, SEEN FROM BEHIND.
(From the model of His.)
The kidneys are somewhat lower than usual in their relations to the ribs.



duodenal area to the lateral border, the ascending colon and right colic flexure. Almost the entire upper half, however, and a small portion of the lower pole are covered directly by peritoneum, the upper peritoneal area having an indirect relation with the lower surface of the liver, upon which it produces the renal impression.

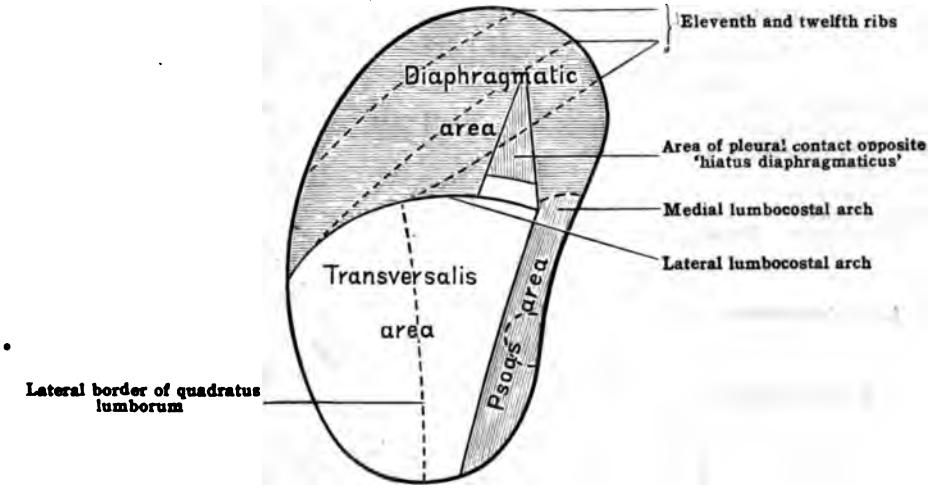
Similarly the anterior surface of the left kidney (figs. 1020, 1021) is in direct contact with the pancreas throughout a broad transverse band situated a little above the middle of the organ, and the splenic artery pursues its tortuous course along the upper border of this pancreatic area, while the corresponding vein is interposed between the pancreas and the surface of the kidney. Below the pancreas, the lateral portion of the kidney is in direct contact with the descending colon and the left colic (splenic) flexure, but the remainder of the lower extremity and a small upper area of the kidney is directly covered by peritoneum. The upper peritoneal area has, as an indirect relation, the posterior surface of the stomach medially, and the spleen laterally (figs. 965, 1021).

The **medial border** of the right kidney approaches the vena cava inferior closely, especially above; that of the left is separated from the aorta by an interval of about 2.5 cm.

Variation in position.—The position of the kidneys in the abdominal cavity is subject to considerable variation. Thus while the upper pole of the right kidney may be said to lie usually opposite the lower half of the eleventh thoracic vertebra, it may be placed as high as the lower part of the tenth thoracic or as low as the upper half of the first lumbar. Similarly while the upper pole of the left kidney is as a rule opposite the middle of the eleventh thoracic vertebra it may lie half a vertebra higher or as low as the lower part of the second lumbar vertebra. The lower poles are distant from the crests of the ilia anywhere from 1.0 cm.–3.0 cm., the distance being, as a rule, somewhat less in females than in males. Occasionally the lower pole may extend even below the iliac crest, especially on the right side.

The lateral border of each kidney lies 8.5–10.0 cm. lateral to the spines of the lumbar vertebræ, a distance that brings them lateral to the lateral edge of the sacrospinalis muscle and even beyond the lateral edge of the quadratus lumborum, so that this border of the kidney may be readily approached through the posterior wall of the body. It must be remembered, however, that the upper part of the kidney rests upon the diaphragm, so that in the event of the twelfth rib being very short there may be danger of the incision being carried too far upward, resulting in injury to the diaphragm and pleura. It is also worthy of note that the diaphragmatic area of the kidney corresponds to the region where a hiatus diaphragmaticus between the costal and lumbar portions of the muscle may occur, and if this be pronounced the upper part of the posterior surface of the kidney may come into more or less direct relations to the pleura (fig. 1019).

FIG. 1019.—DIAGRAM OF RELATIONS OF POSTERIOR SURFACE OF LEFT KIDNEY.



Just as there may be variation in the position of the kidneys, so too there may be considerable variation in the extent to which they are in relation to the various structures mentioned above. And this is especially true as regards their relations to the colons; for if the kidneys were lower than usual they might lie entirely beneath the line of attachment of the transverse mesocolon and thus have no direct relations with either colon, or on the other hand either the ascending or descending colon, or both, may be provided with a mesentery, whereby they would be removed from direct contact with the kidney.

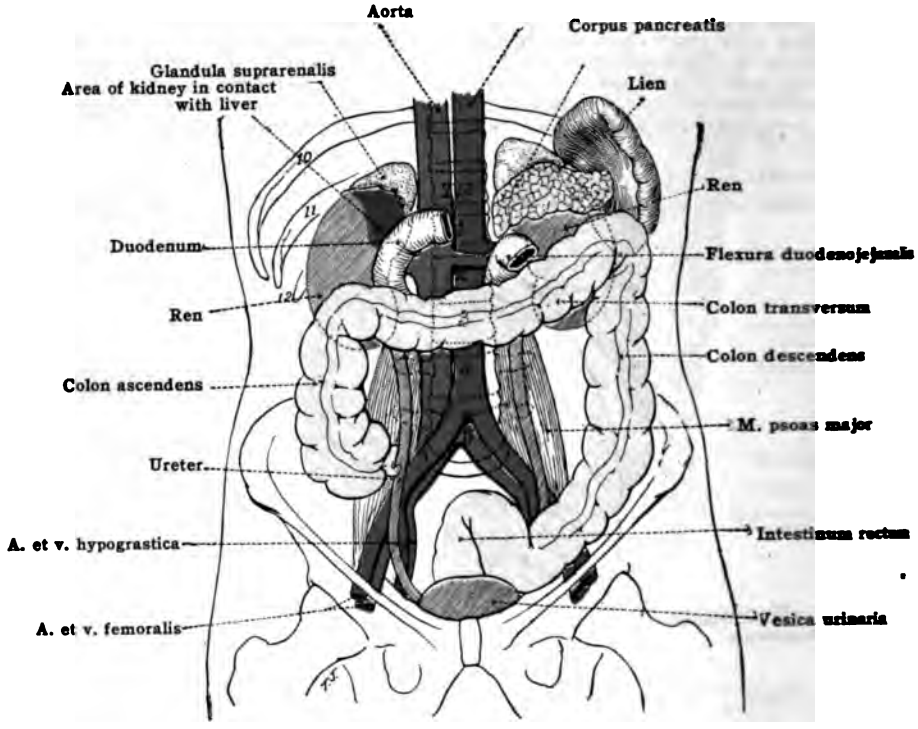
Structure.—A section through the kidney shows its substance to be composed of an external **cortex** [substantia corticalis] and an internal **medulla** [substantia medullaris] (fig. 1022). The medulla consists of a variable number (eight to eighteen) of conical segments termed **renal pyramids** [pyramides renales (Malpighii)], the apices of which project into the bottom of the sinus (fig. 1017) and are received into the primary segments (calyces) of the pelvis, while their bases are turned toward the surface, but are separated from it and from each other by the cortex. The pyramids are smooth and somewhat glistening in section and are marked with delicate striæ which converge from the base to the apex and indicate the course of the renal tubules. The blunted apex, or **papilla**, of each pyramid, either singly or blended with one or even two of its fellows, is embraced by a *calyx* (fig. 1017), and, if examined with a hand-lens, will be seen to present a variable number (twelve to eighty) of minute apertures, the **foramina papillaria**, which represent the terminations of as many ducts (of Bellini) through which the urine passes into the renal pelvis.

The **cortex** may be regarded as composed of two portions, (1) a peripheral layer, the cortex proper, which is about 12 mm. in thickness and extends from the fibrous tunic to the bases of the pyramids, and (2) processes termed **renal columns** [columnæ renales (Bertini)] which dip inward between the pyramids to reach the bottom of the sinus (fig. 1022). In section the cortex is somewhat granular in aspect, and when examined closely shows a differentiation into a number of imperfectly separated portions termed *cortical lobules* [lobuli corticales].

Each of these is composed of a *convoluted portion* [pars convoluta], surrounding an axial *radiate portion* [pars radiata (processus Ferreini)]. The latter consists of a group of tubules which extend from the cortex into the base of one of the medullary pyramids, whence it is also termed a medullary ray; and each medullary pyramid is formed from the rays of a number of cortical lobules, these structures, therefore, greatly exceeding the pyramids in number.

Renal tubules (fig. 1023).—The structure described above is the result of the arrangement of the renal tubules, which constitute the essential units of the kidney. Each of these commences in a spherical **glomerular capsule,** one wall is invaginated by a small *glomerulus* of blood-vessels, the combination of glomerulus and capsule forming what is termed a renal **(Malpighian) corpuscle.** These corpuscles are situated in the convoluted parts of the cortical lobules, and from each of them there arises by a narrow neck a tubule, which quickly becomes wide and convoluted, this portion being termed the **first convoluted tubule.** This enters the radiate part of the cortical lobules, where it narrows again and descends as a straight

Fig. 1020.—Topographic Relations of the Kidneys, etc. Anterior View.



tubule, the **descending limb of Henle's loop,** into the subjacent medullary pyramid, and, turning upon itself, forming the **loop of Henle,** ascends to the cortex as the **ascending limb of Henle's loop,** where it again becomes wide and contorted, forming the **second convoluted tubule.** This returns to the convoluted portion of the cortical lobule, and, becoming narrower, opens with other similar tubules into a straight or collecting **tubule,** which passes into the radiate part of the cortical lobule, then descends into the subjacent medullary pyramid where it unites with other collecting tubules, and finally opens into the renal plevis at the summit of a papilla.

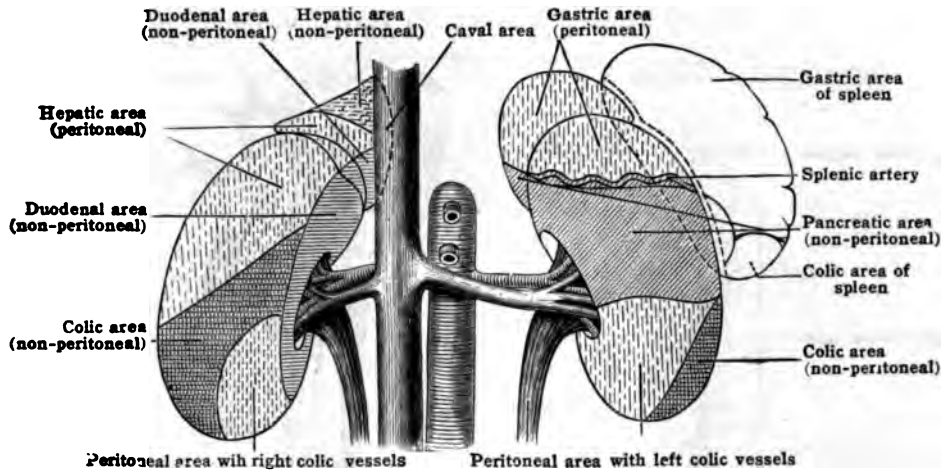
The tubules are lined with epithelium throughout, the cells being flat in the capsule, irregularly cubical and imbricated in the convoluted tubules, flattened in the descending limb of Henle's loop, changing to cuboidal in the loop. The epithelium is cubical in the ascending limb of Henle's loop and in the smaller collecting tubules but becomes columnar in the larger collecting tubules and ducts of Bellini.

Vessels (fig. 1023).—The kidney is very vascular. The larger *arterial branches,* arranged in the sinus as has already been described, enter the substance of the kidney and pass up as the *interlobar arteries* in the renal columns. On reaching the bases of the pyramids they bend so as to run horizontally between these and the cortex, forming the *arcuate arteries* [arteriæ arciformes] from which interlobular branches pass up into the cortex and supply *afferent* branches to the glomeruli. *Efferent* stems which issue from the glomeruli break up into capillaries which supply the tubules contained in the cortex. From the arcuate arteries numerous branches, the *arteriolæ rectæ,* pass down into the pyramids, supplying the tubules of which these are composed. *Veins* corresponding to the arteriolæ rectæ and to the interlobular, arcuate and interlobar arteries drain into the renal veins. At the surface of the kidney, arranged in star-like groups, are the *stellate veins* [venæ stellatæ], which open into the interlobular veins and also communicate with the veins of the adipose capsule. The renal *lymphatics* may be divided into two sets, capsular and parenchymatous. They terminate in the upper lumbar nodes.

Nerves.—The nerves form a plexus accompanying the vessels, and are derived from the sympathetic and vagus through the renal plexuses.

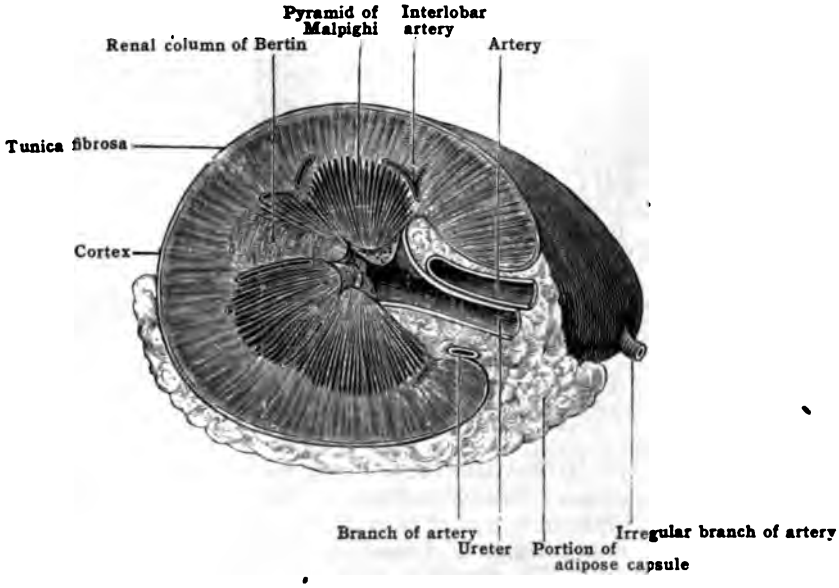
Variations.—The kidney of a fetus differs from that of the adult in being divided into a number of distinct renal lobes, each of which corresponds to the base of a renal pyramid and is capped by a thin layer of cortex. Such a condition is permanent in some of the lower animals; but in man the superficial indications of morphological segmentation usually become obliterated during the progress of growth of the cortical tissue, and are seldom visible after the age of ten.

FIG. 1021.—DIAGRAM SHOWING ANTERIOR RELATIONS OF KIDNEYS AND SUPRARENAL BODIES



Development.—In the development of the embryo, representatives of three different sets of excretory organs occur, the permanent kidney (metanephros) being the last to form. The two earlier sets (pronephros and mesonephros) have a common duct, the **Wolffian duct,** and from the lower end of this an outgrowth develops, which extends upward on the posterior abdominal wall and comes into connection with a mass of embryonic tissue known as the **metanephric blastema.** The outgrowth gives rise to the ureter, pelvis and collecting tubules, while the remaining portions of the tubules are formed from the blastema. For further details, see DEVELOPMENTAL ANATOMY, p. 50.

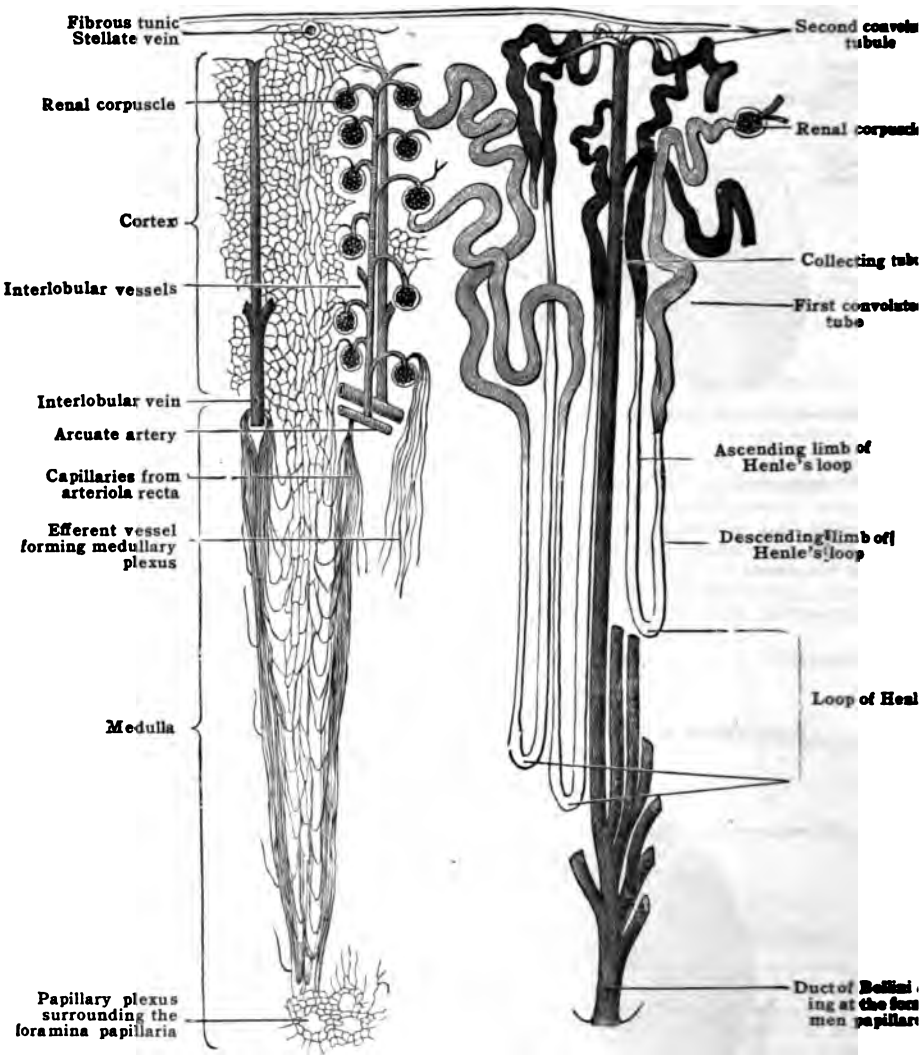
FIG. 1022.—HORIZONTAL SECTION OF KIDNEY.



Various *abnormalities* may result from modifications of the development of the kidneys. (1) Occasionally the ureteric outgrowth of one side fails to develop, the result being the occurrence of a single kidney. (2) The blastema may fail to attain its normal position, in which case the kidney may be situated in the iliac region or even in the pelvis; or the blastema may be drawn into an unusual position, the kidney resting on the vertebral column, or even on the opposite side of the abdomen; (3) or the two blastemas may fuse to a greater or less extent,

forming a 'horse-shoe kidney,' extending across the vertebral column; or, if the fusion be extensive, an apparently single kidney, which may rest upon the vertebral column, or to side of it. Such fused kidneys may be distinguished from single kidneys by the fact that possess two ureters opening normally into the bladder. (4) In rare cases, a blastema ma come divided, an accessory kidney of varying size being thus produced. (5) Finally, in o more of the tubules there may be a failure of the union of the portion derived from the tema with the collecting tubule derived from the ureteric upgrowth, and the secretion h no means of escape from such malformed tubules, they become greatly dilated, produc cystic kidney.

FIG. 1023.—SCHEME OF TUBULES AND VESSELS OF THE KIDNEY.



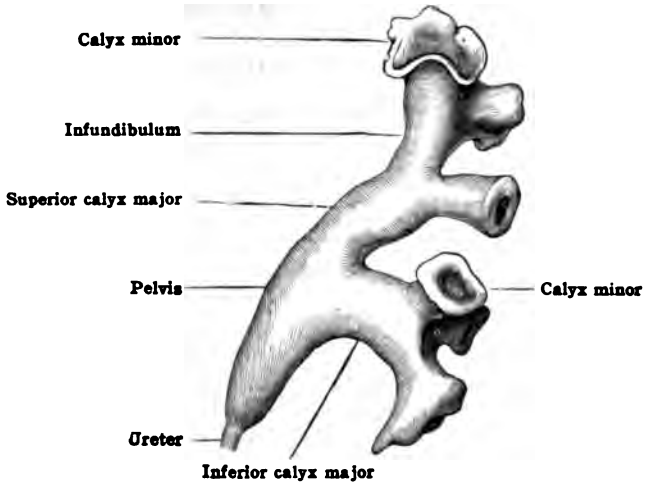
THE URETERS

The **ureter** (figs. 1015, 1018, 1021, 1024, 1026), which conveys the urine f the kidney to the bladder is a tube, expanded and irregularly branched above, narrow and of fairly uniform dimensions throughout the rest of its course. A origin in the renal sinus it consists of a number of short tubes, usually eigh nine, called **calyces minores** (fig. 1024), each of which embraces a renal pap or occasionally two papillæ may be connected with a single calyx. These cal minores open directly or by means of short intermediate tubes (**infundibula**) two short passages, the superior and inferior **calyces majores**, which in turn u after a longer or shorter course to form the **pelvis**. Occasionally a third or mi calyx major is present.

The **pelvis** [pelvis renalis] (fig. 1024) is usually more or less funnel-shaped, being wider above, where it lies between the two lips of the hilus, and narrower below, where it arches downward and medially to become continuous with the ureter proper. It is, however, very variable in shape and in some cases is hardly larger than the ureter. Usually it is flattened dorsoventrally so that its anterior and posterior walls are in contact and its cavity represented merely by a fissure. The majority of the branches of the renal vein and artery lie in front of it, imbedded in fat tissue, and anterior to these are the descending portion of the duodenum on the right side and (usually) the pancreas on the left. The intrarenal portions of the ducts, including the pelvis, are considered parts of the kidney.

The **ureter** proper (fig. 1018) extends from the termination of the pelvis to the bladder, its course lying in the subperitoneal tissue. It is a tube about 5 mm. in diameter when distended and it is fairly uniform in size, except that a slight constriction occurs where it enters the pelvis and a second one occurs at about the middle of its abdominal portion. Its length is variously stated, but the average in the male adult may be taken as about 30 cm., the right being usually a little the shorter.

FIG. 1024.—PELVIS AND UPPER PORTION OF URETER. (After Henle.)



Course and relations.—The course of each ureter may be conveniently divided into two portions, abdominal and pelvic. The **abdominal portion** [pars abdominalis] runs downward and slightly medially and is in relation *posteriorly* with the psoas muscle and its fascia; it crosses the genitofemoral nerve obliquely and in the lower part of its course passes in front of the common iliac artery near its bifurcation. *Anteriorly* it is covered by peritoneum and is crossed by the spermatic or ovarian vessels. *Medially* it is in relation on the right side with the inferior vena cava and on the left with the aorta, the vein being almost in contact with the right ureter, while the artery is separated from the left one by an interval that diminishes from 2.5 cm. above, to 1.5 cm. opposite the bifurcation of the vessel.

The **pelvic portion** [pars pelvina] passes in front of the sacroiliac articulation and then forward and downward upon the obturator internus and its fascia behind and below the psoas, crossing the obturator vessels and nerve and having anterior to it in the female the posterior border of the ovary. It thus reaches the level of the floor of the peritoneal cavity, whereupon, at about the level of the ischial spine, its course is directed forward and medially toward the bladder. In this part of its course *in the male*, it is crossed superiorly and medially by the ductus deferens, and then passes under cover of the free extremity of the vesicula seminalis. *In the female* the ureter runs parallel with, and 8 to 12 mm. distant from, the cervix uteri, passes behind the uterine artery, through the uterine plexus of veins (fig. 531), and beneath the root of the broad ligament, and finally crosses the upper third of the lateral wall of the vagina to reach the vesicovaginal interspace and enters the substance of the bladder at about the junction of its posterior, superior and lateral surfaces.

When the ureters reach the bladder they are about 5 cm. apart. As they pass over into the wall of the bladder they become imbedded in its musculature in which they extend obliquely for a distance of some 2 cm. where they open by slit-like apertures. The lips of these apertures are said to function as valves when the bladder is distended and thus prevent a backward flow of urine. When the bladder is distended the openings of the ureters are about 5 cm. apart, but when contracted the openings are not more than 2.5 cm. apart.

Structure.—The wall of the ureter is about 1 mm. in thickness, and consists of a mucous membrane, a muscular coat, and an external connective tissue investment. The mucous membrane is longitudinally plicated, and is lined by transitional epithelium, continuous with that of the papillæ above and with that of the bladder below. Mucous follicles of simple form have been found in the upper part of the tube. The muscularis is about 0.5 mm. in thickness, and consists of two layers, an external, composed of annular fibers, and an internal, of fibers longitudinally disposed. After the tube has entered the bladder the circular fibers form a kind of sphincter around its vesical orifice; while the longitudinal fibers are continued onward through the wall of the bladder and terminate beneath its mucous membrane.

Vessels and nerves.—The *arteries* supplying the pelvis and upper part of the ureter come from the renal; the rest of the abdominal portion of the ureter is supplied by the spermatic (or ovarian), and its pelvic portion receives branches from the middle hemorrhoidal and inferior vesical; the *veins* terminate in the corresponding trunks; and the *lymphatics* pass to the lumbar and hypogastric nodes. The *nerves* are supplied by the spermatic, renal, and hypogastric plexuses.

Variations.—Occasionally the depression which separates the two calyces majores extends through the pelvis, so that the calyces appear to open directly into the ureter. The fission may also affect the ureter to a greater or less extent, in extreme cases producing a duplication of the tube throughout its entire length with double openings into the bladder.

THE URINARY BLADDER

The **urinary bladder** [vesica urinaria] is a receptacle, whose form, size, and position vary with the amount of its contents. The adult organ in its empty or moderately filled condition lies entirely below the level of the oblique plane of the pelvic inlet; but when considerably distended it rises into the abdomen and shows itself as a characteristic mesial projection above the symphysis, a projection which in extreme distention of the bladder may extend nearly to the level of the umbilicus.

Form.—When distended the bladder assumes in the male an ovoid shape with its longest diameter directed from above downward and backward; but in the female the transverse diameter is the greatest, in accordance with the greater breadth of the pelvic cavity. When empty, it becomes tetrahedral in form. In the child it is somewhat pear-shaped, the stalk being represented by the urachus.

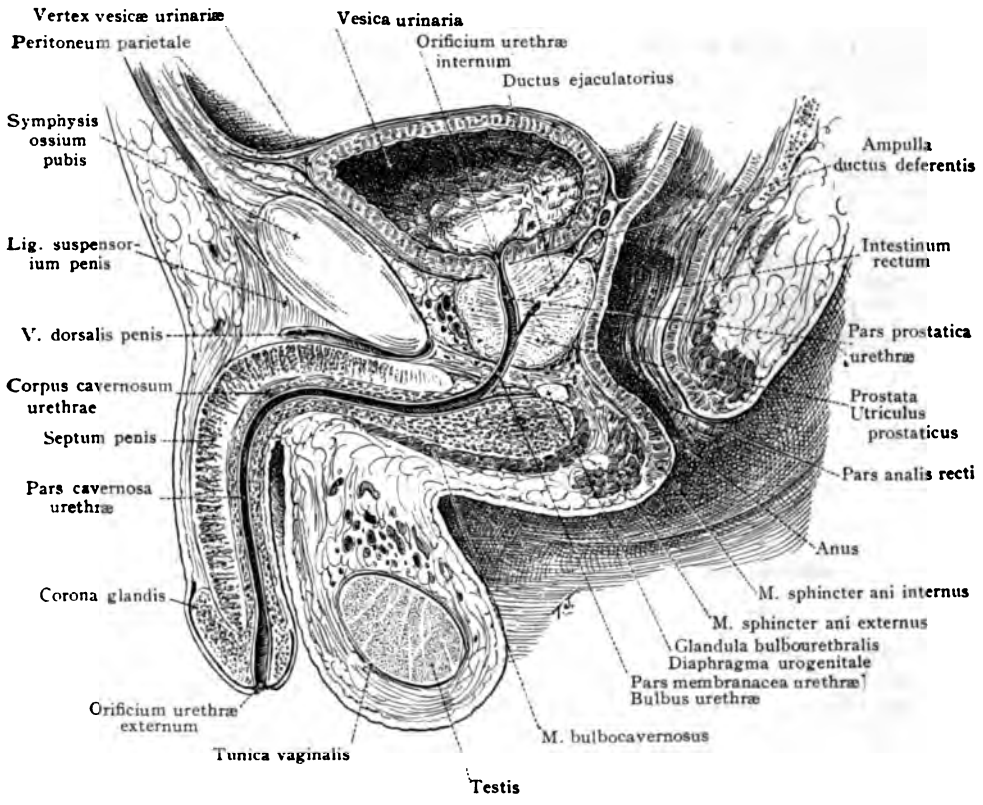
Parts.—For convenience in description four surfaces may be recognized, which are fairly well marked in the empty bladder, but are indistinctly separated when it is distended. The **superior surface** is covered with peritoneum. The two **inferolateral surfaces** rest upon the pelvic diaphragm, and join anteriorly in a rounded border (sometimes termed the anterior surface). The **posterior surface,** sometimes flat and sometimes, especially in old age, convex, forms what is known as the base or **fundus** [fundus vesicæ]. The portion of the bladder between the vertex and fundus is termed the **body** [corpus vesicæ]. The superior and inferolateral surfaces meet at the **vertex** of the bladder, from which the **middle umbilical ligament** (**urachus**) extends to the umbilicus. Inferiorly, in the angle formed by the fundus and the inferolateral surfaces is the **internal urethral orifice** [orificium urethræ internum], by which the bladder communicates with the urethra. The portion of the organ immediately surrounding this is sometimes spoken of as the **neck.**

When the bladder is empty and relaxed, the superior surface sinks down upon the other surfaces, thus becoming concave, and the cavity of the organ is reduced to a T- or Y-shaped fissure. In the contracted empty bladder, especially in the female, the cavity in midsagittal section often more nearly resembles a figure 7 (see fig. 1046).

Relations.—The *anterior border* looks downward and forward toward the symphysis pubis (figs. 1025, 1046). It is uncovered by peritoneum, but is separated from the pubic bones by a space known as the **retropubic or prevesical space** (**cavum Retzii**), which contains a variable quantity of loose fat continuous with the pelvic and abdominal subperitoneal tissue. The *inferolateral surface* on each side is separated from the levator ani and obturator internus by subperitoneal tissue, which usually bears much fat in its meshes and ensheaths the vesical vessels and nerves. Near the border separating the inferolateral from

the superior surface on each side is the obliterated hypogastric artery anteriorly, and (in the male) the ductus deferens posteriorly. The latter passes between the ureter and the wall of the bladder, a little above the level at which the former enters the wall of the bladder, at the angle formed by the superior, inferolateral and posterior surfaces. The *posterior surface* is in direct contact *in the male* (fig. 1025) with the anterior wall of the rectum and with the lower part of the ductus deferentes and the vesiculæ seminales. Between the diverging ductus deferentes there is a triangular space (fig. 1030), whose base is formed by the line of reflection of the rectovesical peritoneal excavation and the apex by the meeting of the ejaculatory ducts at the summit of the prostate. It represents the area of direct contact of the posterior wall of the bladder with the rectum. *In the*

FIG. 1025.—MIDSAGITTAL SECTION OF THE MALE PELVIS. (After Sobotta and Spalteholz.)



female the posterior surface is adherent to the cervix of the uterus and the upper part of the anterior wall of the vagina (fig. 1046), and is usually not in contact with peritoneum. The *superior surface* is entirely covered by peritoneum. It looks almost directly upward into the abdominal cavity and has resting upon it coils of the small intestine and sometimes a portion of the sigmoid colon.

Variation in position.—In the normal condition the bladder of the adult lies below the upper border of the symphysis pubis, but if fully distended it may rise above this level, carrying with it the reflection of peritoneum from its upper surface to the anterior abdominal wall. The anterior surface of the bladder is thus brought into relation with the anterior abdominal wall, being separated from it only by the enlarged prevesical space, and it is thus possible to enter the bladder above the symphysis pubis without penetrating the peritoneum.

In the infant, owing to the smaller extent of the pelvic cavity, the bladder lies at a somewhat higher level than in the adult and rises into the abdominal cavity. Indeed the entire bladder is above the horizontal level of the pubic crests, the urethral orifice being behind the upper margin of the symphysis pubis. As the child learns to walk, however, this position gradually alters and usually by the age of six years the adult relations have been acquired.

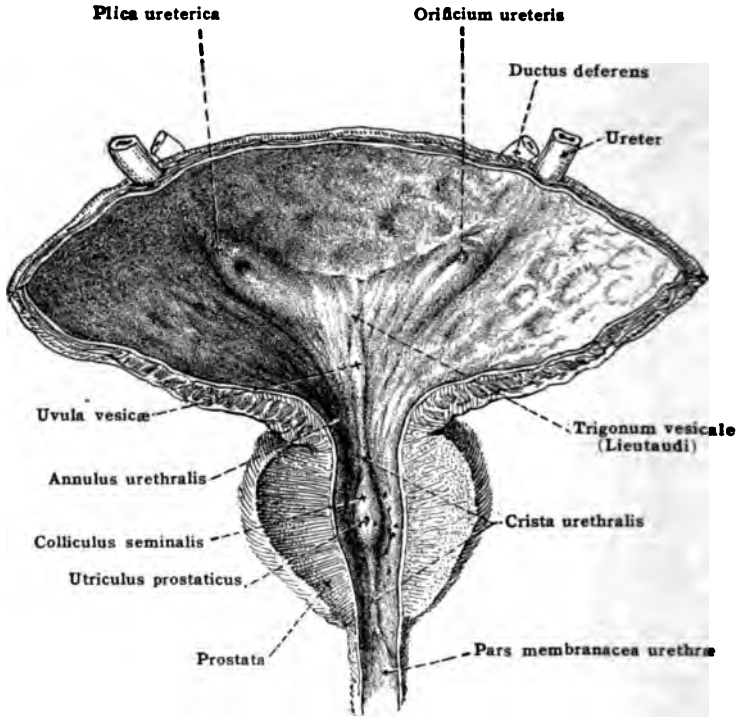
The fixation of the bladder.—The reflections of the peritoneum from the superior surface of the bladder to the anterior abdominal wall and the corresponding walls of the pelvis are sometimes described as the superior, lateral and posterior *false ligaments*. Furthermore there extends from the apex of the bladder to the umbilicus a fibrous cord, the *urachus*, the remains

of the embryonic allantois; this is described as the ***middle umbilical ligament*** of the bladder (fig. 1046). The *lateral umbilical ligaments* are formed by the obliterated hypogastric arteries which carry the fetal blood to the placenta and in the adult are represented by fibrous cords passing along the sides of the bladder and ascending to the umbilicus.

In addition to these structures certain thickenings of the endopelvic fascia, where it comes into relation with the bladder and prostate gland, constitute what are termed the true ligaments. Two such thickenings extend from the anterior surface of the capsule of the prostate gland, or from the lower part of the anterior aspect of the bladder in the female, to the pubic bones and constitute what are known as the *middle puboprostatic (pubovesical) ligaments*, with which muscle fibers [m. pubovesicalis] are usually associated. Similarly, thickenings of the fascia extending from the sides of the prostate gland or from the sides of the lower part of the bladder to the lateral walls of the pelvis form the *lateral true ligaments*.

Muscle fibers [m. rectovesicalis] also occur in the subperitoneal tissue contained within the peritoneal folds (posterior false ligaments) extending from the back of the bladder to the posterior wall of the pelvis and bounding the rectovesical pouch of peritoneum in the male. They correspond to the *mm. rectouterini* of the female.

FIG. 1026.—THE TRIGONE OF THE BLADDER AND THE FLOOR OF THE PROSTATIC URETHRA.



The internal surface.—The mucous membrane lining the internal surface of the bladder is soft and rose-colored during life, and in the empty bladder is thrown into irregular folds which become effaced by distention. It is modified over a triangular area at the base of the bladder, termed the ***trigone*** [trigonum vesicæ (Lieutaudi)] (fig. 1026) whose three angles correspond with the orifices of the urethra and of the two ureters. This area is paler in color and free from the plication that characterizes the rest of the mucous membrane; it is bounded posteriorly by a transverse ridge, the *plica ureterica*, extending between the orifices of the ureters, and toward the urethral orifice presents a median longitudinal elevation, the *uvula vesicæ*, which is apt to be especially prominent in aged persons. The *internal urethral orifice* is normally situated at the lowest point of the bladder, at the junction of the inferolateral and posterior surfaces. It is surrounded by a more or less distinct circular elevation, the ***urethral annulus***, and is usually on a level with about the center of the symphysis pubis and from 2.0 to 2.5 cm. behind it.

Structure.—The general characteristics of the *mucous membrane* of the bladder, which is lined by epithelium of the transitional variety, have already been described. It rests upon a loose *submucous coat* which is made up of areolar tissue. The greater part of the thickness of the wall is formed, however, of the *muscular coat*, consisting of smooth muscle-tissue, the fibers of which are arranged in three more or less distinct layers. The *outer layer* is composed

mainly of longitudinal fibers, some of which are continued forward to the pubis from the neck of the bladder to form the mm. pubovesicales and others backward to form the mm. rectovesicales. To this outer layer the term *m. detrusor urinæ* has been applied, but it should be noted that it does not contract independently of the circular layer. The *middle layer* is thicker than the outer and more uniformly developed. It consists of fibers having for the most part a circular direction and is well developed over all the upper portion of the bladder, but becomes thinner in the region corresponding to the trigone. It is here that the *inner layer* is chiefly developed, consisting of fibers, which are situated partly in the submucous tissue and have a general longitudinal direction throughout the region of the trigone. At the neck of the bladder, however, they form a strong circular bundle, which is continued into the prostatic portion of the urethra and forms what is termed the *internal sphincter* of the bladder.

Vessels.—The *arteries* of the bladder are usually three in number, the superior, middle and inferior vesical, branches of the hypogastric artery; the fundus also receives branches from the middle hemorrhoidal and in the female twigs are also sent to it from the uterine and vaginal arteries. The *veins* form an extensive plexus at the sides of the bladder, from which stems pass to the hypogastric trunk. The *lymphatics* accompany the veins and communicate with the hypogastric nodes, some of those from the fundus passing to nodes situated at the promontory of the sacrum.

Nerves.—The *nerves* are derived partly from the hypogastric sympathetic plexus and partly from the second and third sacral nerves. The fibers from the latter constitute the nervi erigentes, stimulation of which produces contraction of the general musculature and relaxation of the internal sphincter. On each side of the bladder there is formed a sympathetic *vesical plexus*, from which *superior* and *inferior vesical* nerves pass to the corresponding parts of the bladder.

Development.—In the earlier stages of development (cf. p. 51) the urogenital ducts and the digestive tract open below into a common cavity, the *cloaca*, from the ventral portion of which a long tubular outgrowth, the *allantois*, extends out to the placenta through the umbilical cord. Later the cloaca becomes divided in the frontal plane into a ventral portion which receives the urogenital ducts, and a dorsal portion, which becomes the lower end of the rectum. From the upper part of the ventral portion the bladder is developed. Since the cloaca is lined by endoderm the epithelial lining of the bladder is mainly derived from that embryonic layer, but it is worthy of note that portions of the lower ends of the ureters are taken up into the wall of the bladder, giving rise to the area of the trigone, whose lining membrane is thus of mesodermal origin. The portion of the allantois within the body of the fetus is transformed after birth into a fibrous cord, the *urachus*.

The **urethra** will be considered later in connection with the reproductive organs.

B. THE REPRODUCTIVE ORGANS

The reproductive organs include those of the male [organa genitalia virilia and those of the female [organa genitalia muliebria].

THE MALE REPRODUCTIVE ORGANS

The reproductive organs of the male consist of (1) two **testes** in which the spermatozoa are formed, (2) their ducts, the **ductus deferentes,** enclosed throughout a portion of their course in the **spermatic cord;** and the **seminal vesicles,** reservoirs for the semen, connected with the ductus deferentes; (3) the **penis,** the organ of copulation, which is traversed by the urethra; (4) the **urethra,** a canal into which the ductus deferentes open and which also gives exit to the contents of the bladder; (5) the **prostate gland,** a musculoglandular structure surrounding the beginning of the urethra; (6) the **bulbourethral glands** which open into the urethra.

1. The Testes and Their Appendages

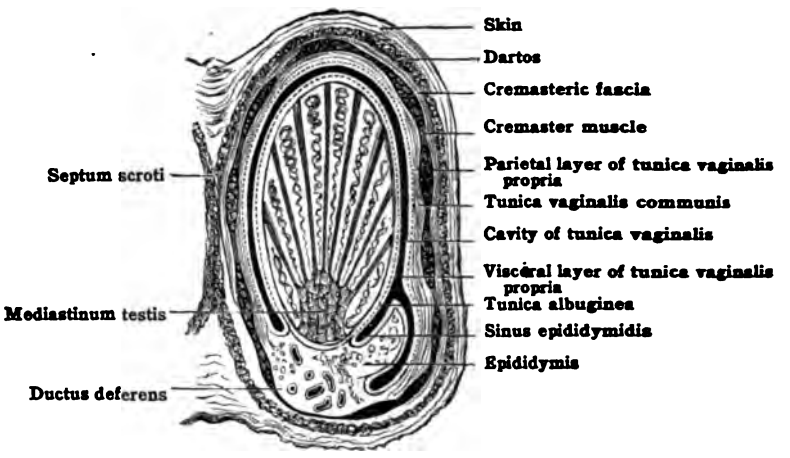
The scrotum.—The two testes, together with the beginning of the ductus deferentes, are contained within a pouch, the *scrotum*, which is divided into two compartments by a median sagittal septum, the edge of which is indicated on the surface by a ridge-like thickening of the integument, termed the *raphe*.

This double condition of the scrotum is explained by its origin from the fusion of two outpouchings of the lower portion of the abdominal wall, the inguinal canals forming, as it were, the necks of the outpouchings. The testes are primarily retroperitoneal abdominal organs, but later they descend through the inguinal canals into the scrotal outpouchings, where they lie between the peritoneal sac which each of these contains and the remaining layers of the wall, thus retaining their retroperitoneal position. The peritoneal sacs are at first in communication with the abdominal cavity, but after the descent of the testes each undergoes degeneration in its upper part, the cavity disappearing and the peritoneal tissue becoming converted into a portion of the connective tissue in which the ductus deferens and the vessels and nerves associated with it are imbedded in their course through the *spermatic cord*. The portion of the sac

in relation with each testis persists, however, and wrapping itself around that structure forms for it a serous investment, the *tunica vaginalis propria* (fig. 1027).

The *integument* of the scrotum is more or less pigmented and presents numerous transverse ridges extending laterally on either side from the raphe. It is furnished in the adult with coarse, scattered hairs and its sebaceous and sudoriparous glands are well developed. The deeper layers of the dermis, have a pinkish color, and form what is termed the *dartos* (fig. 1027), the coloration being due to the presence in it of numerous smooth muscle fibers, which are for the most part arranged at right angles to the wrinkles of the surface and are the cause of these. The more superficial fibers of the dartos, like the rest of the integument, form a common investment for both testes, but the deeper ones of either side bend inward at the raphe and assist in the formation of the septum.

FIG. 1027.—HORIZONTAL SECTION OF THE SCROTUM AND TESTIS. (Diagrammatic.)



Internal to the dartos and closely related to it is a layer of laminated connective tissue, the *external spermatic fascia*. It is destitute of fat and is continuous at the subcutaneous inguinal ring with the intercrural fibers. It is succeeded by the *cremasteric fascia*, which contain longitudinal bands of striated muscle-tissue, forming what is termed the *cremaster muscle* (figs. 420, 1027) and is continuous above with the fibers of the internal oblique muscle of the abdomen. Internal to this is a thin layer of connective tissue, the *tunica vaginalis communis*, or infundibuliform fascia which is continuous with the transversalis fascia through the inguinal canal.

Forming the innermost layer of the scrotum is the *tunica vaginalis propria*, which forms the serous investment of the testis and, as has been stated, is of peritoneal origin. Like other similar serous investments it has the form of a double sac, the outer or parietal layer of which is closely adherent to the tunica vaginalis communis and contains numerous plain muscle-fibers. The inner or visceral layer is thinner and closely invests the testis and a portion of the epididymis, being reflected from the inferior and posterior parts of the latter to be continuous with the parietal layer. Toward the upper part of the lateral surface of the testis it is folded in between that structure and the epididymis, forming a well-marked pocket the *sinus epididymidis* (digital fossa) (figs. 1027, 1028), whose upper and lower lips form what are termed the *ligamenta epididymidis*.

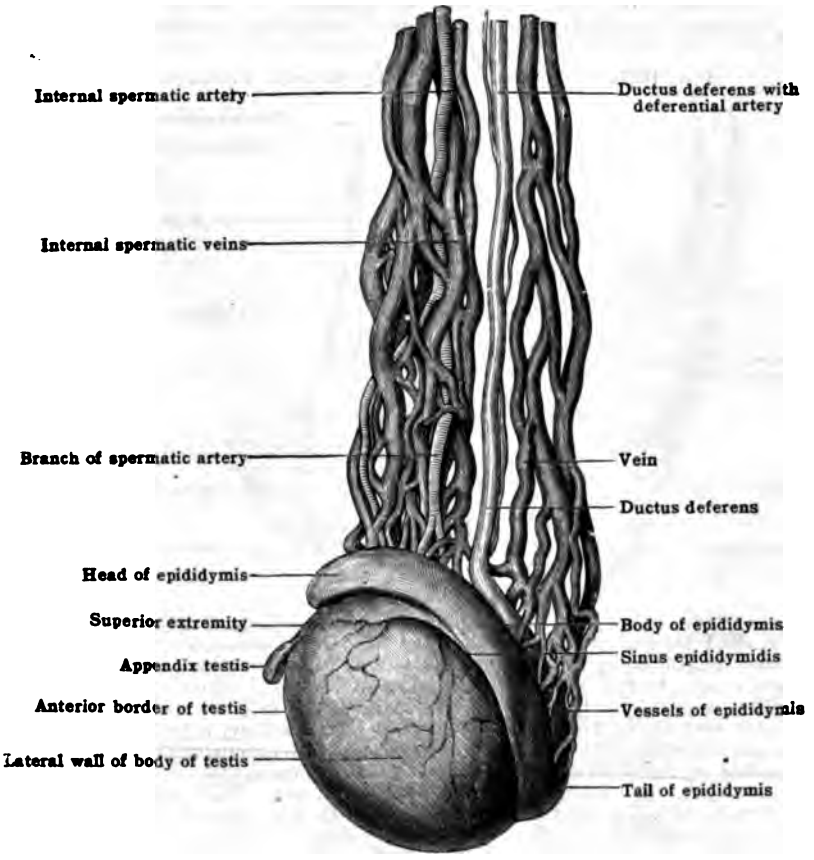
Vessels and nerves.—The skin and dartos of the scrotum are supplied partly by the perineal branch of the internal pudendal *artery* and partly by the external pudendal branches of the femoral. The deeper layers are supplied by the spermatic branch of the inferior epigastric. The *veins* accompany the arteries, the external pudendals opening into the internal saphenous vein near its termination. The *lymphatics* terminate in the more medial inguinal nodes. Several *nerves* take part in the supply of the scrotum. The external spermatic branch of the genitofemoral gives sensory branches to the anterior and lateral surfaces and also supplies the external cremaster muscle; the posterior surface is supplied by the perineal branch of the pudendal nerve; and the inferior surface by the perineal branches of the posterior femoral cutaneous. The anterior surface of the scrotum is also supplied by anterior scrotal branches of the ilioinguinal. The smooth musculature is probably supplied by the internal spermatic nerve from the hypogastric plexus.

Hernia.—The communication of the tunica vaginalis propria with the abdominal peritoneum is usually obliterated within a few days after birth, but sometimes the process of obliteration is more or less incomplete. If the communication remains open there is a free passage

for a loop of the intestine to enter the cavity of the tunica vaginalis, such a condition constituting what is known as the *congenital* variety of inguinal hernia. If the communication be interrupted only at the upper part of the original sac, so that the cavity of the tunica vaginalis propria extends a considerable distance up the spermatic cord a hernia, passing through the inguinal canal, may invaginate the upper part of the tunica vaginalis into the lower, producing what is termed the *encysted* variety of hernia. Or if, finally, the obliteration of the communication begins in the neighborhood of the testis, a funnel-shaped prolongation of the peritoneal cavity may extend downward into the spermatic cord, and hernia into this constitutes the variety known as *hernia into the funicular process.* (Cf. also p. 1398.)

The testis and epididymis.—The **testes** (fig. 1028) are the essential male organs of reproduction and are contained within the scrotum. They are two in number, each being of a flattened oval form, with two *surfaces*, *medial* and *lateral*,

FIG. 1028.—THE LEFT TESTIS WITH VESSELS AND DUCT. (After Sappey.)



two *borders*, *anterior* and *posterior*, and two *extremities*, *superior* and *inferior*. To the whole of the posterior border there is attached the *epididymis*, formed by the efferent ducts. The testis is obliquely placed, so that the medial surface also looks somewhat forward and downward. The average dimensions of the testis are: 4–5 cm. in length and 2.5–3 cm. in width.

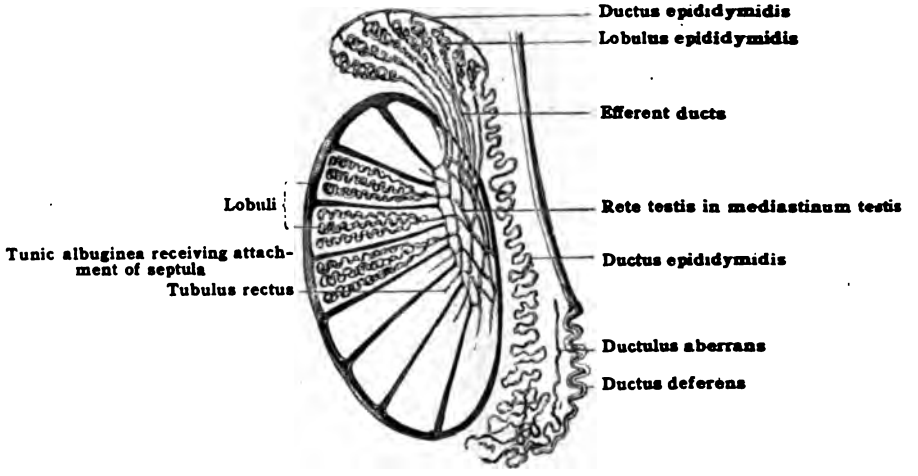
The surface of the testis is covered by the visceral layer of the tunica vaginalis propria except where it is in contact with the epididymis. Within the visceral layer of the tunica vaginalis is a dense white inelastic capsule, the *tunica albuginea*, beneath which is a looser and more vascular layer which extends along the septula and thus gives rise to a vascular investment of the lobules. From the inner surface of the albuginea, lamella of connective tissue, known as *septula*, converge toward the posterior border of the testis and toward its upper part unite to form a network (fig. 1029), the *mediastinum testis* (or corpus Highmori), through which blood-vessels and lymphatics enter and leave the testis. The tubules of the testis as they pass into the meshes of the mediastinum form the *rete testis*.

The septula divide the substance of the testis into a number of compartments or *lobuli*, each of which is occupied by a number of slender, greatly contorted canals, the *seminiferous tubules* [tubuli seminiferi], from whose epithelial lining the spermatozoa are formed. The tubules of each lobule converge to form a single, almost straight duct and these *tubuli recti* extend toward the mediastinum, where they pass into the rete testis. In the lobules the seminiferous tubules are imbedded in a loose connective tissue that contains certain peculiar cells, the *interstitial cells*, to which has been attributed the formation of an internal secretion.

The **epididymis** (fig. 1028), which lies along the posterior border of the testis, is an elongated structure with a *body* [corpus epididymidis], enlarged above to form the *head* [caput] and to a less extent below to form the *tail* [cauda]. It is invested by a tunica albuginea, continuous with, but much thinner than that of the testis, and is formed mainly by the greatly contorted duct of the epididymis, which is continued into the ductus deferens.

The head is formed by 12–14 tubules, the *efferent ducts* (fig. 1029), which take their origin from the rete testis as almost straight tubules, but gradually become greatly coiled, so that each duct has the form of an elongated cone, its coiled portion forming what is termed a *lobulus*

FIG. 1029.—DIAGRAM OF THE TESTICULAR TUBULES.



epididymidis. At their coiled ends the various efferent ducts open into a single tube, the *ductus epididymidis*. Its diameter is only about 0.4 mm., but it measures 6.0–7.0 meters (18–21 feet) in its entire length, being coiled so extensively as to be contained within the body and tail of the epididymis. In this latter region it passes over into the ductus deferens.

Vessels.—The principal *artery* supplying the testis is the internal spermatic, from which branches are also sent to the epididymis. The deferential artery, a branch of the superior vesical, also sends branches to the epididymis and enters into extensive anastomoses with the testicular branches of the internal spermatic, and anastomoses also occur with the vessels supplying the scrotum. The *veins* correspond to the arteries. The *lymphatics* of the testis and epididymis unite to form four to six large stems which pass upward in the spermatic cord to terminate in the lower lumbar nodes.

Morphology.—For the development of the testis, see DEVELOPMENTAL ANATOMY, p. 52. The testis is primarily an abdominal organ and is developed in close relationship with the provisional kidney [mesonephros] whose duct, indeed, becomes the ductus deferens and some of whose tubules, becoming the efferent ducts, place the seminiferous tubules in communication with the ductus deferens. The epididymis may therefore be said to be developed from the mesonephros. The portions of this structure that are not concerned in the formation of the efferent ducts disappear for the most part; a few of the tubules persist, however, as rudimentary organs associated with the epididymis. Among these may be mentioned one or more blindly ending, coiled tubules, varying from 5–30 cm. in length, which are connected with the ductus epididymidis usually in the tail of the epididymis. They are known as the *ductuli aberrantes* (fig. 1029) and may be regarded as persistent mesonephric tubules. Another of the rudimentary organs is the *paradidymis* (*organ of Giraldès*), which is a whitish body, situated immediately above the head of the epididymis, and is composed of irregularly coiled tubules, which terminate blindly at both extremities. They may be regarded as efferent ducts that have failed to connect with the testis and are of interest in that they sometimes develop into cysts connected with the epididymis.

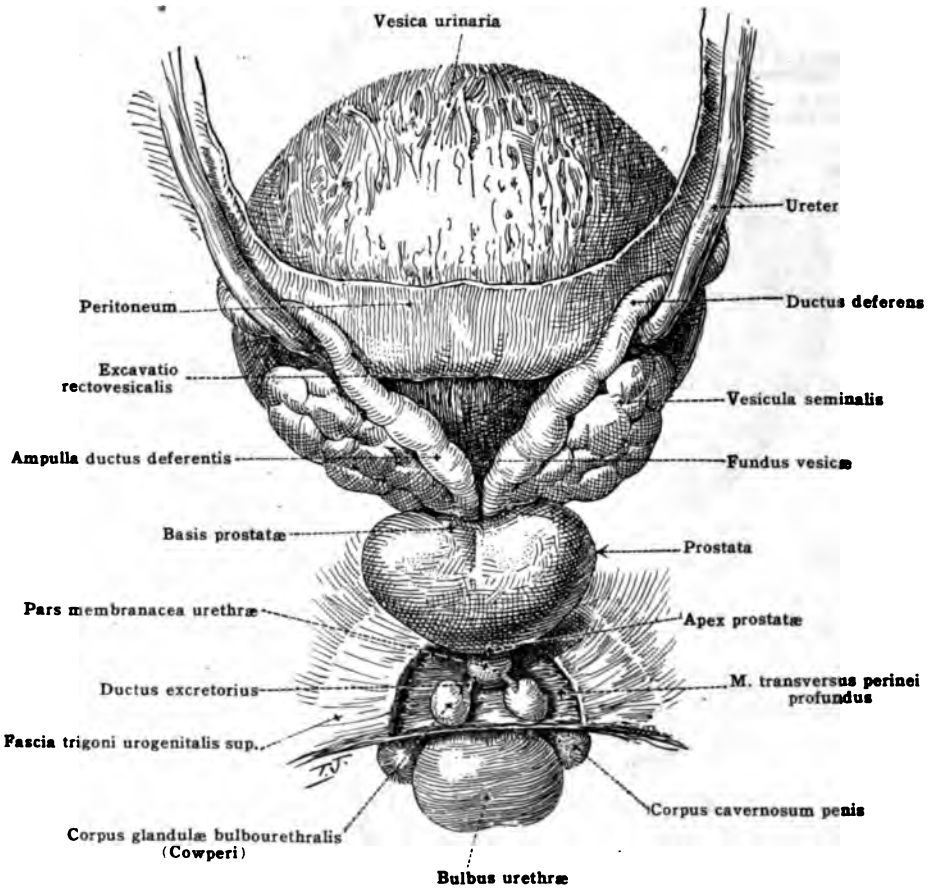
In addition there is frequently attached to the upper extremity of the testis a solid, oval body composed of connective tissue, known as the *appendix testis* (*hydatid of Morgagni*) (fig. 1028). It measures from 3 to 8 mm. in length and its significance is doubtful. A similar, though smaller structure, the *appendix epididymidis*, is attached less frequently to the head of the epididymis. It is usually provided with a distinct stalk and contains a cavity; it is believed to

represent the upper end of the Müllerian duct, present in the embryo and giving rise to the tuba uterina in the female, but almost completely degenerating in the male (fig. 1051).

The testis begins its descent from the abdominal cavity into the scrotum at the third month of fetal life and reaches the abdominal inguinal ring at about the sixth month, but it is not until shortly before birth that it arrives at its final location in the scrotum. The cause of the descent is still uncertain, but it is supposed to be partly due to the failure of a band of connective tissue, which extends from the lower pole of the embryonic testis to the bottom of the scrotal pouch, to keep pace with the growth of the body walls. This ligament, which is known as the *gubernaculum testis*, thus becomes relatively shorter and draws the testis downward toward the point of its attachments to the scrotum. There are various features in the descent, however, that cannot be explained by the simple traction of the gubernaculum and it must be regarded as a complicated growth process whose meaning is yet uncertain. The gubernaculum testis apparently undergoes degeneration after the testis has reached its definitive location and cannot be recognized in connection with the adult testis.

Occasionally the descent of the testis is interrupted, the organ remaining either in the abdomen or in the inguinal canal. This condition of **cryptorchism** is always associated with a suppression of the function of the organ.

FIG. 1030.—RELATIONS OF BLADDER, DUCTUS DEFERENS, SEMINAL VESICLES, PROSTATE, ETC. Posterior view.



2. THE DUCTUS DEFERENTES AND VESICULÆ SEMINALES

Each **ductus (vas) deferens** is the continuation of a ductus epididymidis and extends from the tail of the epididymis to the prostatic portion of the urethra. At its beginning it ascends along the posterior border of the epididymis (*testicular portion*) and is at first slender and tortuous (fig. 1029), but before reaching the level of the head of the epididymis it becomes straighter and thicker (fig. 1028), owing to the development in its walls of strong layers of longitudinal and circular smooth muscle-tissue. Thence it is continued almost vertically upward as one of the constituents of the spermatic cord (*funicular portion*) to the subcutaneous inguinal ring, and, entering this, traverses the inguinal canal (*inguinla*

portion), still forming a portion of the cord. At the abdominal ring it separa from the other constituents of the cord and, looping over the inferior epigast

FIG. 1031.—DUCTUS DEFERENTES AND VESICULÆ SEMINALES. (After Sappey.)

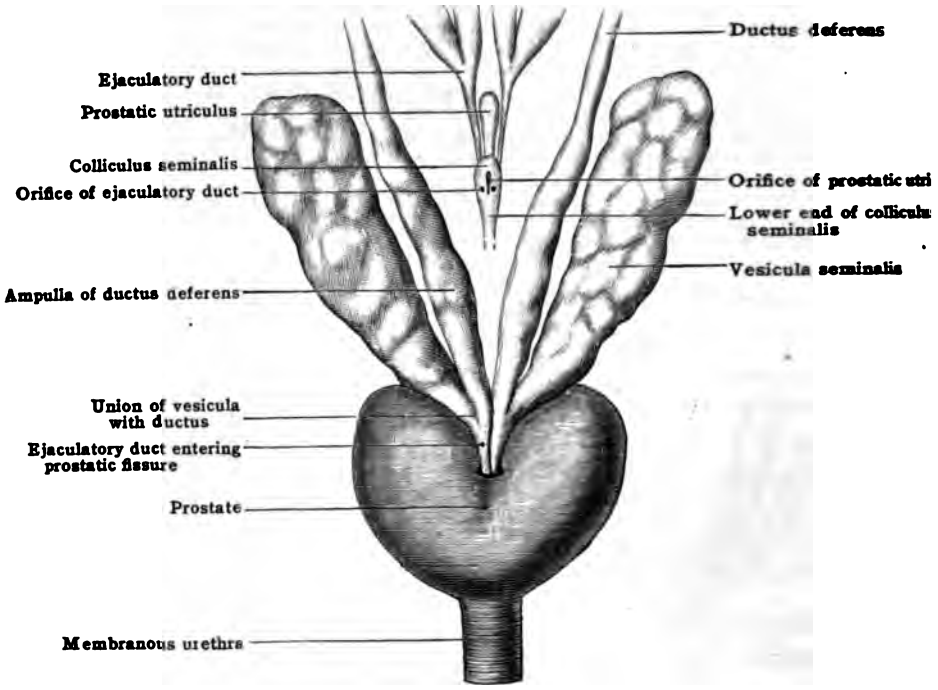
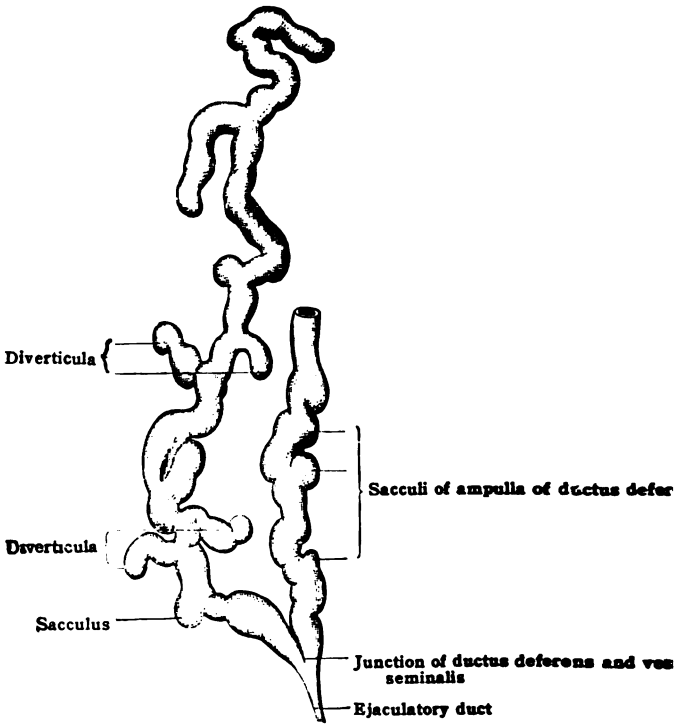


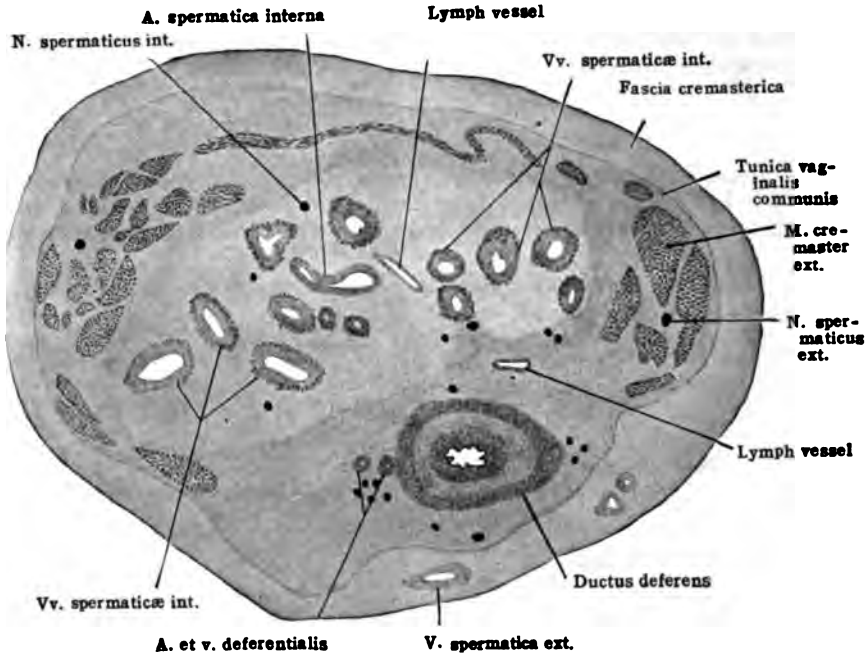
FIG. 1032.—DUCTUS DEFERENS AND VESICULA SEMINALIS DISSECTED. (After Sappe



artery near its origin, passes downward and backward over the lateral surfac the bladder (*pelvic portion*). At the junction of the posterior and superior s

faces of the bladder it passes medially to the ureter and is then continued downward, forward and medially upon the base of the bladder until it reaches the prostate gland (figs. 1030, 1031). Just before it reaches the prostate gland each ductus deferens presents an irregular spindle-shaped enlargement, the *ampulla* (figs. 1030 –1032), whose walls are somewhat sacculated. Just beyond this it is joined upon its lateral surface by the excretory duct of a club-shaped lobulated structure, the **vesicula seminalis.** The union of the ductus deferens with the excretory duct of the seminal vesicle gives rise to the *ductus ejaculatorius* which traverses the substance of the prostate and opens into the urethra on the colliculus seminalis (fig. 1031). Each vesicle measures 4.5–5.5 cm. in length and has a greatest diameter of about 2 cm. It rests upon the posterior surface of the bladder, lying parallel with and lateral to the corresponding ductus deferens, and in its upper one-third is in relation posteriorly with the peritoneum which forms the anterior wall of the rectovesical pouch, while below it is in contact with the an-

FIG. 1033.—CROSS-SECTION OF THE SPERMATIC CORD.



terior wall of the lower part of the rectum, through which it may be palpated. Indeed, the two vesiculæ, together with the ductus deferentes, form the lateral boundaries of the triangular area at the base of the bladder, through which that organ is in relation to the rectum.

Each vesicle is enclosed within a fine capsule of connective tissue, which contains numerous smooth muscle-fibers and is continuous below with the capsule of the prostate gland. On removing this capsule the vesicle will be found to consist of a greatly coiled tube, 10–12 cm. in length, which ends blindly and has attached to it on either side a number of short diverticula (fig. 1032). The walls of the tube and diverticula are formed of smooth muscle-tissue, arranged in layers similar to those of the ductus deferentes, and are lined by a much folded mucous membrane. The epithelium of this membrane is composed of two layers of cells, an inner columnar and an outer cuboidal. These cells and the adjacent connective tissue contain considerable quantities of a yellowish-brown pigment. The cells of the epithelium exhibit appearances which lead to the supposition that they contribute a secretion to the seminal fluid. In addition to having this function the vesiculæ may serve as receptacles for the spermatozoa. They arise as diverticula from the embryonic ductus deferens, and it is worthy of note that a number (4 or 5) of similar but quite small diverticula arise from the upper part of each ductus ejaculatorius.

Vessels and nerves.—The *artery* supplying the ductus deferens is the a. deferentialis, a branch of the superior vesical. It accompanies the ductus to the tail of the epididymis and also gives a branch to the vesicula seminalis. The latter also receives branches from the middle hæmorrhoidal and inferior vesical arteries. The deferential *vein* accompanies the ductus deferens to the base of the bladder where it breaks up into a plexus that communicates with

the seminal venous plexus formed by the veins from the seminal vesicles. This joins with the vesical and pudendal plexus and so communicates with the hypogastric vein. The *lymphatics* of the ductus deferentes and seminal vesicles pass to the external iliac and hypogastric nodes. The *nerves* of both structures are derived from the hypogastric plexus.

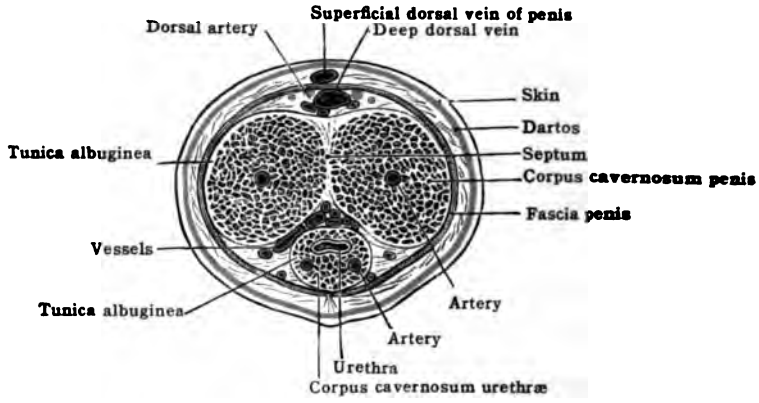
The spermatic cord.—In its descent through the inguinal canal into the scrotum the testis necessarily carries with it the ductus deferens and the testicular vessels and nerves, these structures coming together at the abdominal inguinal ring to form what is termed the *spermatic cord* [funiculus spermaticus]. This structure extends, therefore, from the abdominal inguinal ring, through the inguinal canal and the neck of the scrotal sack to the testis, and is enclosed within the same investing layers as the testis.

The various essential constituents of the spermatic cord are as follows (figs. 1028, 1033): (1) the *ductus deferens*, occupying the posterior surface of the cord and having associated with it the deferential artery and veins and the deferential plexus of nerve-fibers; (2) the *internal spermatic artery*, which occupies the axis of the cord and is surrounded by (3) the *internal spermatic veins* which form a complicated network, known as the *pampiniform plexus;* (4) the *testicular lymphatics;* and (5) the *internal spermatic plexus* of nerves from the hypogastric plexus and (6) branches of the *external spermatic vessels and nerve* for the supply of the cremaster muscle. All these structures are united by a loose connective tissue.

3. The Penis

The **penis** is formed by three rod-like bodies composed of erectile tissue (figs. 1034, 1035), firmly united together and invested by fascia and integument. When this erectile tissue becomes engorged with blood the organ assumes an

Fig. 1034.—Transverse Section through the Body of the Penis.



erect position, but otherwise it is pendulous, hanging downward in front of the scrotum from its attachment to the symphysis pubis. The erectile bodies are, however, prolonged backward beyond the symphysis pubis into the perineal region, and it is customary to speak of this perineal portion as the *root* of the penis [radix penis] or *pars fixa* in contrast to the *body* of the penis [corpus penis] or *pars libera*.

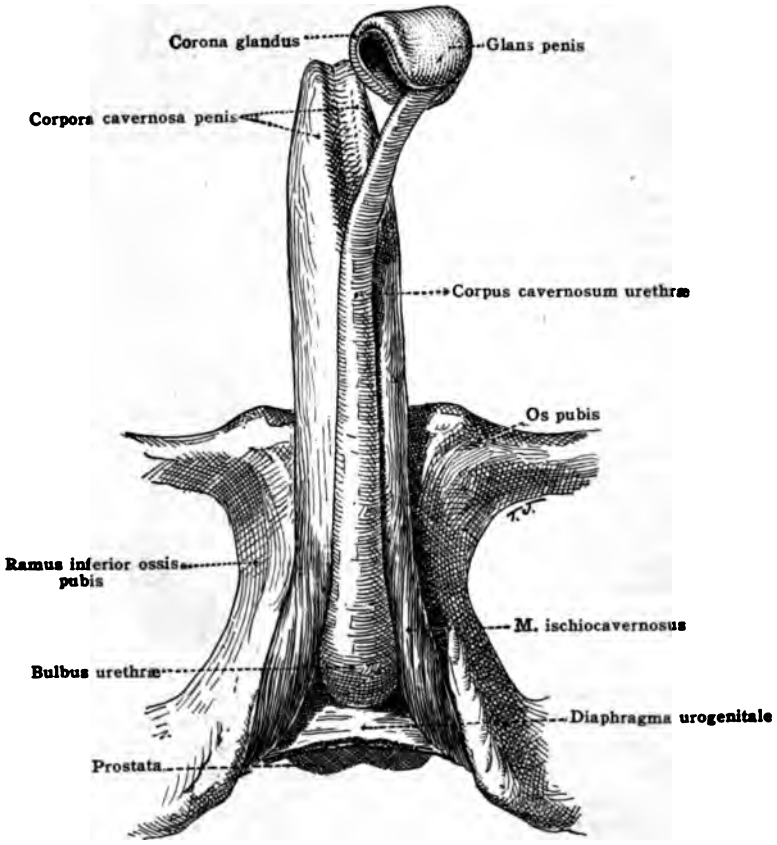
The **body of the penis** in its flaccid condition is almost cylindrical, but in erection it becomes somewhat triangular in section, what was the anterior surface or *dorsum penis** becoming flattened, while the opposite one, the *urethral surface* [facies urethralis], becomes more rounded. At the free extremity of the penis there is a blunt conical enlargement, the glans penis (fig. 1035), at the apex of which is the external orifice of the urethra. The glans is separated from the body by a constriction, the *neck* [collum glandis], and from this region a fold of integument arises, which more or less completely encloses the glans, forming the *prepuce* [præputium] (fig. 1036). The prepuce is quite free from the glans dorsally but in the ventral mid-line it is attached, almost to the urethral orifice.

* It should be noted that the terms 'dorsum' and 'dorsal' are used for the penis in a sense directly opposite their usual meaning.

by a narrow line of adhesion, the *frenulum* [frenulum præputii], which contains blood-vessels of considerable size. The base of the glans has a well-marked rounded border, the *corona* [corona glandis], and is deeply concave for the reception of the distal ends of the corpora cavernosa penis.

The integument of the penis is continuous with that of the scrotum and like it is pigmented and contains no fat. Immediately below it there is a layer of non-striated muscular tissue, the *dartos*, and beneath this a layer of loose connective tissue, containing the superficial vessels and nevers of the penis; beneath this again is a denser, elastic sheet of connective tissue, the *fascia penis* (fig. 1034), which encloses the erectile bodies as far as the base of the glans and is continuous with the superficial fascia of the perineum and inguinal region. Where it passes beneath the symphysis pubis it receives from the anterior surface of the latter a strong band of fibrous tissue, which forms the *suspensory ligament* of the penis [lig. suspensorium penis.]

FIG. 1035.—DISSECTION OF THE PERINEUM SHOWING THE STRUCTURE AND RELATIONS OF THE PENIS.



Two of the erectile bodies of the penis, the **corpora cavernosa penis,** are paired (figs. 1034, 1035). They are attached at their proximal ends to the base of the tuberosity of the ischium of each side, and in this part of their extent are termed the *crura penis*, being composed of fibrous connective tissue, which has resting upon it the m. ischiocavernosus (see Section V). The two **crura** are situated in the lateral portions of the superficial perineal interspace and pass forward parallel with the rami of the ischium and pubis, gradually becoming transformed into cavernous erectile tissue. Shortly before they reach the level of the symphysis pubis the two corpora come into contact in the median line, their medial walls fusing to form a *septum*, and thus united they extend throughout the entire length of the body of the penis, occupying the dorsal portion of the space enclosed by the fascia penis (fig. 1034). They terminate at the posterior surface of the glans, where they taper somewhat to be received into its basal concavity (fig. 1036). The septum in its proximal part forms a complete partition between the two bodies, but distally it is broken through by numerous clefts by which the blood lacunæ of the two bodies are placed in communication.

Each corpus cavernosum penis consists of a strong elastic fibrous sheath, the *tunica albuginea*, from which trabecula extend into the substance of the organ, dividing it into a network of communicating cavities, into which open terminal branches of the a. profunda penis, which traverses the axis of the corpus. These cavities consequently are to be regarded as vascular lacunæ, which, becoming engorged with blood, produce the enlargement and erection of the organ.

The third erectile organ is the **corpus cavernosum urethræ** (formerly 'corpus spongiosum') (figs. 1034–1036), so called because it is traversed throughout its entire length by the urethra. It is an unpaired, median structure, having no bony attachments and begins posteriorly in the superficial perineal interspace with an enlargement, the **bulb** [bulbus urethræ] (fig. 1035), whose posterior surface rests on the superficial fascia of the urogenital diaphragm and is enclosed by the m. bulbocavernosus. Anteriorly the bulb gradually tapers to a rather slender cylindrical portion, the *body*, very uniform in diameter, which extends throughout the entire length of the body of the penis, lying in the median line beneath the fused corpora cavernosa penis (figs. 1034, 1035). At the neck of the penis it undergoes a sudden enlargement to form the *glans*, the whole of that structure which has already been described, being formed by the corpus cavernosum urethræ. The structure of the corpus cavernosum urethræ is essentially the same as that of the corpora cavernosa penis, the tunica albuginea, however, being much thinner.

Vessels and nerves.—The principal *arterial* supply of the penis is derived from the internal pudendal artery (see p. 647), although the proximal portion of its integument is also supplied by the external pudendal branches of the femoral artery. The *veins* from the integument collect into one or more stems, the superficial dorsal vein, which runs along the dorsal midline and, bifurcates, draining into the great saphenous vein of each side (fig. 563). The deep veins from the corpora cavernosa open into a median deep dorsal vein, which communicates with the internal pudendal veins and terminates in the pudendal plexus. Both the superficial and deep *lymphatics* terminate in the superficial inguinal nodes. The lymph-vessels from the glans are said to follow those of the urethra and end in the deep inguinal and external iliac nodes.

The *nerves* supplying the penis are the anterior scrotal branches of the ilioinguinal, and the perineal branches and dorsal nerve of the penis from the pudendal. Sympathetic fibers also pass to the penis from the hypogastric plexus and these with fibers from the third and fourth sacral nerves constitute what is termed *nervus erigens*, since stimulation of it produces erection of the organ. An anatomical provision for the production of this phenomenon has been found in the occurrence of peculiar thickenings of the intima of the arteries of the penis, by which the lumina of the vessels are greatly diminished or even occluded when in a state of moderate contraction, as when the organ is flaccid. When the arteries are dilated the intimal thickenings become reduced in height and the blood is afforded a free passage into the lacunar spaces of the corpora cavernosa, which thus become engorged.

4. The Male Urethra

The **urethra** is the canal which extends from the bladder to the extremity of the glans penis and serves for the passage of both the urine and the seminal fluid. In its course (fig. 1036) it traverses first the prostate gland, then the urogenital diaphgram and then the entire length of the corpus cavernosum urethræ, and may thus be regarded as being composed of three portions.

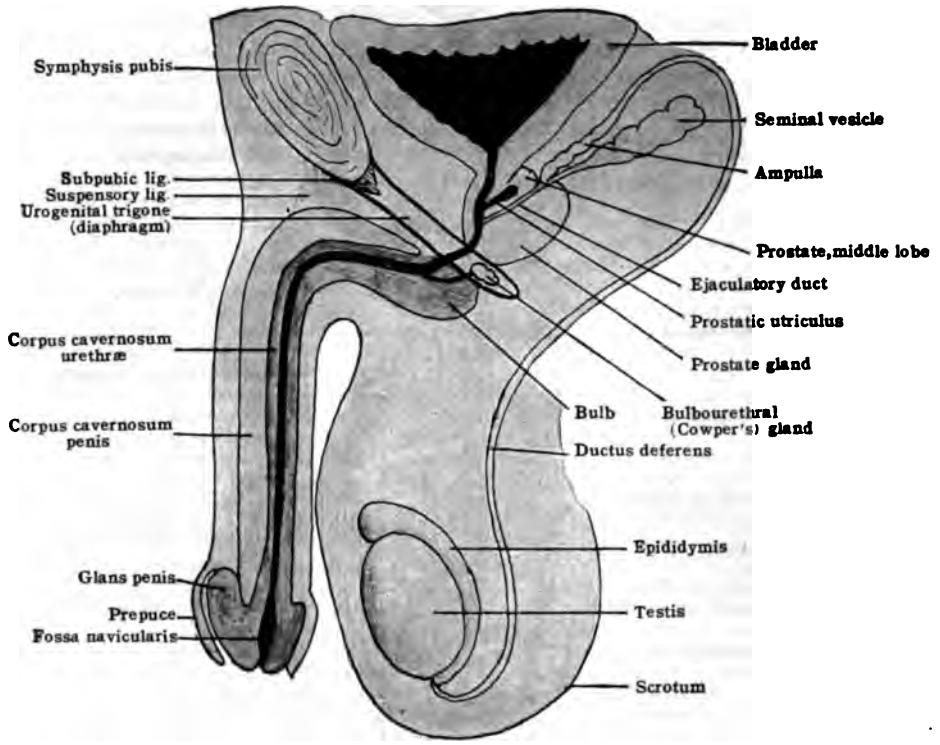
The **prostatic portion** [pars prostatica] (fig. 1036) extends almost vertically downward from the neck of the bladder, traversing the substance of the prostate gland. In its proximal part there is on its posterior wall a median longitudinal ridge, the *crista urethralis*, which below dilates into an oval enlargement, the *colliculus seminalis* (figs. 1026, 1037), to accommodate which there is a marked widening of the lumen of the urethra in this part of its course. At the center of the colliculus there is an elongated opening of a pouch of varying depth, termed the *utriculus prostaticus* ('uterus masculinus'), which corresponds to the lower part of the vagina in the female (see p. 1297). Situated one on either side near the utriculus are the much smaller openings of the *ejaculatory ducts*. Owing to the prominence formed by the colliculus a cross-section of the urethra in this region is somewhat ∩-shaped, and at the bottom of the furrows on either side of the median elevation are the minute openings of the numerous ducts of the prostate gland (fig. 1037).

On its emergence from the prostate gland the urethra at once penetrates the deep layer of fascia of the urogenital diaphragm and enters the deep perineal interspace, this portion of its course being known as the **membranous portion** [pars membranacea]. Its direction is now downward and slightly forward, curving

beneath the subpubic ligament, from which it is separated by a plexus of veins and by the fibers of the *sphincter urethræ membranaceæ*, which form an almost complete investment for it. The lumen of this part of the urethra is much narrower than that of the prostatic portion, and since it traverses the rather unyielding fascia of the urogenital diaphragm it is less dilatable than in other parts of its extent, with the exception of the external orifice.

Passing through the superficial layer of fascia of the urogenital diaphragm the urethra then enters the bulb of the corpus cavernosum urethræ (fig. 1036) and is invested throughout the remainder of its extent by this structure; hence this portion is known as the **cavernous portion** [pars cavernosa]. In its proximal part

FIG. 1036.—MIDSAGITTAL SECTION (DIAGRAMMATIC) SHOWING MALE BLADDER, URETHRA, ETC.

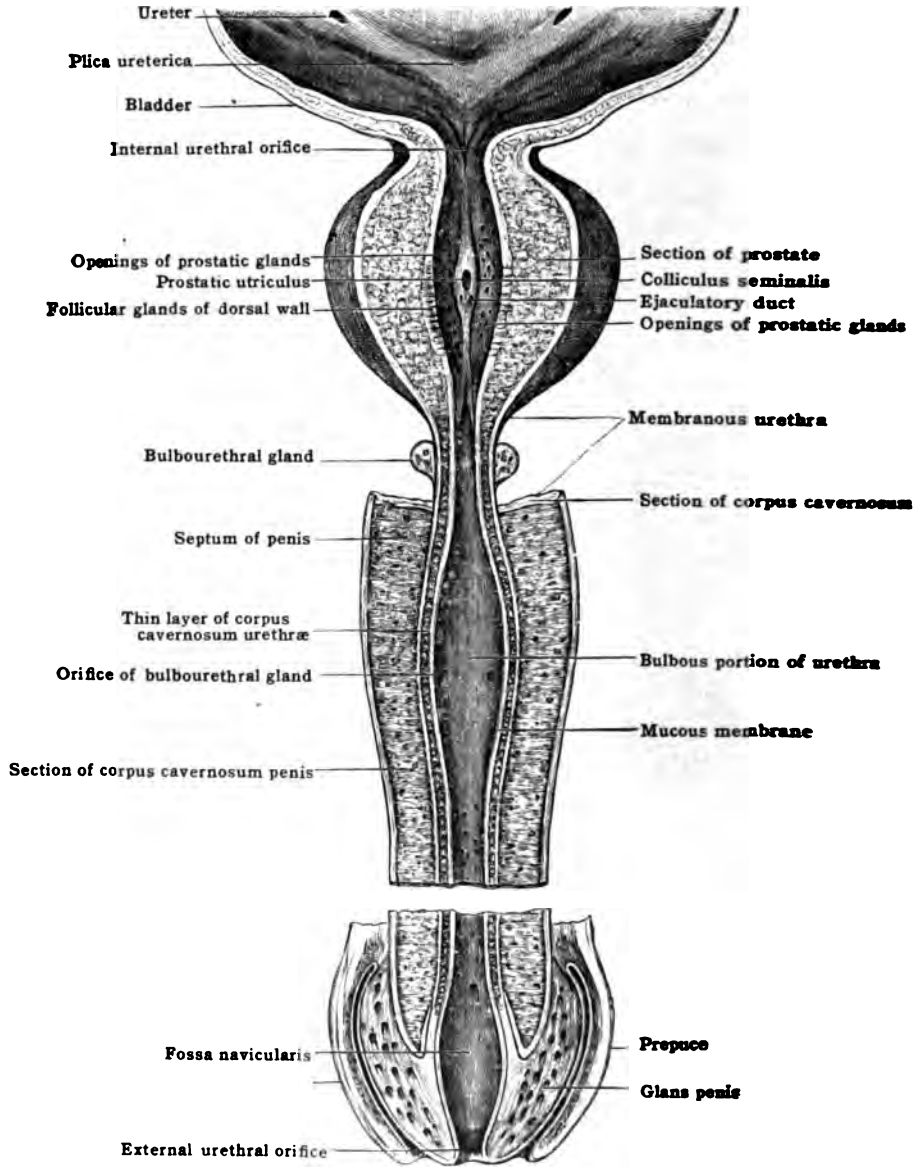


this lies in the superficial interspace of the perineum and passes almost directly forward; but more distally, where it enters the body of the penis, it accommodates itself to the position of that organ, which it traverses lengthwise, lying in the midline near its ventral surface (fig. 1034). Thus the proximal portion of the cavernous and the whole of the membranous and prostatic portions have a fixed position, whence they are sometimes associated as the *pars fixa* of the urethra, while the penial portion forms the *pars mobilis*. On entering the bulb the lumen of the urethra dilates somewhat and in this region has opening into it the ducts of the bulbourethral glands (fig. 1037), but as it enters the body of the corpus cavernosum it diminishes again and maintains a uniform diameter throughout the extent of that structure. When it reaches the glans penis it undergoes another dilation, which is known as the *fossa navicularis* (fig. 1037), beyond which it diminishes to the slit-like *external orifice*, situated at the extremity of the glans and forming the least dilatable portion of the entire urethral canal.

Throughout the greater part of its extent the cavernous portion of the urethra shows upon its dorsal wall the openings of numerous tubular depressions of the mucous membrane, the *urethral lacunæ* [lacunæ urethrales (Morgagnii)]. There is frequently found in the middorsal line of the proximal part of the fossa navicularis, a valve-like fold [valvula fossæ navicularis] of the mucous membrane which gives rise to a pocket sufficiently large to receive the point of a small catheter. Numerous minute glands [gl. urethrales] open upon the surface of the urethral mucosa. They are most abundant in the anterior wall, but occur also on the sides and floor.

Dimensions of the urethra.—The entire length of the urethra is somewhat variabl different individuals, the greatest variation being in the length of the pars mobilis. Of the fixa the prostatic portion is 2.5–3.0 cm. in length, the membranous portion about 1.0 cm., the fixed part of the cavernous portion 6.5 cm., the entire pars fixa having thus a length of what over 10.0 cm. (4 in.). The average diameter of the urethra is 5.0–7.0 mm., but it v noted that the canal presents in its course three dilations; namely, (1) at the fossa n ularis, which begins about 0.5 cm. from the external orifice; (2) the bulb of the corpus ca

FIG. 1037.—THE MALE URETHRA, WITH SURROUNDING PARTS.



sum urethræ; and (3) in the prostatic portion. Furthermore there are two regions in whicl is distinctly narrowed; namely, at the external orifice and in the membranous portion. Wh the remaining portions are capable of considerable distention, these are relatively inelas the maximum diameter to which they may be dilated being about 10 mm. Arranged in ascending order according to their capability for distention the parts would have the followi order: external orifice, membranous portion, penial portion, prostatic portion, bulbar porti

5. THE PROSTATE GLAND

The prostate gland [prostata] (figs. 1025, 1026, 1030, 1036 and 1037) is a mas of glandular and muscular tissue surrounding the proximal portion of the ma

urethra, and may, indeed, be regarded as a special development of the wall of this portion of the canal. It is a more or less flattened conical structure whose *base* [basis prostatæ] is in contact with the lower surface of the bladder and the *apex* [apex prostatæ] with the deep fascia of the urogenital diaphragm. Its *anterior surface* [facies anterior] is behind the symphysis pubis, from which it is separated by the pudendal plexus of veins and a considerable amount of areolar or adipose tissue in the lower part of the prevesical space of Retzius. Its *posterior surface* [facies posterior] is in contact with the anterior wall of the lower portion of the rectum. Laterally it is in relation with the levatores ani. From the neighboring endopelvic fascia it receives a fibrous *sheath*, containing the venous prostatic plexus and loosely connected with the denser fibrous *capsule* of the prostate.

The *urethra* enters the base of the prostate near its anterior border and descends through it almost vertically, so that the greater portion of the gland is posterior to the canal. On the posterior surface of the gland is a more or less distinct median vertical groove, which serves to separate the *lateral lobes* [lobus dexter et sinister], although the demarcation is merely superficial. The groove terminates above in a well-marked notch on the posterior border of the base, and immediately in front of this there is a deep funnel-shaped depression of the surface, which receives the ejaculatory ducts (figs. 1031, 1036).

Beginning at this depression two grooves pass forward and slightly lateralward across the surface of the base of the prostate, marking off a more or less pronounced median elevation, which, when enlarged, constitutes what is termed the *middle lobe* [lobus medius] (fig. 1036); since this lies beneath the trigone of the bladder behind the internal orifice of the urethra its enlargement may produce more or less occlusion of the latter. Ordinarily, however, this middle portion of the prostate, seen in median section between the urethra and the ejaculatory duct, forms merely a commissure [*isthmus prostatæ*] joining the lateral lobes.

Dimensions.—The longest *axis* of the prostate, which is almost vertical in the erect posture measures 2.5–3.0 cm., the *transverse* diameter at the base is 4.0–4.5 cm. and the *thickness* 2.0–2.5 cm. Its *weight* is normally 20–25 grms. but in old age it may be double that, its dimensions having correspondingly increased.

Structure.—The prostate consists of some 15–30 branched tubular glands imbedded in a stroma of connective tissue, containing a large amount of smooth muscle-tissue and forming at the surface of the prostate a strong fibromuscular *capsule* from which prolongations are contributed to the pubovesical ligaments and muscles. The glands, which vary greatly in their development, are outgrowths from the mucous membrane of the urethra, into which their ducts open at the bottom of the grooves that lie lateral to the colliculus seminalis; similarly, the matrix with its muscle tissue is evidently the modified muscular coat of the urethra. Consequently there is no distinct demarcation between the wall of the urethra and the substance of the prostate, and from the developmental standpoint the prostate is to be regarded as the modified wall of the urethra.

The fact that the prostate shows a special development at puberty and undergoes more or less extensive degenerative changes with the cessation of the reproductive function, as seen in old age and in castrates, indicates that it is associated physiologically with the reproductive organs. Its secretion is a thin alkaline fluid, which may contain round or elongate, concentrically layered bodies, measuring 0.3–0.5 mm. in diameter and known as *amyloid bodies*, although they are really albuminous in chemical composition. They are constantly found in adults in the lumina of the glands and may become calcified. The secretion has been found to have a stimulating effect upon the spermatozoa, and this may be its principal function.

Vessels and nerves.—The *arterial* supply of the prostate is derived from the inferior vesical and middle hemorrhoidal branches of the hypogastric artery. The *veins* form a rich prostatic plexus in the immediate vicinity of the gland, this being part of the pudendal plexus around the lower part of the bladder and communicating posteriorly with the hemorrhoidal plexus and superiorly with the vesical plexus. It drains finally into the hypogastric vein. The *lymphatics* are very abundant and form a network on the posterior surface of the gland from which several vessels pass to the hypogastric nodes. The *nerves* are derived from the hypogastric plexus.

6. The Bulbourethral Glands

The **bulbourethral glands** [gl. bulbourethralis (Cowperi)] or **Cowper's glands** (figs. 1030, 1036, 1037) are two small tubuloalveolar glands which lie one on either side of the membranous portion of the urethra, imbedded among the fibers of the sphincter urethræ membranaceæ, between the two layers of fascia of the urogenital diaphragm. Each is a rounded body with a diameter of 4.0–9.0 mm. and is drained by a duct [ductus excretorius] which perforates the superficial fascia of the diaphragm and, entering the substance of the bulb of the corpus cavernosum urethræ, traverses it to open on the floor of the bulbar portion of the urethra after a total course of 3.0–4.0 cm. They have a mucoid secretion.

THE FEMALE REPRODUCTIVE ORGANS

The organs of reproduction in the female consist of (1) the *ovaries*, the essential organs of reproduction; (2) the *tubæ uterinæ* (Fallopian tubes), which serve as

FIG. 1038.—THE FEMALE ORGANS OF REPRODUCTION. (Modified from Sappey.) (Vagina divided and laid open behind.)

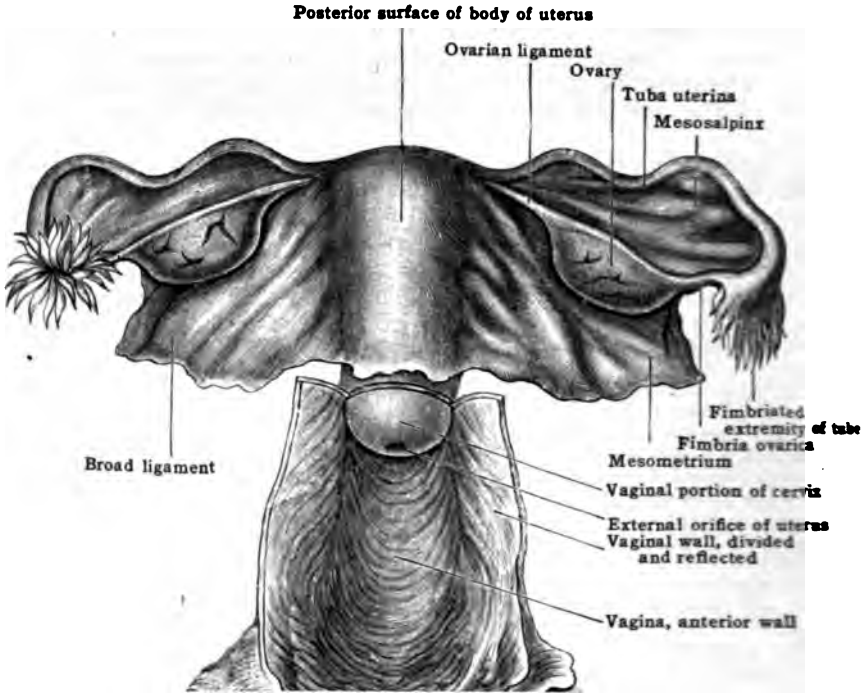
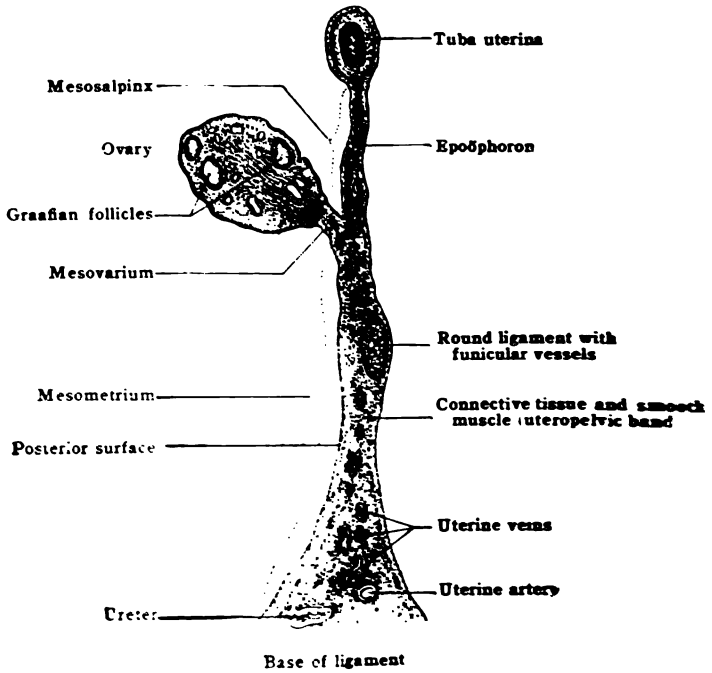


FIG. 1039.—DIAGRAMMATIC SAGITTAL SECTION OF THE BROAD LIGAMENT.

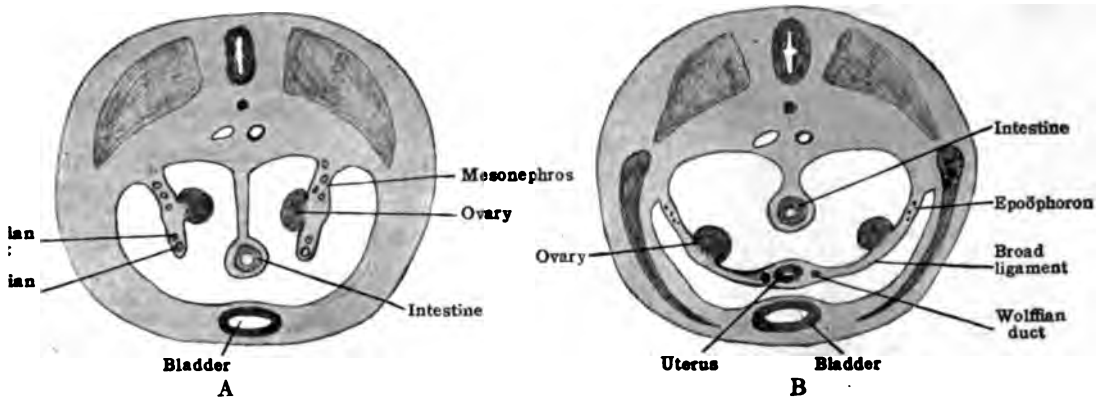


ducts for the conveyance of the ova to 3. the *uterus*, in which the embryo normally undergoes its development; 4. the vagina, a canal by which the ute

is placed in communication with the exterior; and (5) the *external genitalia.* In addition it will be necessary to consider here the female *urethra,* although it differs from that of the male in that it serves merely as a passage for the contents of the bladder and does not transmit the reproductive elements.

Broad ligament.—The ovaries, uterine tubes and uterus are entirely contained within the minor pelvis and are associated with a transverse fold of peritoneum which rises from the floor of the pelvic cavity between the bladder and the rectum, incompletely dividing the cavity into an anterior and a posterior compartment. It is known as the *broad ligament* of the uterus [lig. latum uteri] (figs. 1038, 1039, 1047). The broad ligament appears to extend laterally from the sides of the uterus to the lateral walls and floor of the pelvis, although in reality it extends across the pelvic cavity from side to side and encloses the uterus between the two layers of which it is composed. It is attached to the floor of the pelvis below, where the two layers are reflected, the one upon the anterior wall of the pelvis and the superior surface of the bladder, and the other posteriorly over the floor of the pelvis to the posterior pelvic wall and the rectum, forming the anterior wall of a deep depression between the rectum and uterus, known as the *rectouterine pouch*

FIG. 1040.—CROSS-SECTIONS OF THE BODY ILLUSTRATING THE DEVELOPMENT OF THE FEMALE UROGENITAL SYSTEM. A, AT HIGHER LEVEL. B, AT LOWER LEVEL.



(*of Douglas*) [excavatio rectouterina (cavum Douglasi)] (figs. 1041, 1046). Its lower border is continuous with the lateral borders passing upward upon the sides of the pelvis, resting upon the pelvic fascia. The upper border is free and contains the fundus of the uterus in the midline and the uterine tube on either side. The most lateral portion of the upper border forms the *suspensory ligament of the ovary* (figs. 1041, 1046), through which the ovarian vessels enter the broad ligament.

Attached to the posterior layer of the broad ligament a little below its upper border and therefore projecting into the posterior compartment of the pelvis, there is a horizontal shelf, termed the **mesovarium,** since it has the ovary attached to its free edge (fig. 1039). The portion of the broad ligament above this is known as the **mesosalpinx** (salpinx = tuba), while that below is termed the **mesometrium** (metra = uterus). The remaining structures that occur between the two layers of the broad ligament will be described with the organs with which they are associated, but it is to be noted that the ligament in its upper part is broader than the transverse diameter of the pelvic cavity and its sides are accordingly folded back upon the lateral walls of the cavity, following the course of the uterine tubes.

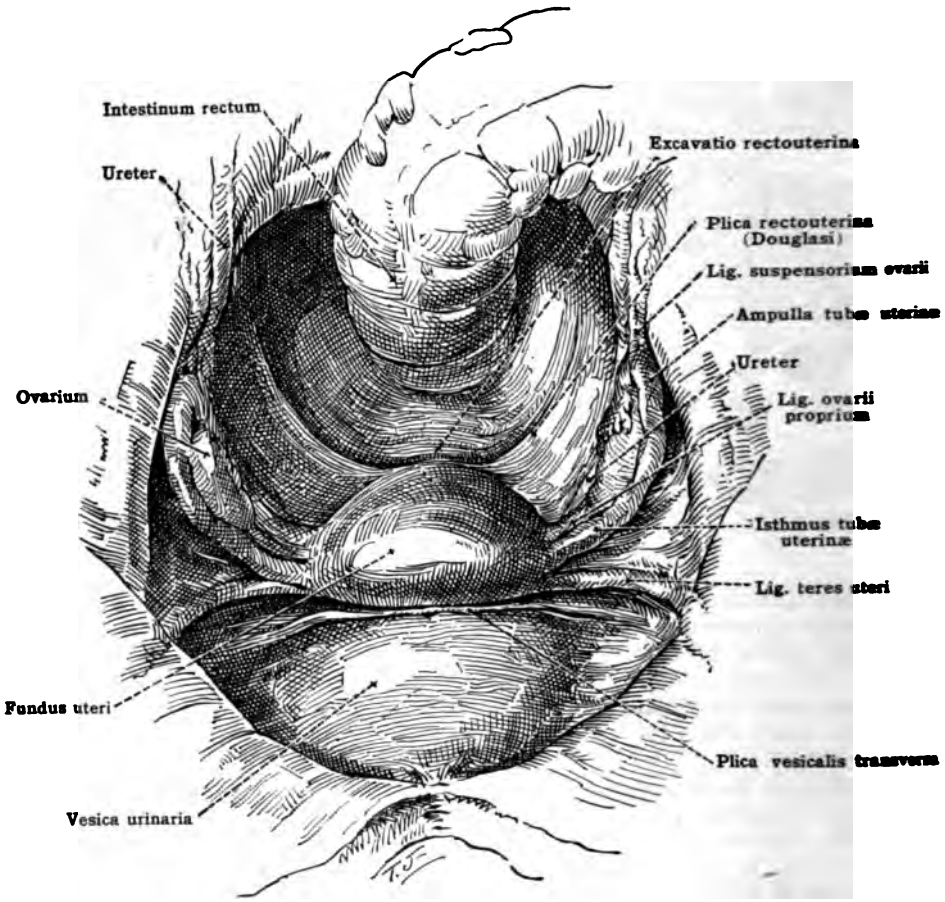
Development.—The broad ligament is the adult representative of the fold of peritoneum which encloses the embryonic excretory organ, the mesonephros. This is for a time a voluminous organ, projecting under cover of the peritoneum from the dorsal wall of the abdomen and bearing upon its medial wall a thickening, the **genital ridge** from which the reproductive gland develops (fig. 1040,A). In the free edge of the peritoneal fold two ducts occur, the **Wolffian duct,** which is the duct of the excretory organ and becomes the ductus deferens of the male, and the **Müllerian duct.** With the progress of development the two Müllerian ducts fuse in the lower portions of their course to form the uterus and vagina (prostatic utriculus of the male), while in their upper parts they remain separate and form the tubæ uterinæ. By this fusion the two peritoneal folds are brought into continuity at their edges, and (the mesonephros de-

generating on the formation of the permanent kidney) constitute the broad ligament (fig. 1040,B). This structure therefore contains between its two layers the uterus and the remains of the mesonephros, and has the ovary attached to its posterior surface. In the male what corresponds to the broad ligament fuses with the peritoneum covering the posterior surface of the bladder.

1. The Ovaries

Form and position.—The *ovaries* [ovaria] (figs. 1038, 1039, 1041, 1046) are two whitish organs, situated one on either side of the pelvic cavity. Each has somewhat the shape of an almond. It is attached by its anterior border [margo mesovaricus] to the border of the mesovarium, and since it is along this line of attachment that the vascular and nerve supply enters the substance of the organ

Fig. 1041.—The Female Pelvic Organs Viewed from Above. (Spaltehols.)



this border is spoken of as the *hilus* [hilus ovarii]. The opposite border is free [margo liber]. The larger rounded end is directed toward the free extremity of the tuba uterina and hence is known as the *tubal extremity* [extremitas tubaria], while the other, the *uterine extremity* [extremitas uterina], is directed toward the uterus; the two surfaces, owing to their topographic relations, are known as the *lateral* and *medial surfaces* [facies medialis et lateralis].

The exact position of the ovary in the pelvis is subject to some variation, but usually it lies almost in a sagittal plane (fig. 1041) against the lateral wall of the pelvis, resting in a distinct depression, the *fossa ovarica*. This fossa is lined by peritoneum and is bounded above by the external iliac vessels and behind by the ureter and uterine artery, while beneath its floor are the obturator vessels and nerve. The long axis of the ovary is almost vertical when the body is erect, the tubal pole being upward; the mesovarial border is directed forward and some-

what laterally, its free border backward and medially, while its surfaces look almost laterally and medially.

Frequently, however, the uterus is displaced to one side, dragging the uterine extremity of the opposite ovary (by the attachment of the ovarian ligament) toward the midplane. The long axis of the ovary thus becomes oblique, approaching more or less the horizontal. The ascending portion of the tuba uterina rests upon its mesovarial border and the fimbriated mouth of the tube is in contact with its medial surface When enlarged the ovary may be felt through the lateral wall of the vagina and, better, through that of the rectum. Its position with regard to the surface may be indicated by a point midway between the anterior superior spine of the ilium and the symphysis pubis or the opposite pubic tubercle.

Ligaments.—In addition to its attachment to the broad ligament through the mesovarium, the ovary is also connected to the side of the uterus by the *ovarian ligament* [lig. ovarii proprium] (figs. 1038, 1040), a band of connective tissue with which numerous smooth muscle-fibers are intermingled. It lies between the two layers of the broad ligament, on the boundary line between the mesosalpinx and the mesometrium, and ex ends from the uterine pole of the ovary to the side of the uterus. Here it is attached just below the origin of the tuba uterina and above the point of attachment of the round ligament of the uterus, with which it is primarily continuous. Another ligament, termed the *suspensory ligament* of the ovary (figs. 1041, 1046), extends laterally between the two layers of the broad ligament, from the tubal extremity of the ovary to the pelvic walls, forming the lateral portion of the free boundary of the broad ligament. It is formed chiefly by the vessels and nerves (ovarian) passing to and from the ovary, and from the point where it meets the lateral pelvic wall it may be traced upward for some distance upon the posterior wall of the abdomen, behind the peritoneum, which it elevates into a more or less distinct fold, whose lateral wall on the right side becomes continuous above with the peritoneum lining the subcecal fossa.

Size.—The size of the ovary varies considerably, that of the right side being as a rule somewhat larger than that of the left. The length may be anywhere from 2.5 to 5.0 cm., the breadth about half the length and the thickness half the breadth. Its average weight in the adult is from 6.0 to 8.0 grams., but in old age it may fall to 2.0 grams.

Structure.—The ovary is covered by a layer of columnar epithelium which is continuous with the peritoneal epithelium along the line of the attachment of the mesovarium; the ovary consequently is not covered by peritoneum, but is rather to be regarded as a local thickening of the peritoneum. It is supported by a network of connective tissue, in which smooth muscle-fibers also occur, which is known as the *stroma*. The more central portions of this are largely occupied by blood-vessels but in the cortical portions are multitudes of immature ova, surrounded by their follicle-cells [folliculi oophori primarii]; and also numbers of cavities of various sizes, lined with follicle-cells and filled with fluid, each containing an ovum [ovulum] in a more or less advanced stage toward maturity. These are the *Graafian follicles* [folliculi oophori vesiculosi (Graafi)], and as they ripen they increase in diameter and approach the surface, upon which they may form marked prominences (fig. 1039). When mature the follicles burst, allowing the escape of the ovum, and the follicle becomes transformed into a *corpus luteum*. This in turn is later replaced by scar-tissue, forming a *corpus albicans*. If the ovum becomes fertilized and pregnancy results, the corpus lutem becomes larger and persists longer.

Epoophoron and paroophoron.—Closely associated with the ovaries are two rudimentary organs situated between the layers of the mesosalpinx and representing remains of the mesonephros of the embryo. The larger of these is the *epoophoron* (fig. 1042). It consists of a longitudinal duct [ductus epoophori longitudinalis (Gartneri)], lying parallel with the tuba uterina and closed at either extremity, and also 10–15 transverse ducts [ductuli transversi] which open into the longitudinal duct. It is the remains of the upper or reproductive portion of the mesonephros and therefore is the homolog of the epididymis of the male. In addition there is frequently to be found in the neighborhood of the epoophoron and close to the mouth of the tuba uterina one or more stalked, oval cysts, the *appendices vesiculosi* (*hydatids of Morgagni*), which may reach the size of a small pea.

The other rudimentary organ is the *paroophoron*. It is much smaller than the epoophoron and usually disappears before adult life, but when present consists of a small group of coiled tubules, more or less distinct, representing a portion of the excretory part of the mesonephros. Its equivalent in the male is therefore the paradidymis.

Vessels and nerves.—The chief *artery* is the ovarian, which together with the ovarian veins and lymphatics passes to the ovary in the suspensory ligament. An additional blood supply is furnished by the ovarian branch of the uterine artery. The *veins* follow the course of the arteries. As they emerge from the hilus they form a well-developed plexus (*pampiniform plexus*) between the layers of the mesovarium. Smooth muscle-fibers occur in the meshes of the plexus and the whole structure has much the appearance of erectile tissue. The *lymphatics* accompany the blood-vessels and terminate in the lumbar nodes. *Nerves* pass to the ovary with the ovarian artery from the ovarian plexus and from the hypogastric plexus.

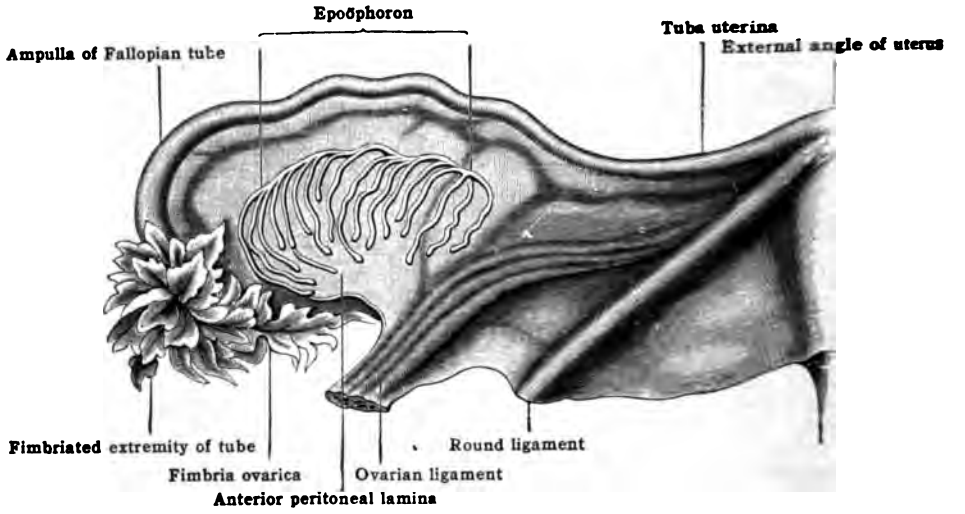
2. The Uterine Tubes

The **uterine** or **Fallopian tubes** [tubæ uterinæ] (figs. 1038 to 1042) serve to convey the ova to the uterus. They are two trumpet-shaped tubes, continuous with the superior angles of the uterus and running in the superior border of the broad ligament (mesosalpinx) to come into relation with the ovaries distally. Each tube opens proximally into the uterine cavity and distally communicates with the pelvic portion of the peritoneal cavity by a funnel-shaped mouth, the

ostium abdominale, which under normal conditions is closely applied to the surface of the ovary, so as to receive the ova as they are expelled from the Graafian follicles. Each tube is from 7 to 14 cm. in length and consists of a narrow straight portion, the **isthmus,** immediately adjoining the uterus, followed by a broader more or less flexuous portion, the **ampulla,** which terminates in a funnel-like dilation, the **infundibulum.** The margins of the infundibulum are fringed by numerous diverging processes, the **fimbriæ,** one of which, the **fimbria ovarica,** is much longer than the rest and extends along the free border of the mesosalpinx to reach the tubal pole of the ovary.

From its attachment to the uterus, the course of each tube is at first almost horizontally laterally and backward until it reaches the lateral wall of the pelvis and there comes into relation with the uterine extremity of the ovary (figs. 1041, 1046). It then bends at right angles and passes upward along the meso-

FIG. 1042.—THE BROAD LIGAMENT AND ITS CONTENTS, SEEN FROM THE FRONT. (After Sappey.)



varial border of the ovary until it reaches its tubal extremity, where it curves downward and backward so that the mouth of the infundibulum and the fimbriæ rest upon the medial surface of the ovary.

Structure.—The tubes occupy the upper free edge of the mesosalpinx and are therefore enclosed within a *peritoneal covering* [tunica serosa] except a small strip along their lower surface (fig. 1039), and hence a rupture of one of them may lead to the escape of its contents either into the peritoneal cavity or into the subserous areolar tissue between the two layers of the broad ligament. At the margins of the infundibulum and the borders of its fimbriæ the peritoneal epithelium becomes directly continuous with the mucous membrane lining the interior of the tube. The *subserous areolar* tissue [tunica adventitia] in the immediate vicinity of the tube is lax and contains the blood-vessels and nerves by which the tube is supplied; it forms a loose connection between the peritoneum and the *muscular wall* [tunica muscularis] of the tube. This consists of two layers of smooth muscle-fibers, an outer longitudinal and an inner circular layer, and reaches its greatest development toward the uterine end of the tube. The inner layer [tunica mucosa] of the tube is lined by a columnar ciliated epithelium which is raised into numerous folds, simple in the region of the isthmus, but becoming higher and more complex in the ampulla, where, in transverse sections, the lumen seems to have a labyrinthine form. The beat of the cilia is toward the uterus.

Vessels and nerves.—The *arteries* of the tubes are derived from the ovarian and uterine, each of which gives off a tubal branch, which passes between the two layers of the mesosalpinx, the one medially and the other laterally, and anastomose to form a single stem. The *veins* accompany the arteries. The *lymphatics* accompany those from the ovary and fundus uteri and terminate chiefly in the lumbar nodes (fig. 627). The *nerves* of the ampulla are given off from the branches passing to the ovary, while those of the isthmus come from the uterine branches.

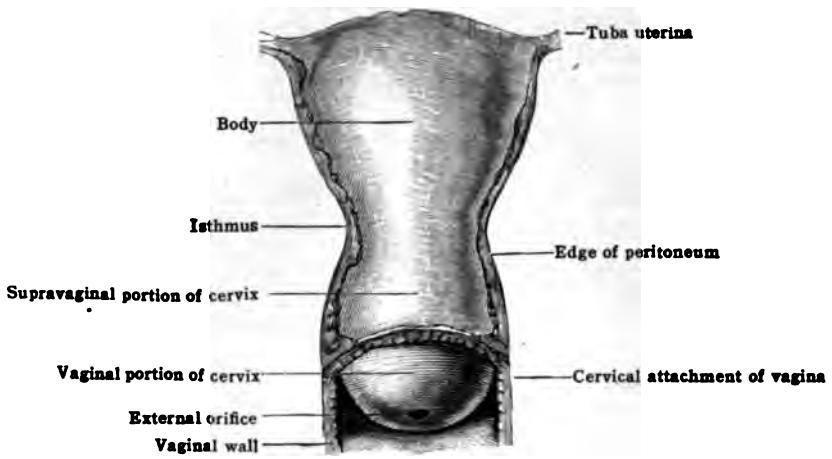
3. THE UTERUS

The **uterus** (figs. 1043 to 1047) is an unpaired organ, situated between the two layers of the broad ligament and communicating above with the uterine tubes and

below with the vagina. It is pyriform in outline, although flattened anteroposteriorly (figs. 1043, 1044) and it is divided into two main portions, the **body** [corpus uteri] and the **cervix,** by a transverse constriction, the **isthmus.**

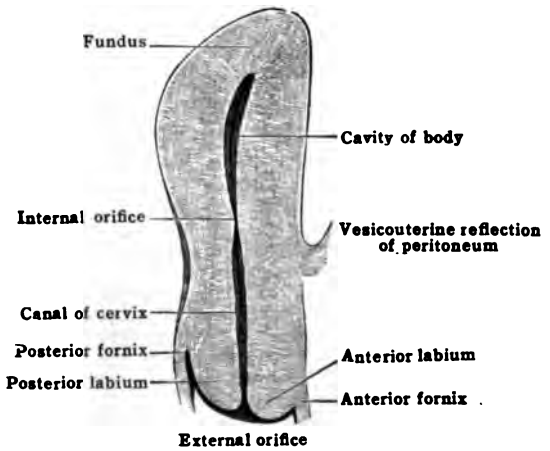
The **body** is the portion above the isthmus and in adults, especially in women who have borne children, is much larger than the cervix, although the reverse is the case in children. At puberty the two parts are about equal in size. The **anterior** or *vesical surface* facies vesicalis] is almost flat (fig. 1044), while the **pos-**

FIG. 1043.—THE POSTERIOR SURFACE OF THE UTERUS. (After Sappey.)



terior or *intestinal surface* [facies intestinalis] is distinctly convex, the two surfaces meeting in well-marked rounded borders, at the upper extremities of which the tubæ uterinæ are attached. The superior portion which extends between the points of attachment of the two tubes is thick and rounded, forming what is termed the *fundus uteri.* The *cavity* [cavum uteri] of the body is flattened anteroposteriorly (fig. 1044) and has a triangular form (fig. 1045), broad above where it communicates on either side with the cavity of a uterine

FIG. 1044.—SAGITTAL SECTION OF THE VIRGIN UTERUS. (After Sappey.)

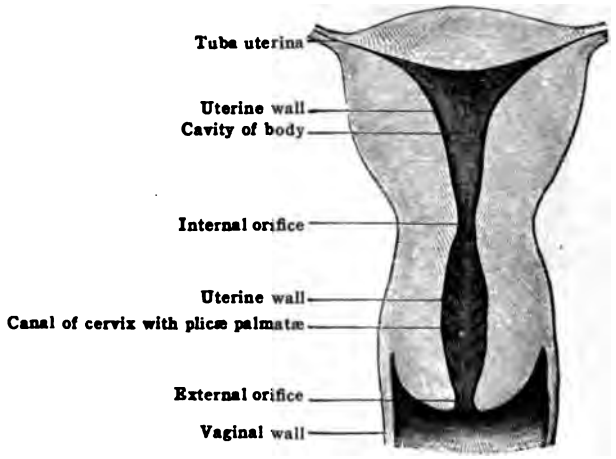


tube, but narrow below where it communicates with the cavity of the cervix. This communication, which corresponds in position to the isthmus, forms what is known as the *internal orifice* [orificium internum] (internal os uteri).

The **cervix** is more cylindrical in form, though slightly expanded in the middle of its length, and is divided into a *supravaginal* [portio supravaginalis] and a *vaginal portion* [portio vaginalis] by the attachment to it of the vagina (fig. 1043). The line of this attachment is oblique, about one-third of the anterior surface of

the cervix and about one-half of the posterior surface belonging to the vaginal portion. At the lower extremity of the cervix is the ***external orifice*** [orificium externum] (external os uteri), which is round or oval before parturition has taken place and is bounded by two prominent ***labia***, anterior and posterior, the anterior [labium anterius] being shorter and thicker than the posterior [labium posterius] and reaching a lower level (figs. 1044, 1046). In women who have borne children the external orifice assumes a form more like a transverse slit, and the labia become notched and irregular. The cavity known as the ***canal of the cervix*** [canalis cervicis] is fusiform in shape, and extends from the internal to the external orifice. On its anterior and posterior walls are folds known as the ***plicæ palmatæ*** (fig. 1045), consisting of a median longitudinal ridge from which shorter elevations extend laterally and slightly upward. These are most distinct in young individuals and are apt to become obliterated by parturition.

FIG. 1045.—FRONTAL SECTION OF THE VIRGIN UTERUS. (After Sappey.)



Position and relations.—The direction of the axis of the uterus is apparently variable within considerable limits, not only in different individuals, but also in any one individual in correspondence with the degree of distention of the bladder anteriorly and of the rectum posteriorly. In what may be regarded as the typical condition (fig. 1046) the external orifice lies at about the level of the upper border of the symphysis pubis and in the plane of the spines of the ischia. From this point the axis of the cervix is directed upward and slightly forward, the lower level of the anterior labium being thus brought about. The entire uterus is, accordingly, anteverted, and, furthermore, the body is bent forward (anteflexed) upon the cervix at the isthmus, the axis of the two portions making an angle, open anteriorly, of from 80° to 120°. Frequently, also, the body is slightly inclined either to the right or to the left.

The anterior surface of the uterus rests upon the upper and posterior surfaces of the bladder (figs. 1041, 1046), from which the body is separated by the uterovesical pouch of peritoneum. The anterior layer of the broad ligament as it passes over the anterior surface of the uterus forms the posterior wall of this pouch and is reflected forward to the superior surface of the bladder at about the level of the isthmus (figs. 1044, 1046), so that the whole of the anterior wall of the cervix is below the floor of the pouch and is separated from the posterior surface of the bladder only by connective tissue. Posteriorly, however, the peritoneal covering of the uterus, which here forms the anterior wall of the rectouterine pouch (of Douglas), extends down as far as the uppermost portion of the vagina and consequently invests the entire surface of the uterus, whose convex posterior wall is thus separated from the rectum by the rectouterine pouch (figs. 1041, 1046). Coils of the small intestine rest upon the posterior surface of the body and may occasionally be interposed between the cervix and the rectum. An important relation is that of the ureters to the cervix; these ducts, as they pass to the bladder, running parallel with the cervix at a distance of from 8 to 12 mm. from it.

Ligaments.—The *broad ligament* between whose layers the uterus is situated has already been described (p. 1297). In addition there is attached to each border of the uterus, immediately below the point of attachment of the ovarian ligament, the *ligamentum teres* (round ligament) (figs. 1041, 1042), which is a fibrous cord

FIG. 1046.—MIDSAGITTAL SECTION OF THE FEMALE PELVIS. (Spalteholz.)

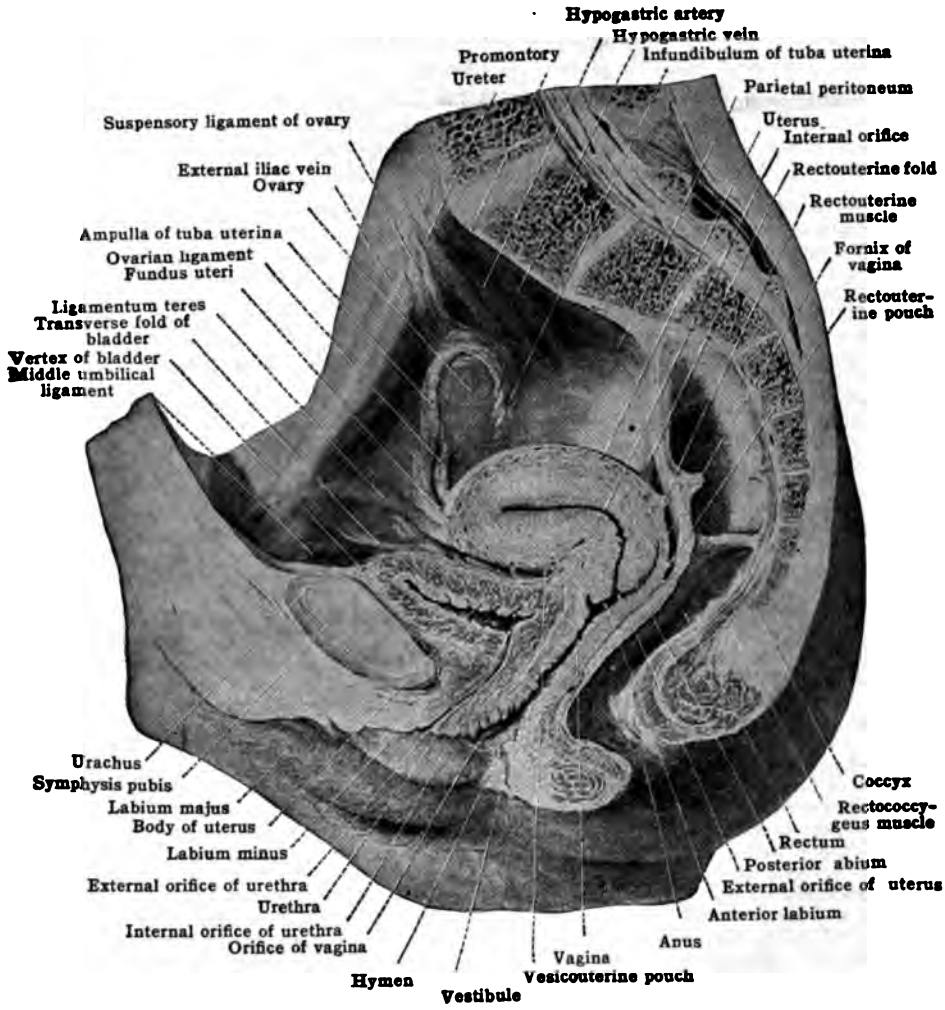
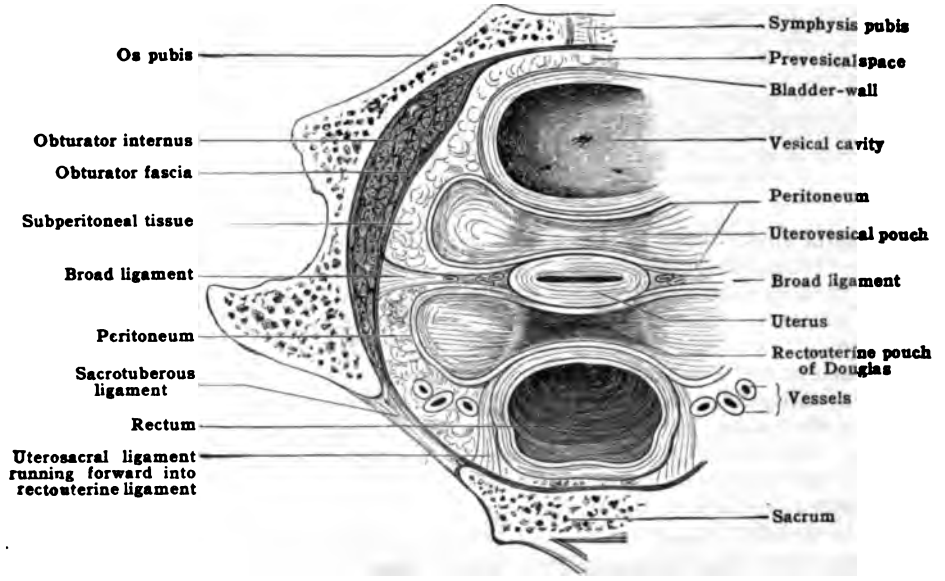


FIG. 1047.—SECTION OF THE PELVIS SHOWING THE LIGAMENTS OF THE UTERUS.



containing smooth muscle-tissue. It extends downward, laterally and forward between the two layers of the mesometrium toward the abdominal inguinal ring, and, traversing this and the inguinal canal, it terminates in the labium majus by becoming continuous with its connective tissue.

It is accompanied by a funicular branch of the ovarian artery and a branch from the ovarian venous plexus, and in the lower part of its course by a branch from the inferior epigastric artery over which it passes as it enters the abdominal ring. In its course through the inguinal canal it is accompanied by the ilioinguinal nerve and the external spermatic branch of the genitofemoral.

The *uterosacral ligaments* (fig. 1047) are flat fibromuscular bands which extend, one on each side, from the upper part of the cervix uteri to the sides of the sacrum opposite the lower border of the sacroiliac articulation. They produce the *rectouterine folds* (fig. 1041) of peritoneum, which form the lateral boundaries of the mouth of the rectouterine pouch (of Douglas) and their muscle-fibers [m. rectouterinus] are continuous at one extremity with the muscular tissue of the uterus and at the other with that of the rectum. The anterior ligament is the vesicouterine fold of peritoneum which is reflected on the bladder from the front of the uterus. The posterior ligament is the rectovaginal fold of peritoneum which is reflected on the front of the rectum from the back of the posterior fornix of the vagina.

Structure.—The portion of the broad ligament that invests the uterus forms the serous covering [tunica serosa] of the organ and is sometimes termed the *perimetrium*. Over the fundus and the greater portion of the body it is thin and firmly adherent to the subjacent muscular substance of the uterus, so that it cannot readily be separated. Over the posterior surface of the cervix and the lower part of the anterior surface of the body, however, it is thicker, and is separated from the muscular substance by a layer of loose connective tissue, the *parametrium*, which also extends upward along the sides of the uterus between the two layers of the broad ligament, with whose subserous areolar tissue it is continuous. Owing to this disposition of the parametrium the whole of the cervix may be amputated without encroaching upon the peritoneal cavity.

The main mass of the uterus is formed by the muscle tissue [tunica muscularis] or *myometrium*, whose fibers have a very complicated arrangement. Two principal layers may be distinguished, an outer, weak one, composed partly of longitudinal fibers continuous with those of the tubæ uterinæ, and of the round and uterosacral ligaments, and a much stronger inner one, whose fibers run in various directions and have intermingled with them in the body of the uterus large venous plexuses. The inner surface of the myometrium is lined by a mucous membrane [tunica mucosa] or *endometrium*, which has a thickness of from 0.5 to 1.0 mm. and is composed of tissue resembling embryonic connective tissue, bearing upon its free surface a single layer of ciliated columnar epithelium. On account of its structure the tissue is rather delicate and friable, and numerous simple tubular glands, which open into the cavity of the uterus, traverse its entire thickness. In the cervix the mouths of some of the glands may become occluded, producing retention cysts, which appear as minute vesicles projecting from the surface between the plicæ palmatæ; they are known as *ovula Nabothi*, after the anatomist who first described them.

Vessels and nerves.—The principal *artery* of the uterus is the uterine, whose terminal portion ascends along the lateral border of the uterus in a tortuous course through the parametrium (fig. 531), giving off lateral branches to both surfaces of the uterus. Above, it anastomoses with the ovarian artery, which thus forms an accessory source of blood supply during pregnancy. The *veins* (fig. 571) form a plexus that is drained by the ovarian and uterine veins, a communication with the inferior epigastric being also made by way of the vein accompanying the round ligament. The *lymphatics* from the greater portion of the body pass to the iliac nodes; those of the fundus accompany the ovarian vessels to the lumbar nodes. A vessel also accompanies the round ligament to terminate in one of the superficial inguinal nodes. The lymph-vessels from the cervix terminate in the external iliac, hypogastric and lateral sacral nodes. The *nerves* of the uterus come from two sympathetic ganglia, situated one on either side of the cervix, whence they are termed the cervical ganglia, and forming part of the *plexus uterovaginalis*. Branches pass to the ganglia from the hypogastric plexus and also from the second, third and fourth sacral nerves.

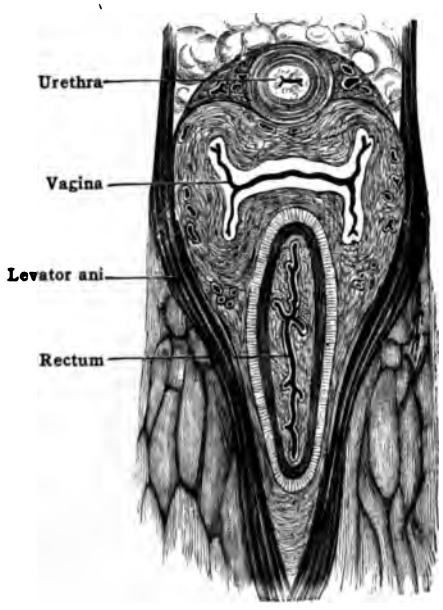
4. The Vagina

The **vagina** (figs. 1046, 1047) is a muscular, highly dilatable canal lined by mucous membrane, and extends from the uterus to the external genitalia, where it opens to the exterior. Its long axis is practically parallel with that of the lower part of the sacrum and it therefore meets the cervix uteri at a wide angle which is open anteriorly. Its anterior wall is, accordingly, somewhat shorter than the posterior, measuring 6.0–7.0 cm., while the posterior one is about 1.5 cm. longer. It becomes continuous with the cervix uteri some distance above the lower extremity of that structure (fig. 1043), which thus projects into the lumen of the vagina; and there is so formed a narrow circular space between the wall of the vagina and the vaginal portion of the cervix uteri. The roof of the space is formed by the reflection of the vagina upon the cervix and is termed the *fornix*. Owing to the greater length of the posterior wall of the vagina the portion of the

circular space below the posterior fornix is considerably deeper than that below the anterior.

In its ordinary condition the lumen of the vaginal canal is a fissure, which in transverse section resembles the form of the letter **H** with a rather long transverse bar (fig. 1048). On both the anterior and the posterior wall there is in the median line a well-marked longitudinal ridge, the *columna rugarum*, which is especially distinct in the lower part of the anterior wall, where it lies immediately beneath the urethra and forms what is known as the *urethral carina*. From both columnæ other ridges pass laterally and upward on either side, forming the *rugæ vaginales*. Both these and the columnæ diminish in distinctness with advance in age and with successive parturitions. Toward its lower end the vagina traverses the urogenital diaphragm, being much less dilatable in this region than elsewhere, and it opens below into the vestibule of the external genitalia. Its orifice is partially closed by a fold of connective tissue, rich in blood-vessels, and lined on both surfaces by mucous membrane. This structure, known as the

FIG. 1048.—HORIZONTAL SECTION OF VAGINA AND ADJACENT STRUCTURES. (After Henle.)



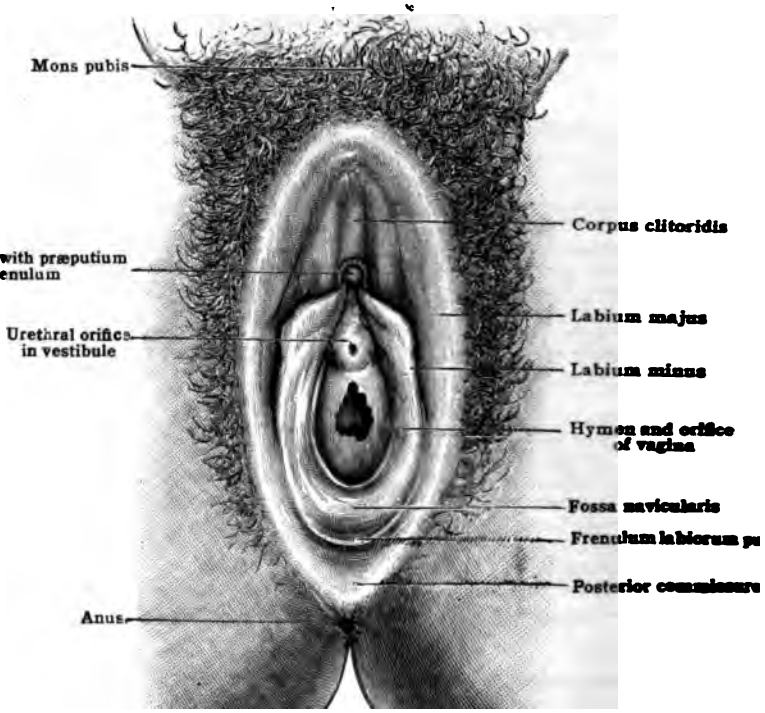
hymen, has usually a somewhat semilunar form, covering the posterior border of the orifice, but it may take the form of a circular curtain pierced by one or several apertures.

The hymen varies greatly in strength and development and although it is nearly always ruptured by the first act of sexual congress, it may remain unbroken until parturition. Rarely it takes the form of a complete imperforate curtain and may necessitate a surgical operation at the commencement of the menstrual periods. After rupture the remains of the hymen persist as small lobed or wart-like structures, the *carunculæ hymenales*, around the vaginal orifice.

Relations.—The uppermost part of the posterior wall of the vagina is in relation with the peritoneum forming the floor of the rectouterine pouch (of Douglas), but elsewhere the canal is entirely below the floor of the peritoneal cavity. *Posteriorly* the vagina rests almost directly upon the rectum (figs. 1046, 1048), and the contents of that viscus may be readily felt through the vaginal wall. *Anteriorly* it is in intimate relation with the urethra and the posterior wall of the bladder (figs. 1046, 1048). *Laterally* it is crossed obliquely in its upper portion by the ureters (fig. 531) as they pass to the base of the bladder, and in its lower two-thirds by the edges of the anterior portion of the levatores ani. The *duct of Gartner*, the remains of the lower portion of the Wolffian duct may occasionally be found at the side of the upper half of the vagina as a minute tube or fibrous cord. The external orifice is surrounded by the fibers of the bulbocavernosus muscle, which may be regarded as forming a sphincter (*sphincter vaginæ*).

The female **external genitalia** [partes genitales externæ] present an el
depression, occupying the perineal region and bounded laterally by two
integument, the *labia majora* (fig. 1049). These anteriorly are continued

FIG. 1049.—THE EXTERNAL GENITALIA OF THE FEMALE.

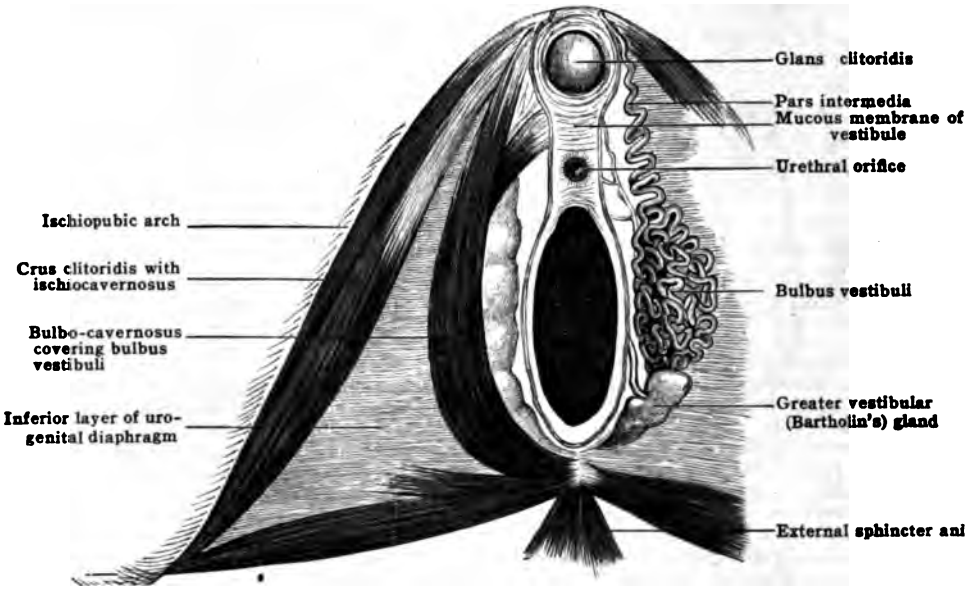


being destitute of hairs and fat. They are usually concealed by the labia majora, but are sometimes largely developed and may then project through the rima pudendi, assuming a dried and pigmented appearance.

The labia minora divide and unite anteriorly over the distal extremity of the clitoris, forming the *præputium clitoridis* in front of the clitoris, and the *frenulum clitoridis* behind it. Posterior to this they diverge and reach their greatest height, gradually diminishing as they pass backward to terminate in a slight, inconstant, transverse fold, the *frenulum labiorum pudendi*, situated just anterior to the posterior commissure of the labia majora. Anterior to the frenulum is the *fossa navicularis* of the vestibule.

The vestibule.—The space between the two labia minora is termed the *vestibule* [vestibulum]. Into its most anterior portion there projects the extremity of an erectile organ, the **clitoris** (fig. 1049), which is comparable to the penis of the male. It is, however, relatively small and is not perforated by the urethra, which lies below it. It is composed of two masses of erectile tissue, the *corpora cavernosa clitoridis*, which differ from the corresponding structures of the penis only in size. They are attached posteriorly to the rami of the pubis by the *crura clitoridis* (fig. 1050), and as they pass forward they converge and meet to form the body of the organ [corpus clitoridis], which, beneath the symphysis pubis, bends sharply

FIG. 1050.—DIAGRAMMATIC REPRESENTATION OF THE PERINEAL STRUCTURES IN THE FEMALE.



upon itself and passes posteriorly beneath the anterior commissure of the labia majora. Distally the corpora cavernosa abut upon another mass of erectile tissue, which fits like a cap over their extremities; it is formed by an anterior prolongation of the bulbi vestibuli and is termed the *glans clitoridis* (figs. 1049, 1050), being comparable to the glans penis, from which it differs chiefly in not being perforated by the urethra.

A short distance posterior to the glans clitoridis is the *external urethral orifice* [orificium urethræ externum], situated upon the summit of a slight papilla-like elevation. Lateral to this orifice are sometimes found the openings, one on either side, of two elongated slender ducts, the *paraurethral ducts* (ducts of Skene). More posteriorly is the orifice of the *vagina* [orificium vaginæ], partially closed in the virgin by the *hymen*. Lateral to this, in the angles between the hymen and the labium minus on either side, is the opening of the greater vestibular gland, while the lesser glands open at various points on the floor of the vestibule, sometimes at the bottom of more or less distinct depressions.

Beneath the floor of the vestibule and resting upon the superficial layer of the urogenital diaphragm are two oval masses of erectile tissue, the *bulbi vestibuli* (fig. 1050), homologous with the corpus cavernosum urethræ of the male. They consist principally of a dense venous network, enclosed within a thin investment of

connective tissue. From the main mass of each bulbus a slender prolongation the *pars intermedia*, extends anteriorly past the side of the urethra, to join the glans clitoridis.

The *greater vestibular glands* [gl. vestibularis major (Bartholini)] or glands of Bartholin (fig. 1050) correspond to the bulbourethral glands of the male. They are two small, compound tubular glands, situated one on either side immediately posterior to the bulbi vestibuli.

The single *duct* of each gland opens on the floor of the vestibule in the angle between the hymen and the orifice of the vagina and a little posterior to the midtransverse line of the latter. Numerous small tubular glands occur in the integument forming the floor of the vestibule; they are termed the *lesser vestibular glands* and are especially developed in the interval between the urethral and vaginal orifices.

The **muscles** of the female external genitalia (fig. 1050) correspond to the perineal muscles of the male (see Section IV). There are two *transverse perineal* muscles, which have the same relations as in the male, and two *ischiocavernosi*, which are related to the crura clitoridis just as those of the male are to the crura penis. The *bulbocavernosi*, however, present somewhat different relations, each being band-like in form, arising from the central point of the perineum and extending forward past the orifice of the vagina, over the greater vestibular gland and the bulbus, to form with its fellow of the other side a tendinous investment of the body of the clitoris. The two muscles act as a sphincter to the vagina and are sometimes termed the *sphincter vaginæ*.

The urethra.—The urethra of the female [urethra muliebris] (figs. 1046, 1048) corresponds only to the prostatic and membranous portions of the male, and is a relatively short canal, measuring from 3.0 to 4.0 cm. in length. At its origin from the bladder it lies about opposite the middle of the symphysis pubis and thence extends downward and slightly forward to open into the vestibule between the glans clitoridis and the orifice of the vagina. Its posterior wall is closely united with the anterior wall of the vagina, especially in the lower part of its course where it forms the *urethral carina* of the vaginal wall; laterally and anteriorly it is surrounded by the pudendal plexus of veins. Above it is separated anteriorly from the symphysis pubis by the lower part of the prevesical space of Retzius.

Structure.—Its walls are very distensible, and are lined by a mucous membrane with numerous longitudinal folds, one of which on the posterior side is more prominent and is termed the *crista urethralis*. The mucosa contains numerous small glands [gl. urethrales], a group of which on each side is drained by the inconstant *ductus paraurethralis*, opening into the vestibule as mentioned above. External to the loose submucosa is a sheet of smooth muscle, whose fibers are arranged in an outer circular and an inner longitudinal layer, a rich plexus of veins lying betwen the two and giving the entire sheet a somewhat spongy appearance. The circular fibers are especially developed at the vesical end of the canal, forming there a strong sphincter, and striped muscle-fibers, derived from the bulbocavernosus form a sphincter around its vestibular orifice. The female urethra differs from that of the male in not being enclosed within a prostate gland; but what are probably rudiments of this structure are to be found in the groups of urethral glands drained by the paraurethral ducts.

Vessels and nerves.—The *arteries* supplying the external female genitalia are the internal and external pudendals, and the *veins* terminate in corresponding trunks. The *lymphatics*, which are very richly developed, drain for the most part to the inguinal nodes; those from the urethra pass to the iliac nodes. The *nerves* are partly sympathetic and partly spinal; the former are derived from the hypogastric plexus, the latter principally from the pudendal, the anterior portions of the labia majora being supplied by the ilioinguinal and the external spermatic branch of the genitofemoral.

DEVELOPMENT OF THE REPRODUCTIVE ORGANS

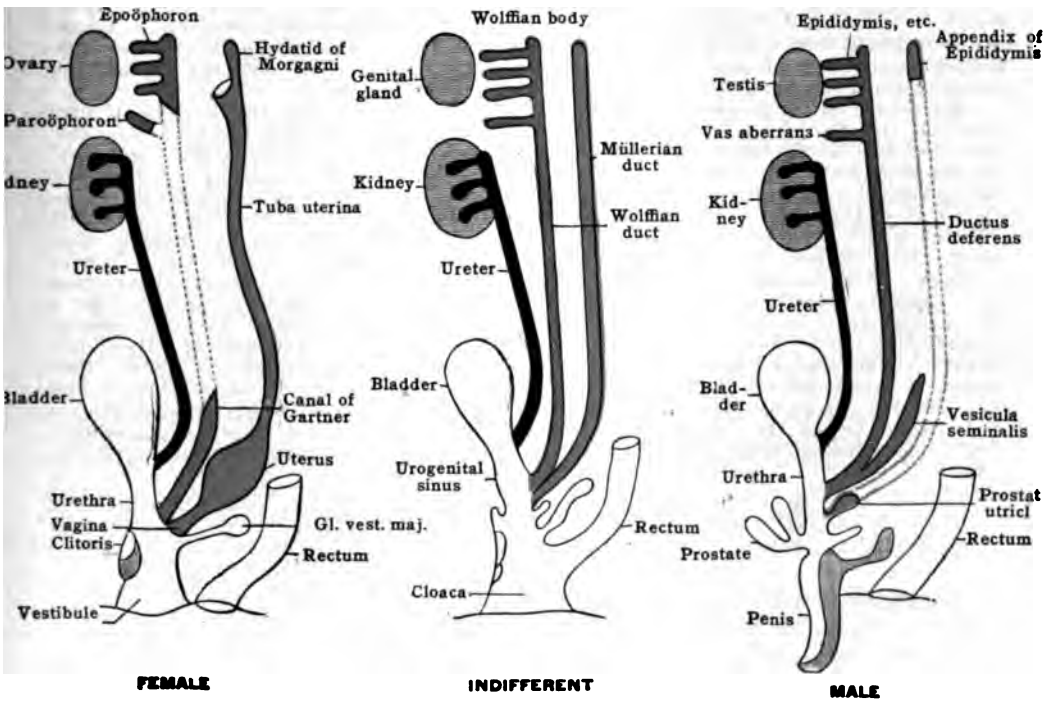
An account of the development of the urogenital tract in the two sexes is given in the section on DEVELOPMENTAL ANATOMY (pp. 52, 53). As also mentioned on p. 50, during development a transitory excretory organ, the **mesonephros** or **Wolffian body**, reaches a high degree of development, and its duct, the **Wolffian duct**, opens into a **cloaca** or **common outlet** for the intestinal and urinary passages. The mesonephros forms a marked projection from the dorsal wall of the abdomen into the body-cavity, and on the medial surface of the peritoneum which covers it a thickening appears which is termed the **genital ridge**. The upper part of this ridge becomes the ovary or testis, as the case may be, while the remainder of it becomes the ovarian and round ligaments in the female and the gubernaculum testis in the male.

As the ovary or testis develops, the tubules of the upper part of the **Wolffian body** enter into relation with it, forming, indeed, in the case of the testis, a direct union with the seminiferous tubules. The Wolffian body then becomes divisible into a reproductive and an excretory portion, and, when the metanephros or permanent kidney develops, the latter portion degenerates, leaving only a few rudiments, such as the paroöphoron in the female (p 1299) and the

vas aberrans and paradidymis (p. 1286) in the male. The reproductive portion also becomes much reduced in the female, persisting as the tubules of the epoöphoron (p. 1299), but in the **male** it forms the lobules of the epididymis and serves to transmit the spermatozoa to the **Wolffian** duct.

In addition to the Wolffian duct, a second duct, the **Müllerian,** occurs in connection with the genitourinary apparatus, and, like the Wolffian duct, it opens below into the cloaca. The **history** of the two ducts is very different in the two sexes. In the **male** the Wolffian duct persists to form the vas deferens, of which the seminal vesicle is an outgrowth and the ejaculatory duct the continuation, while the Müllerian duct degenerates, its lower end persisting as the prostatic utriculus and its upper end as the appendix of the epididymis. In the **female,** on the contrary, it is the Müllerian duct which persists, its lower portion fusing with the duct of the opposite side to form the vagina and uterus, while its upper portion forms the tuba uterina. Inhibition of the fusion of the lower ends of the two Müllerian ducts gives rise to the bicornuate or divided uteri, or the bilocular uteri and vaginæ which occasionally occur. The Wolffian duct in the female almost completely disappears, persisting only as the longitudinal tube of the epoöphoron and as the rudimentary canal of Gartner (p. 1299). With the degeneration of the mesonephros, the peritoneum which covered it becomes a thin fold, having in its free edge the Müllerian duct and, on the fusion of the lower ends of the ducts, the two folds also fuse and so give rise to the broad ligament.

FIG. 1051.—DIAGRAM OF HOMOLOGIES IN UROGENITAL DEVELOPMENT.



The developmental relations of the male and female organs may be seen from figure 1051 and also from the following table:—

	MALE	FEMALE
Genital ridge	Testis	Ovary
	Gubernaculum testis	Ovarian ligament / Round ligament
Wolffian body (Mesonephros)	Head of epididymis	Epoöphoron
	Paradidymis	Paroöphoron
	Vas aberrans	
Wolffian duct	Body and tail of epididymis	Longitudinal tubule epoöphoron
	Ductus deferens	Canal of Gartner
	Ejaculatory duct	
Müllerian duct	Appendix of epididymis (?)	Uterine (Fallopian) tube
		Uterus
	Prostatic utriculus	Vagina

The development of the external organs of generation in the two sexes presents a similar differentiation from a common condition. The division of the cloaca to form a **urogenital sinus** and the terminal part of the rectum has already been noted (p. 1283). In the floor of the

	MALE	FEMALE
Urogenital sinus	Cavernous portion of urethra	Vestibule
Genital tubercle	Penis	Clitoris
Genital folds	Integument and prepuce of penis	Prepuce of clitoris and labia
Genital swellings	Scrotum	Labia majora

Inhibition of the development of the parts in the male or their over-development female will produce a condition resembling superficially the normal condition of the o sex, and constituting what is termed *pseudohermaphroditism;* or a failure of the genital to fuse may result in what is known as *hypospadias*, the cavernous portion of the urethr merely a groove on the under surface of the otherwise normal penis.

References for the urogenital system. A. **Urinary tract.** (*General, incl. literature t* Disse, in von Bardeleben's Handbuch; Hart, Jour. Anat. and Physical, vol. 35; Lewis Rec., vol. 9; (*Renal blood-vessels*) Brödel, Proc. Ass'n Amer. Anatomists, 1901; Oppe Frankf. Zeitschr. f. Path., Bd. 21; (*Renal tubules*) Huber, Amer. Jour. Anat., vol. 4; Pet Nierenkanälchen, etc., Jena, 1909; (*Topography of female ureter*) Tandler u. Halban, Mon Geburtsh. u. Gynäk., Bd. 15. B. **Male reproductive tract.** (*General, incl. literature t* Eberth, in von Bardeleben's Handbuch; (*Histology and development*) von Lichtenberg. Hefte, Bd. 31; Hill, Amer. Jour. Anat., vol. 9; (*Prostate*) Bruhns (*lymphatics*) Arch. f. u. Entw., 1904; Ferguson (*Stroma*) Anat. Rec., vol. 5; Thompson (topography) Jour. and Physiol., vol. 47; (*External genitals*) Forster, Zeitschr. f. Morph. u. Anthrop., Henneberg, Anat. Hefte, Bd. 50, 55; Thompson, Jour. Anat. and Physiol., vol. 53; C. I **reproductive tract.** (*General, incl. literature to* 1896) Nagel, in von Bardeleben's Hand Waldeyer, Das Becken, Bonn, 1899; (*Lymphatics*) Bruhns, Arch. f. Anat. u. Entw., Polano (*ovary*) Monatschr. Geburtsh. u. Gynäk., Bd. 17; (*Nerves*) Roith, Arch. f. Gynä 81; (*Histology, ovary*) von Winiwarter, Anat. Anz., Bd. 33; (*Development, uterus*) Hegar, B Geburtsh. u. Gynäk., Bd. 13; Stratz, Zeitschr. Geburtsh. u. Gynäk, Bd. 72; (*Lig. teres*) Se Beitr. z. Geburtsh. u. Gynäk., Bd., 4, 1901; *Hymen*, Kustner, Zeitschr. f. Geb. u. Gynäk., I

SECTION XIII

THE GLANDS OF INTERNAL SECRETION

REWRITTEN FOR THE SIXTH EDITION

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TO the group of the **glands of internal secretion** belong a number of rather small organs, which have certain physiological and histological features in common, although anatomically they do not compose a well defined system. These glands are located in widely scattered regions of the body and are derivatives of such different organ-systems, derived from all three embryonic layers, that in text-books of anatomy their grouping together in a separate chapter is mainly upon a physiological basis. Although each of these glands serves its specific purposes, most of them as yet little understood, their *method* of functioning seems to be rather uniform. It is also well known that at least some of these glands have definite chemical relations to each other; so that, physiologically, they doubtless form a system of interdependent units. This interdependence goes so far, that during the processes of development, growth and differentiation, the well regulated interaction of these glands brings about the formation of the normal organism. Furthermore, although without any anatomical relationship, they have, in their finer structure, certain rather striking characteristic features in common, which justify their grouping as a separate system of organs.

1. Being glandular organs, they all (with the possible exception of the interstitial cell-complex of the sex-glands) develop from epithelium. Their physiologically active stratum is therefore of an epithelial or, at least, epithelioid nature. Only one of them, the thyroid, possesses a definite, uniform arrangement of these epithelial cells, while in the other glands we find a rather irregular distribution of these cells in the form of cords, trabeculæ, clusters, etc.

2. The epithelial cells lie in very close approximation to the endothelial cells of the blood- and lymph-channels. The vascular supply of these organs is extremely abundant, the vessels in many of them forming dense sinusoidal plexuses around the epithelial structures.

3. They are *ductless glands* having no excretory duct. Their secretion is carried from the epithelial through the endothelial cells directly into the vascular channels. They are, therefore, glands of *internal* secretion. The absence of a duct, however, is probably only a secondary, phylogenetically acquired feature. We have very good reasons to believe that in the extinct vertebrates (attempts have been made to trace these glands even to the invertebrates) all these structures *did* possess an excretory duct and were thus glands of *external* secretion. In the ontogeny of some of these glands, we still see the anlage of a definite outleading canal, which, however, normally retrogresses.

After further research into the physiology of the ductless glands it will perhaps be possible to place these organs in several groups, such as: (*a*) those that exert their influence mainly upon the growing and differentiating organism; (*b*) those, the action of which is chiefly concerned in regulating the metabolic process of the body; etc. Also the different periods in the life-cycle at which these glands exert their greatest influence have to be taken into account. At present, we can say that the greater number of these glands probably serve both purposes mentioned above, either synchronously or at successive periods. In the latter instance a change of function, or the assumption of an additional function, sets in as the individual goes through the period of differentiation into that of adolescence and maturity (thyroid, hypophysis, etc.). Other glands are glands of a specific developmental period (thymus in the young, sex-gland in the adult), etc.

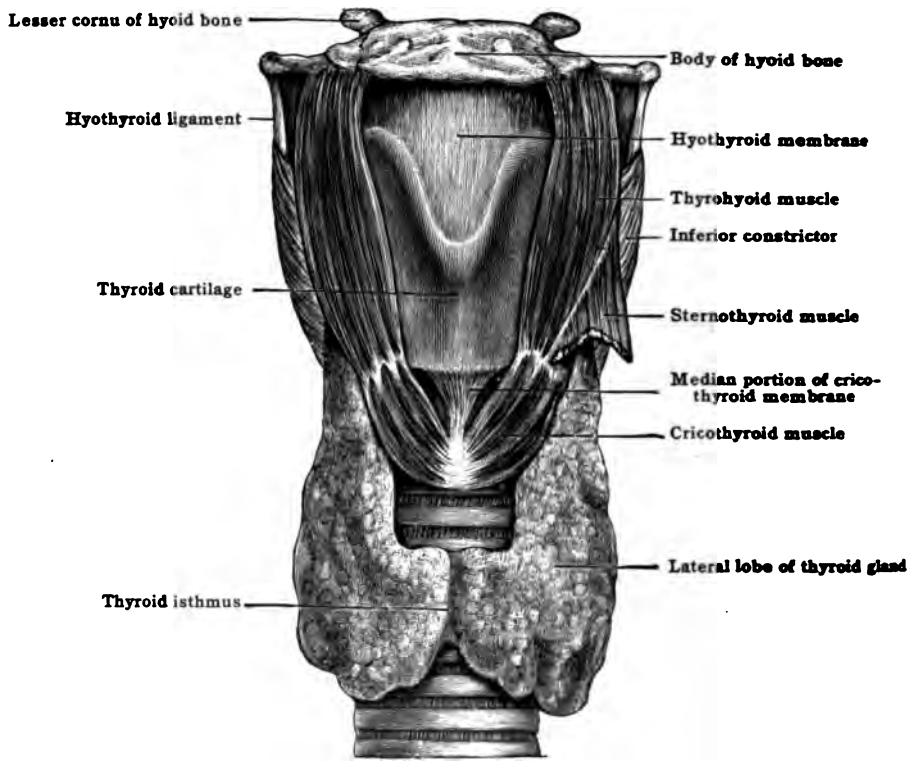
We may also say that *correlation* is most typically shown in the group (*a*) concerned in the processes of differentiation. Several glands of this group may act harmoniously, or one may supersede the work of the other. In the other group, too, the 'metabolic group' (*b*), interaction is distinctly traceable, especially when the chemical processes do not proceed satisfactorily; for instance, disturbances are shown in the hypophysis and thyroid, when the sex-gland is under strain, as in pregnancy; or disorders of the pancreatic islands and the hypophysis in disturbed carbohydrate metabolism; etc. The parathyroids and the chromaffin system seem to stand more aloof from the rest than any other of the ductless glands, although a possible rôle of the suprarenals during development cannot be excluded *a priori*.

To the system of the organs with an internal secretion must be added a number of structures provided with the same physiological mechanism, yet of no definite gross anatomical characteristics, (pancreatic islands, interstitial cell-complex of the sex-glands, corpus luteum, and organs which mainly function in another direction (sex-glands liver, digestive glands (?), placenta, mammary glands, etc.). All such structures are discussed under their respective systems.

THYROID GLAND

The **thyroid gland** [glandula thyreoidea] (fig. 1052) has approximately the form of a horse-shoe, the two lateral portions of which are usually more pronounced than the median connecting piece. These **lateral lobes** are somewhat asymmetrical in size and shape, while their connecting piece, the **isthmus,** varies considerably in size in different individuals. It may be entirely absent, or in other cases

FIG. 1052.—VENTRAL VIEW OF THE THYROID GLAND.

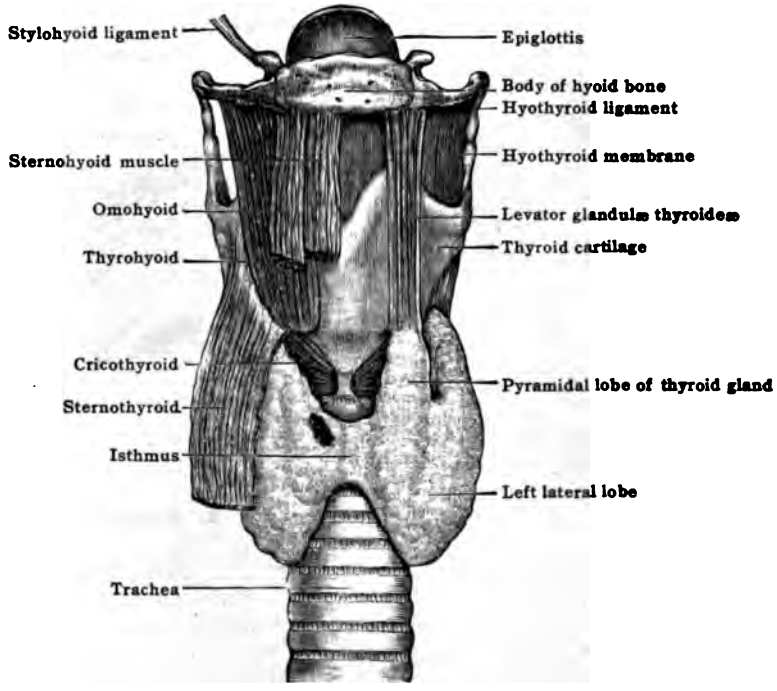


it may represent a considerable portion of the total mass of the organ. In the latter case, it may extend out into a strip which runs for a shorter or longer distance cephalad between the two lateral portions. This short lobe of the thyroid gland usually has the shape of a pyramid, the broad base being represented by the isthmus, while it tapers toward the cephalic end. It is called the **pyramidal lobe** (fig. 1053). The main lateral lobes also somewhat resemble three-sided pyramids, their bases occupying the caudal end, merging there into the isthmus, while the somewhat rounded apex forms the cephalic end. The three surfaces of each lateral lobe (fig. 1054) are: (1) the *lateral* surface, by far the largest, which is somewhat convex and is covered by certain muscles of the neck; (2) the *medial* surface, rather concave, since it is closely applied to the convex surfaces of the

thyroid, cricoid, and tracheal cartilages; and (3) the *posterior* surface, the smallest one, rather flat, facing the great vessels of the neck. The three borders of the lateral lobe are somewhat rounded off. The apex of the lobe lies more dorsally than the base.

The two lateral lobes (figs. 1052, 1053, 1055) are present in the greater number of individuals, although there may at times appear a decided asymmetry in the size and shape of these lobes. The median portion, the **isthmus,** however, is extremely variable in expansion. In a few individuals it is rudimentary or lacking entirely. When well developed (figs. 1052, 1053), it usually does not occupy an extreme caudal position, so that the shape of the entire organ is more that of an 'H' than of a horse-shoe, 'U'. Due to its relations the ventral surface of the isthmus is somewhat convex, while the dorsal one is distinctly concave. In some cases the isthmus is rather voluminous and it may then represent the greater portion of the gland (arrested morphogenesis, see below), while the lateral lobes may be small, or one or the other entirely absent.

FIG. 1053.—THYROID GLAND, WITH PYRAMIDAL LOBE AND LEVATOR MUSCLE.



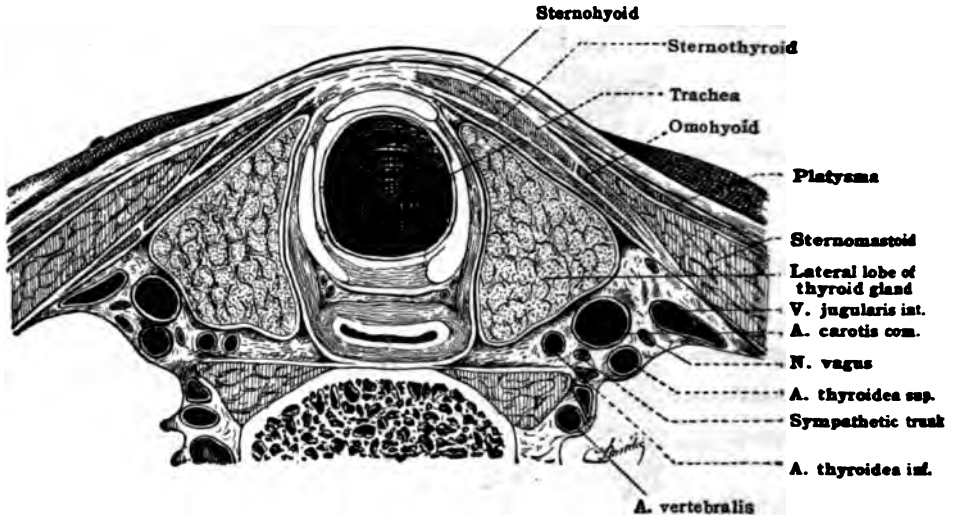
The greatest degree of variation is shown in the size and extension of the so-called **pyramidal lobe** of the thyroid gland (pyramid of L'Alouette, 1743). This pyramidal lobe (figs. 1053, 1055, 1056) usually has the shape of a rather narrow strip, broader at its basal end and tapering toward its cranial apical end. It commonly arises from the isthmus, but may at times be attached to the caudal region of either of the lateral lobes. It may extend as far craniad as the hyoid bone, although more often it ends in the neighborhood of the thyroid cartilage. It usually lies somewhat to the left of the midline and is present in about one-third of the cases.

Size.—The size and weight of the gland are subject to considerable variation. It is next to impossible to give exact measurements, since the line between normal, well developed, and abnormal, hypertrophied, glands is indefinite. In women it enlarges at puberty and is especially liable to periodical changes, its size increasing somewhat during menstruation and considerably so during pregnancy. In older persons the gland decreases in size, due to the partial replacement of the epithelial structures by connective tissue (fibrosis). Especially the pyramidal lobe seems to undergo a gradual physiological atrophy. It is more often found in children than in the adult. The length of the lateral lobes is variously given as ranging from 5 to 8 cm., the width 2 to 4 cm., the thickness 1 to 2.5 cm. The average weight of the gland is given as 34 g. with a range from 11 to 60 g. Racial and geographical differences are considerable. In women the gland is always larger and heavier than in men, a difference not apparent in infants. The gland readily becomes hypertrophied, especially in women, and is apt to undergo pathological changes (goiter or struma). A congenital struma may be found in children of affected mothers, especially in regions where endemic goiter prevails.

The **color** of the thyroid gland is reddish-brown, but may at times become rather bluish. The **consistency** is rather firm, but slightly compressible, the degree of rigidity depending on the physiological state of the gland. The surface of the gland is smooth or slightly uneven.

The thyroid gland is surrounded by a white fibrous connective tissue sheath, which is a part of, and in close connection with, the deep fascia of the neck. According to Sébileau (quoted from Sobotta), the deep fascia of the neck, near its insertion on the lateral vertebral process, gives off a layer, the so-called transverse aponeurosis of the neck. As this approaches the area of the carotid artery, jugular vein and vagus nerve, it splits into two layers, surrounding these structures as the carotid sheath. Medially to the vessels, these two layers do not re-unite; the posterior one is continued behind the pharynx, and fuses with the corresponding layer of the opposite side; the anterior, pretracheal layer forms the thyroid sheath. As it reaches the lateral margin of the gland, it splits into two secondary lamellæ, the anterior one being continued over the lateral and anterior surface of the gland, enclosing partly the inferior thyroid veins, while the posterior one is closely applied to the wall of the trachea. Thus the gland is completely surrounded by its sheath, which is more or less loosely attached to the

FIG. 1054.—CROSS-SECTION OF NECK SHOWING RELATIONS OF THE THYROID GLAND. (After Braune, from Poirier-Charpy.)



surface, so that the gland may easily be shelled out. Finer fibrous trabeculæ connect the sheath with the surface of the organ. This sheath must not be mistaken for the capsule proper of the gland, which can be torn away only by force, since its tough connective tissue is continued into the interior of the gland. There is an interval between the capsule and the sheath, which is traversed by the arteries. The veins also form plexuses in this space (figs. 1055, 1056).

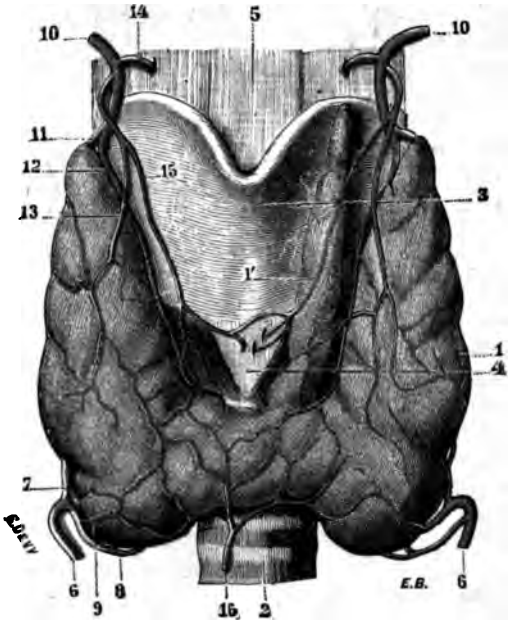
Three suspensory ligaments of the thyroid gland are described (by Gruber), attaching the dorsal surface of the fibrous sheath to the neighboring cartilages: a median, running from the ventral surface of the thyroid cartilage to the dorsal aspect of the isthmus, and two lateral ligaments, attaching the basal portions of the lateral lobes to the tracheal and cricoid cartilages. There may be a fourth ligament, connecting the cranial tip of the pyramidal lobe to the thyroid cartilage or even to the hyoid bone. A muscular band [levator glandulæ thyroideæ] may take the place of this ligament (fig. 1053). A number of other levator muscles have been described, which are simply bundles split off from the neighboring muscles, thyrohyoid, sternohyoid, constrictor pharyngis inferior, etc.

Topography.—The thyroid gland lies ventrally to the trachea in the mid-portion of the neck. A well-developed pyramidal lobe may extend into the subhyoid or even hyoid region (fig. 1056). The isthmus and pyramidal lobe occupy a ventral, superficial position, while the lateral lobes extend back into a more dorsal, deeper area. The isthmus usually covers the second to the fourth tracheal ring. It may, however, reach as high as the cricoid cartilage and then cover the cricotracheal ligament, or as low as the eighth tracheal cartilage. In the midline, the isthmus and pyramidal lobe are covered by the skin and superficial and deep (pretracheal) layers of the fascia only. The lateral lobes lie in the main on the sides of the cricoid and thyroid cartilages and may extend to the fifth or sixth

tracheal ring, about 2 cm. above the sternum. The cranial apices of these lobes may come in contact with the esophagus and pharynx. Their more dorsal position is due to the insertion on the thyroid cartilage of the sternothyroid muscle (fig. 1053). Their anterolateral surface is covered directly by this muscle: more superficially lie the thyrohyoid, omohyoid, sternohyoid, and sternocleidomastoid muscles. The medial surface is applied to the trachea and deeper in to the esophagus (fig. 1054). The position of the recurrent nerve in that region is of surgical importance. The posterior surface lies close against the carotid sheath. Sometimes the common carotid artery makes an impression on that surface. Even the vagus may come in contact with it. The attachment to the pharynx, esophagus and larynx is rather loose, while that to the trachea, especially laterally, is firmer.

Blood-vessels.—The blood-supply of the thyroid gland is extremely abundant. There are usually four arteries (fig. 1055) present: the two superior thyroid arteries, branches of the external carotid artery, and two inferior thyroid arteries, branches of the subclavian artery, or of the thyrocervical trunk. Not uncommonly, a fifth unpaired artery is present, the *thyroidea ima* artery.

FIG. 1055—ARTERIES OF THE THYROID GLAND, ANTERIOR VIEW. 1. Lateral lobe; 1, pyramidal lobe; 2, trachea; 3, thyroid cartilage; 4, cricothyroid membrane; 5, hyothyroid membrane; 6, 7, 8, 9, inferior thyroid artery and branches; 10, 11, 12, 13, 14, 15, superior thyroid artery and branches; 16, thyroidea ima. (Testut and Jacob.)



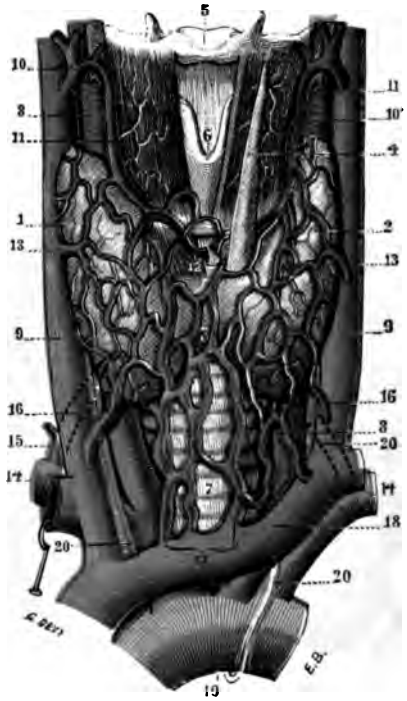
The **superior thyroid artery** (figs. 491, 1055) usually divides into three branches, one coursing over the anterolateral surface, one running along the anterior border to the isthmus, and there anastomosing with its mate of the opposite side, and one spreading over the upper part of the medial surface. The pyramidal lobe is supplied from the second branch. The **inferior thyroid artery** (figs. 491, 1055, 1057) usually has two branches, one running along the inferior border of the lateral lobe to the dorsal aspect of the isthmus and there anastomosing with its partner from the opposite side, the other one supplying the lower region of the dorsal and medial surfaces of the lateral lobes. A third one may establish an anastomosis with the superior branches. In the region of the isthmus there is usually found an anastomosis of all four or five thyroid arteries. The unpaired **thyroidea ima** artery arises from the aortic arch or the innominate artery, ascends ventrally to the trachea somewhat on the right side, until it reaches the isthmus, where it anastomoses with the others (figs. 487, 1055). These arteries send their branches directly into the substance of the gland, the primary ones running in the connective tissue septa, which extend from the capsule into the interior.

The **veins** emerging from the gland form on the anterolateral surface a veritable plexus (fig. 1056) from which arise: the **superior th roid veins,** tributaries to the internal jugular or more often to the common facial vein; the **median thyroid veins,** tributaries to the internal jugular vein; the **inferior thyroid veins,** draining lower down into the jugular or innominate vein; and occasionally, the unpaired **thyroidea ima vein,** draining into the left innominate vein or the venous angle.

Lymphatics.—Of great importance is the lymph-circulation of the thyroid gland, corresponding to the inferior and superior blood-supply. Bartels describes a superior and inferior area of lymphatic drainage, each area supplying medial and lateral channels. The medial superior channels drain the cranial border of the isthmus and the medial surfaces, the lateral superior channels drain the ventral and dorsal surfaces. Both groups run into the deep cervical lymph-nodes. The medial inferior channels drain the isthmus and medial portions of the lateral lobes and run into the pretracheal and paratracheal nodes; the lateral inferior vessels drain the lateral inferior portions and run into the supraclavicular nodes. The lymph-nodes of the thyroid gland, which are surgically important, are, therefore: the deep cervical nodes (superior, as well as supraclavicular), the prelaryngeal, the pretracheal and paratracheal, sometimes also the upper mediastinal nodes. (See p. 75.)

Nerves.—The nerve-supply of the thyroid gland comes mainly from the middle and inferior cervical ganglia of the sympathetic system. The fibers follow the arteries and form a *superior* and an *inferior thyroid plexus*. Fibers have also been described coming from the recurrent, superior and inferior laryngeal, the glossopharyngeal, vagus and hypoglossal nerves.

FIG. 1056.—VESSELS OF THE THYROID GLAND, ANTERIOR VIEW. 1, 2, 3, Lateral lobes and isthmus; 4, pyramidal lobe; 5, hyoid bone; 6, thyroid cartilage; 7, trachea; 8, common carotid; 9, internal jugular; 10, thyro-linguo-facial vein; 11, superior thyroid artery; 12, inferior laryngeal vessels; 13, middle thyroid vein; 14, subclavian artery; 15, inferior thyroid artery; 16, inferior lateral thyroid veins; 17, inferior medial thyroid veins; 18, left innominate vein; 19, aortic arch; 20, vagus nerve. (Testut.)



Development.—The thyroid gland arises (see p. 55) as a ventral median diverticulum of the pharynx (figs. 37A, 41), cranial to the second branchial arches. Grosser has shown that the thyroid anlage is unpaired and that all previous reports as to the paired, lateral origin of the gland have to be discarded. The epithelial diverticulum is first seen in human embryos of about 1.4 mm. length, with 5 or 6 somites. It is usually a hollow diverticulum, which shows a slight terminal swelling. In embryos of 2.5 mm. (23 somites), this bud begins to lose its connection with the pharyngeal tube. The duct, *thyreoglossal duct*, disintegrates, while the vesicle transforms into a solid mass, which lengthens out in a transverse direction, until it forms a strip of epithelial tissue running across the midline and showing a distinct swelling at either end, the beginning of the lateral lobes. The point of origin of the epithelial duct moves somewhat caudad, until it comes to lie between the second gill-bars. In the development of the tongue, this region is taken up into the root of the latter, so that, ultimately, a slight depression, *foramen cecum*, on the back of the tongue marks the original opening of the thyroglossal duct, which may occasionally persist in the adult as the *ductus lingualis*. This duct normally is soon transformed into a solid cord of cells running ventrally to the hyoid bone in the plane of the future lingual septum. Its original position explains the attachment of a well-developed pyramidal lobe to the ventral surface of the hyoid bone. In its further development the thyroid mass moves more caudad and during the lengthening of the branchial region it is carried into its final position, caudal to the larynx. In extreme cases it may even extend into the mediastinum, and findings have been reported of a hernia of the thyroid gland into the thoracic cavity. In older persons, there may be a physiological thyreoptosis, since the larynx gradually assumes a

more caudal position, so that the thyroid is pushed toward the thoracic aperture. The thyroglossal duct lengthens out, of course, until finally it breaks up into small epithelial nodules, which normally disappear. The lateral lobes begin to expand further, numerous capillaries approach the surface of the epithelial tissue, penetrate into the interior and later break it up into numerous smaller groups and clusters of cells. These epithelial nodules finally hollow out, many of them not until after birth, and form closed follicles, in the lumen of which colloid begins to appear as early as the fourth month of fetal life. The mass of the lateral lobes is slightly increased by the addition of epithelial bodies, coming from the ventral portions of the fifth branchial clefts. These *ultimobranchial bodies* are taken into the area of the thyroid tissue, where they gradually disintegrate. Therefore they do *not* form any part of the thyroid gland (Grosser). The capsule of the gland is formed rather late in fetal life, so that tissues, foreign to the thyroid, may easily become enclosed within its area. This sometimes happens with the parathyroids IV; also muscle and ganglion cells have been found therein.

Variations.—All variations and abnormalities in the shape and size of the thyroid gland and the distribution of accessory thyroid nodules can easily be explained on an embryological and phylogenetic basis. The greatest range of variation is found in the pyramidal lobe and isthmus. Apparently, it is the phylogenetic tendency of the organ to lose its connection with the pharynx, push as far caudad as possible and then to spread out transversely, so as to form two distinct lateral lobes. Two symmetrical lobes are normal in some amphibians and birds. The most extreme variations in man would be, on the one hand, a well-developed, unpaired, pyramidal lobe, attached to the lingual septum or hyoid bone, with a well-formed isthmus (selachian and reptilian type); on the other hand, two lateral lobes entirely separated, or connected by a very thin isthmus, which may consist of connective tissue only. Between these two extremes all degrees of variations have been described. Sometimes one lobe may be very small, while the other is large. Remnants of the thyroglossal duct, sometimes *cranially* to the hyoid bone (27 per cent. of cases), may lead to the formation of small accessory thyroid nodules or, at least, epithelial cysts, lying between the fibers of the geniohyoid muscle. Such rudiments, in later life, may undergo a renewed development. Accessory thyroid glands, sometimes five or more, are more often formed from broken-off parts of the pyramidal lobe. All such nodules lie cranially to the gland proper. More distal portions of the gland may become cut off and then lie caudally to the larynx. A possible extension into the mediastinum and thorax has been mentioned above. The main gland may be absent entirely, while a number of smaller nodules assume its function. (In cyclostomes and teleosts we find scattered follicular units in place of a single encapsulated gland.) The connection with the foramen cecum may persist, or the latter may retain the form of a deep, branching canal, with mucous glands in its epithelium.

THE PARATHYROID GLANDS

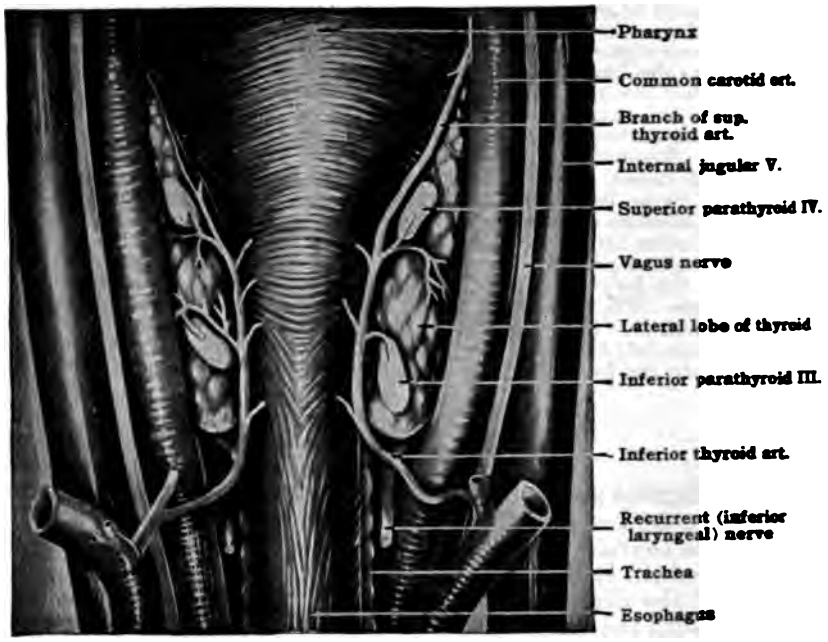
The **parathyroid glands** [glandulæ parathyroideæ] are small structures, usually two on each side, lying in the neighborhood of, or closely attached to, the dorsal surface of the thyroid gland. Not uncommonly, one may find one or the other nodule embedded in the thyroid tissue. Their structure is entirely different from that of the thyroid, as is also their physiology. Therefore they must *not* be grouped with the *accessory* thyroid glands. In spite of their minute size, they are of extreme importance, the removal of all the parathyroids leading usually to death.

The parathyroids are spherical or ovoid bodies, usually somewhat flattened (fig. 1057). Their *size* varies from 2 to 8 mm. in length. In old age they atrophy to some extent. Their *consistency* is firmer than that of the thyroid. Their *color* changes from a light pink in the young to a yellowish-gray in the old. They are easily mistaken for small lymph-nodules, or *vice versa*. Usually, they are situated on the dorsal surface of the lobes of the thyroid, sometimes near the medial border. Their position is rather variable; some may be found within the thyroid, or more caudally toward the sternum, attached to or enclosed in the thymus. The superior pair (parathyroids IV) lie on the finer branches of the inferior thyroid artery, usually dorsal to the recurrent nerve. They may be found as high up as the apices of the lateral lobes of the thyroid. The inferior pair (parathyroids III) lie near the base of the lateral lobes or still further caudal (see development). The average number of parathyroids is 4. It varies, however, from 1 to 12. A reduced number means either a fusion of two or more anlages, misplacement of one or the other bud, or a retrogression (retarded differentiation and ultimate absorption) of some rudiments. Such a process is normal in some mammals. A number higher than 4 would mean a splitting of some of the rudiments into secondary nodules.

The **blood-supply** of the parathyroids (fig. 1057) goes through branches of the inferior (sometimes superior) thyroid arteries and veins, each nodule receiving its artery, which enters at the hilus, a slight depression of the connective tissue capsule. The **lymph-vessels**, in all probability, also belong to the thyroid system. The **nerves** (sympathetic) likewise come from the thyroid branches.

Development.—The parathyroids develop from the epithelium of the dorsal, cranial areas of the most lateral extremities of the third and fourth gill clefts (fig. 41). They are entirely of entodermal origin. These epithelial bodies are soon approached by blood-vessels, which break up the cellular mass into a system of irregularly arranged clusters nd cords of cells, between which the vessels form a complicated system of sinusoidal channels. The epithelial anlages soon lose connection with the branchial epithelium and begin their migration in a caudal direction. The pair coming from the third clefts differs somewhat in its behavior from that coming from the fourth. The parathyroids IV usually form the upper pair of glands, while the parathyroids III travel farther toward the sternal region. The glands IV usually become attached to, sometimes (rarely in man) embedded within, the thyroid. This variation, of course, depends on the time of formation of the capsule of the thyroid gland, and also on the lateral extension of the thyroid band (see development of thyroid), as the latter travels toward the cricoid region. The glands III, on the other hand, may retain their connection with the thymus-anlages, and may then travel as far as the mediastinum, and remain attached to, or,

FIG. 1057.—PARATHYROID GLANDS, VIEWED FROM BEHIND (NATURAL SIZE).



more often, embedded within the thymus. This connection is a very short strip of branchial epithelium and can often be seen even in older embryos; the thymus buds, as it were, pulling along the parathyroids III. Should this connection be broken very early, the parathyroids III may fail to migrate at all, and may then be found in a rather cranial location, even more so than the thyroid.

THYMUS

The thymus gland is distinctly a double organ, so it is perhaps more correct to speak of the right and left thymus instead of its right and left lobes. The two lobes, however, are so closely attached to each other by connective tissue—rarely they are connected by a true isthmus—that usually the thymus has been described as a single, unpaired organ. Its development and the distinct separation into two bodies at the cranial end speak for its duplex anatomical structure.

The shape of the thymus is hard to define, since the gland on account of its very soft consistency easily molds itself to the surrounding structures. It might best be described as a pyramid, the broad base occupying the thoracal end, while the apices are represented by the thinned-out, cervical portions. The dorsoventral diameter is certainly greater than appears in the dissecting room, where the gland often is found to be rather flat. The right lobe usually overlaps the left one.

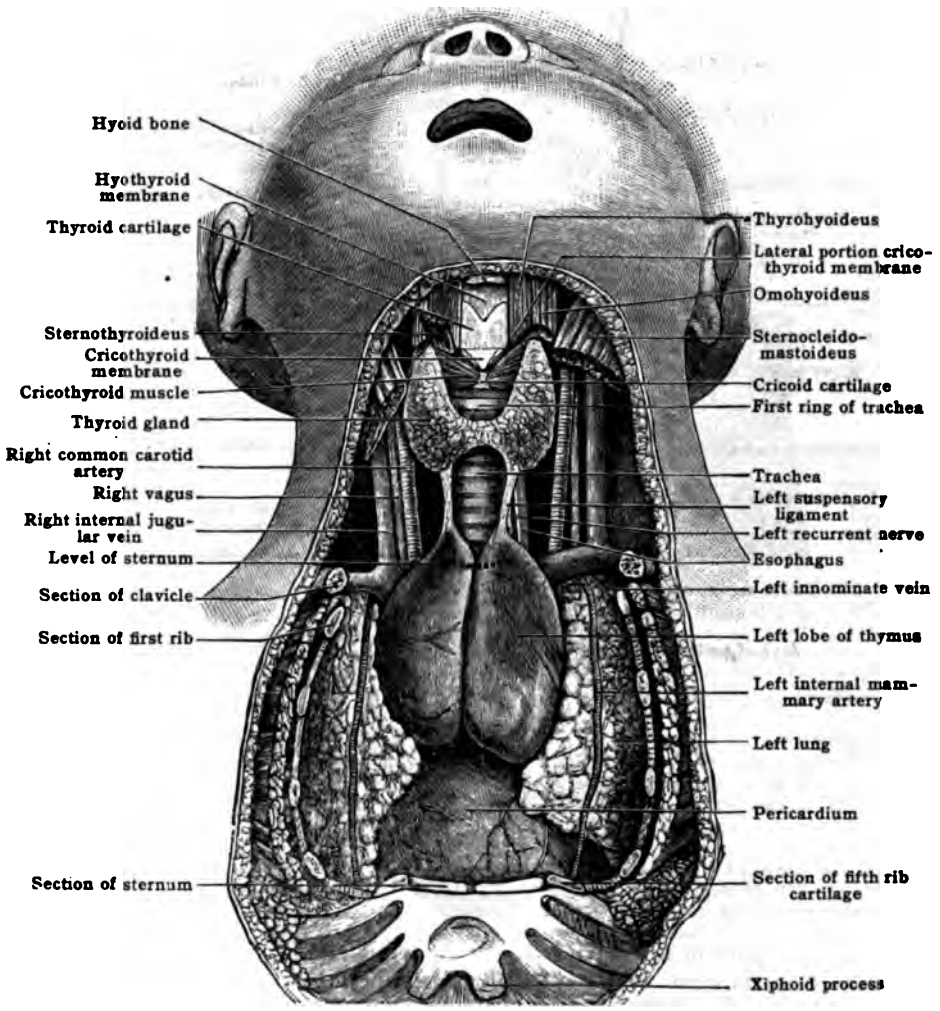
Size.—The thymus is relatively largest in the child (figs. 1058, 1059) and reaches its absolute maximum of development in the adolescent. Soon after puberty it undergoes a retrogression or involution, the thymic tissue gradually being replaced by fat, so that in the dissecting room one rarely finds a true glandular body, but a lobe of adipose tissue in its stead. The shape of the epithelial organ, previous to involution, may approximately be retained, and its replacement

by fat proceeds by no means as fast and to such a degree as was commonly believed. Even in older individuals, thymus parenchymal tissue is still present.

The *length* of the organ in the newborn is variously given from 4 to 6 cm., the width from 1.2 to 4 cm., the thickness from 0.8 to 1.4 cm. More instructive are the *weight* measurements (quoted from Sobotta, after Hammar): newborn, 13.26 g.; 11–15 years, 37.52 g.; 16–20 years, 25.28 g.; 46–55 years, 12.85 g. The greatest weight is, therefore, reached during the adolescent period. In the female, the gland is somewhat lighter than in the male. Still more interesting is the weight of the parenchyma, calculated by Hammar after the exclusion of the adipose and connective tissue: newborn, 12.33 g.; 11–15 years, 25.18 g.; 16–20 years, 12.71 g.; 46–55 years, 1.48 g. Thus the largest amount of glandular tissue is also present at puberty. In disease or malnutrition the thymus readily retrogresses (premature involution).

While it is definitely established that (1) the thymus is a gland of the infantile period (group *a*, see p. 1311); (2) the normal physiology of the thymus is upset by an abnormal progress in

FIG. 1058.—THYMUS AND THYROID GLAND IN A CHILD AT BIRTH.



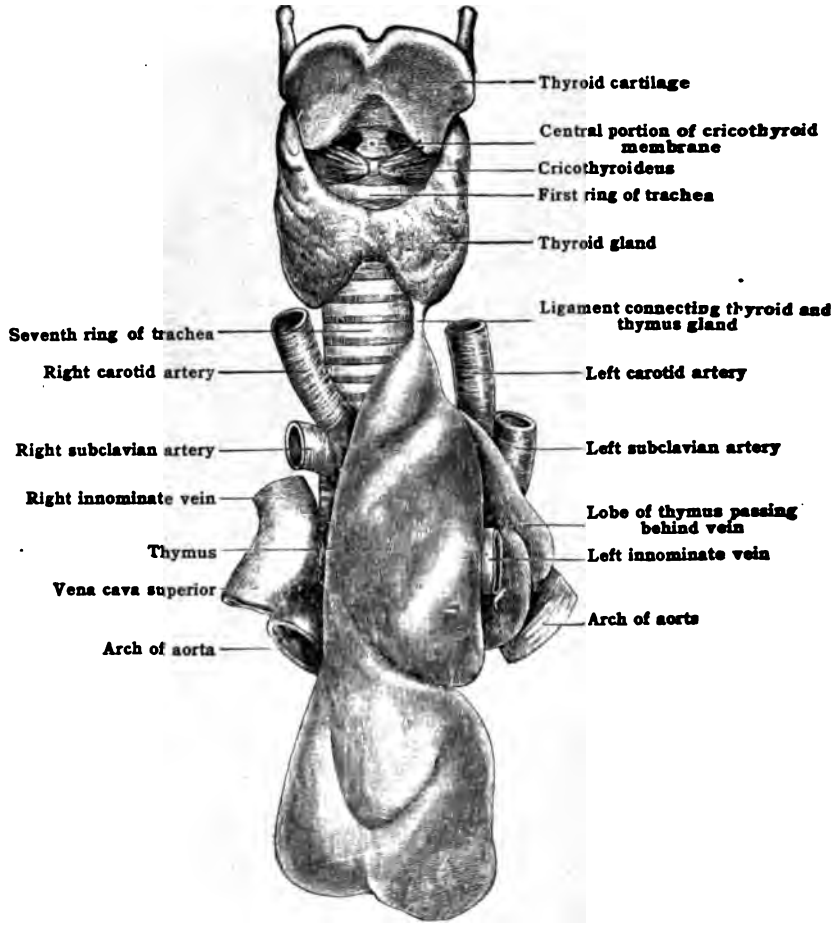
growth and differentiation (precocious involution, delayed involution); (3) the thymus most readily responds to any faulty stimulus exerted by any of the other glands of group *a*, whether hyper- or hypoplastic; yet it is by no means certain whether the thymus is able to act as a *primary, causal* factor in this physiological ring of developmental glands (group *a*), or is simply *secondarily* influenced and controlled by the other members. In other words, a primary internal secretion of the thymus might, perhaps, be questioned. However, there can be no doubt, physiologically, that a reciprocity exists between the condition of the thymus and the state of differentiation of an organism. Anatomically, on the other hand, we must admit that the morphological basis for a secretion is wanting.

The **color** of the thymus changes from a pink or reddish tint in the fetus to a pale reddish-gray in the growing child. Later it assumes the yellowish color of fat. It is surrounded by a fine, but firm, connective tissue **capsule**, sending trabeculæ into the body and dividing the latter into numerous small lobules [lobuli thymi] the outlines of which can be seen and felt on the surface. By looser connective tissue it is attached to the neighboring structures, more so on its dorsal than on its ventral aspect.

Topography.—The greater portion of the thymus lies in the upper anterior mediastinal space (thoracic portion); the cranial extremities of the two lobes, when well developed, extend into the cervical region (cervical portion) (figs. 1058–1060).

The *cervical portion* of the thymus lies ventral to the trachea, in the thoracal aperture and lower cervical region, starting at about the sixth cervical vertebra. It is covered by the superficial and deep layers of the cervical fascia and the sternothyroid and sternohyoid muscles. It is usually surrounded by some adipose tissue of the suprasternal region. It may be connected to the thyroid on each side by a ligament or strand of fibrous connective tissue (figs. 1058, 1059).

FIG. 1059.—THYMUS IN A CHILD OF TWO YEARS.



The *thoracic portion* lies in the upper, anterior mediastinal space between the two mediastinal laminæ of the pleura. The median portion of its somewhat convex, ventral surface rests against the dorsal aspects of the sternum and neighboring costal cartilages (to the fourth). An excessively large thymus may reach to the diaphragm. In the more cranial region of the manubrium, the sternohyoid and sternothyroid muscles intervene between the sternum and the thymus. The more caudal portion of the concave, dorsal surface of the gland is closely applied to the pericardium. The cranial portion of the dorsal surface rests against the large vessels, aortic arch, innominate artery and veins, common carotids, etc. Occasionally, the left innominate vein may lie on the ventral side. As the individual grows, the thymus is withdrawn more and more from the prepericardial mediastinal space and finally occupies only its upper region.

Blood-vessels.—The arteries of the thymus are branches of the subclavian, or of the internal mammary artery, either directly or springing from the anterior mediastinal branches. The cranial portions may be supplied by branches of the inferior or median thyroid (ima) arteries.

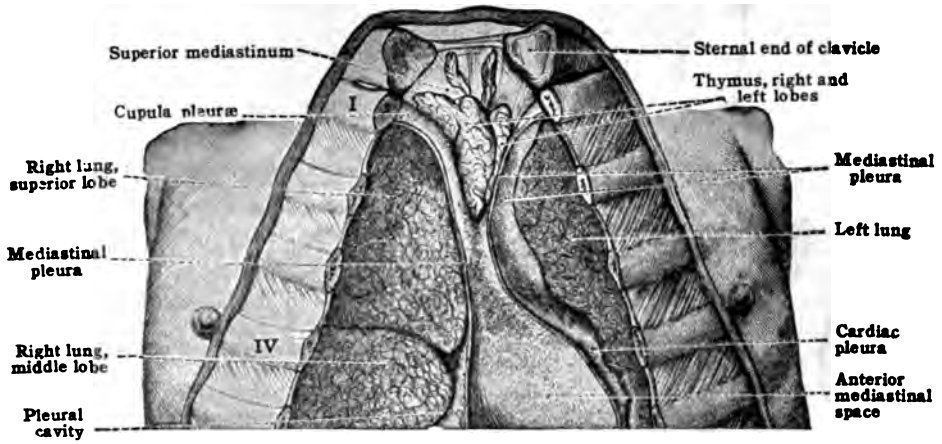
The numerous veins of the thymus drain into the left innominate vein (fig. 564), some into the internal mammary veins and their tributaries or the inferior thyroid veins.

Lymph-vessels.—The exact distribution of the rather scanty lymph-vessels around and within the thymus has still to be investigated, although definite channels have been demonstrated within the connective tissue trabeculæ and parenchyma. The drainage of the large lymph-channels probably proceeds into the anterior mediastinal lymph nodes.

Nerves.—Fine, non-medullated nerve-fibers have been demonstrated within the gland, forming networks around the vessels and in the trabeculæ. They probably belong to the sympathetic system. Fibers from the vagus have also been mentioned.

Development.—The thymus bodies arise (see p. 56) during the fourth week of fetal life (5–7 mm. embryos) from the ventral region of the most lateral extremities of the third, sometimes also of the fourth, gill clefts (fig. 41). In man, the thymus is entirely of entodermal origin. The thymus diverticulum, sometimes distinctly hollow, grows in a ventral and caudal direction and lengthens out into a solid mass of epithelial cells, which loses its connection with the pharyngeal epithelium (at about 12 mm.). Blood-vessels very soon approach its surface and penetrate into the interior. No connection is established with the lobe of the other side. Later, when the two portions move still more caudad into the sternothoracal space, and after a connective tissue capsule has been formed, the two glands lie close against each other, the right one usually in a more ventral position and overlapping the left. If an epithelial body is formed from the fourth gill cleft, it may undergo an independent development. Usually, it is taken up into the

FIG. 1060.—THYMUS IN AN ADULT. ×13. (From Toldt's Atlas.)



main thymic tissue and there retrogresses; or it may form an additional lobe. The parathyroids, which develop from the same gill clefts as the thymus bodies III and IV, may be attached to or enclosed in the thymus-tissue. As the epithelial thymus mass moves caudad, its cranial portion (stalk) disintegrates. The glandular tissue then sprouts out in the form of small lobules. For some time a distinct central tract or possibly even a hollow canal is noticeable.

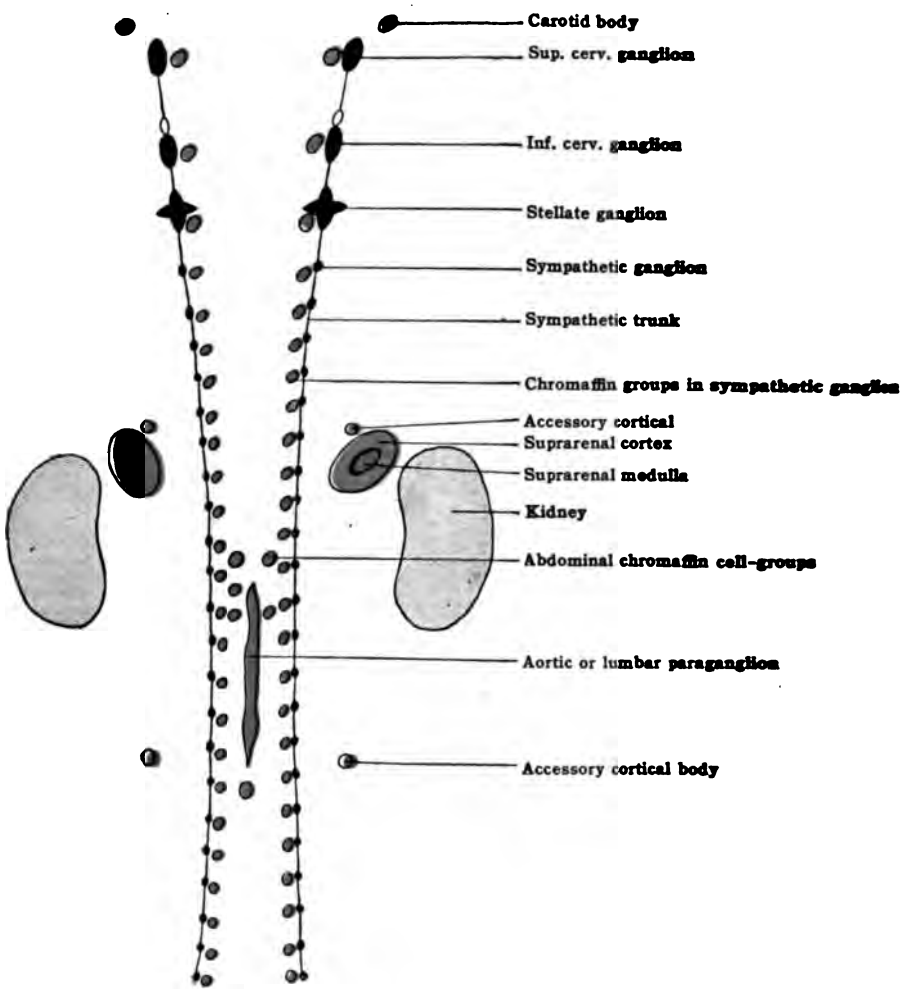
Variations.—Variations from the anatomical norm are usually due to some irregularity in development. Like the thyroid, the thymus seems to have a phylogenetic tendency to move toward the thoracic region. A failure to do so or a failure to reduce the stalk will give a large cervical thymus (reptilian or avian type), sometimes bordering on the thyroid. At times, the cervical portion is represented merely by a strand of connective tissue. Accessory thymus glands may be broken-off portions of the stalk, left behind in the caudal migration of the tissue, or may come directly (in rare cases) from the epithelium of the clefts. In lower forms, several (2–5) branchial clefts assist in the formation of the organ. In monsters (hemicephalic, for instance) the thymus may be absent. An abnormally long persisting thymus is found in the pathological condition of *status lymphaticus* or status thymicus. Also in cases of sudden death in children (thymic death) a large thymus has been found.

THE CHROMAFFIN SYSTEM

To the **chromaffin system** (fig. 1061) belong a number of organs, some minute in size, which are serially arranged along both sides of the dorsal aorta, most of them in close proximity to the sympathetic ganglia. They are mainly made up of chromaffin cells, the term 'chromaffin' designating a special chemical affinity of these cells for certain salts of chromic acid. The cells are derived from cell groups, the greater portion of which is used up in the formation of the sympathetic ganglia. Originally, the sympathochromaffin cells are a part of the ganglionic crest, which, shortly after closure of the neural canal, is constricted off to form the spinal and sympathetic ganglia. The chromaffin cells are, therefore, ectodermal (neural plate) cells, which, by way of the ganglionic bodies, have traveled a

further distance to form the chromaffin or paraganglionic bodies. Due to their place of origin, it is not unusual to find true ganglionic cells in these bodies. To the chain of these paraganglionic bodies belong: the **carotid bodies**; the **paraganglia proper**, the **aortic bodies**; and, in part, the **suprarenal glands**, the medulla of the latter being a pair of larger and further developed **paraganglia**. The chromaffin cells are *not* specialized sympathetic ganglion cells, but present a separate type of cell, which can be recognized as such rather early in development.

FIG. 1061.—DIAGRAM SHOWING THE CONSTITUENTS OF THE CHROMAFFIN SYSTEM IN MAMMALS. Chromaffin structures in red; cortical in blue. (Swale Vincent, 'Internal Secretion and the Ductless Glands.' Edward Arnold, London, 1912.)



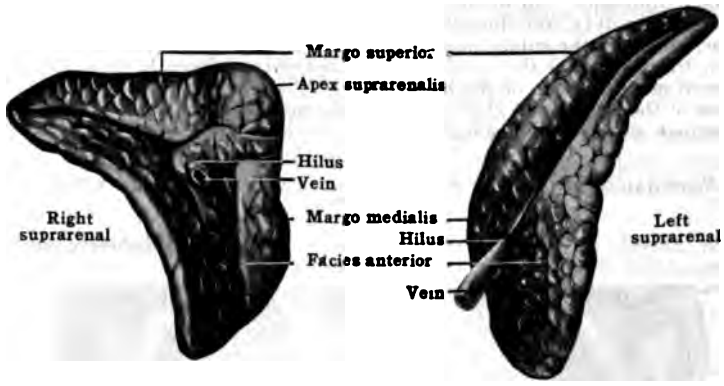
THE SUPRARENAL GLANDS

The **suprarenal gland** [glandula suprarenalis] (adrenal gland) lies near the cranial pole of each kidney, close to that body, so that the convex surface of the kidney causes a concave impression on the suprarenal (fig. 1064). The left gland lies more along the anteromedial border of the kidney, reaching at times as far down as the hilus and touching the renal vessels. Considering the concave surface as the *base*, the suprarenal gland might be described as a very low pyramid, the basal surface resting against the kidney, the *apex* pointing toward the diaphragm (figs. 1062, 1063). Sometimes the pyramid is flattened down to almost a semilunar plate, its convex surface facing craniomedially. This is especially true for the left suprarenal. Each gland has an anterior, a posterior and a basal surface. Superior and medial borders are distinguished, and the left suprarenal also presents a left border. On the anterior surface, there is a slight

groove noticeable, the *hilus*, where the central vein appears on the surface (fig. 1062). The gland is enclosed in its tough, connective tissue *capsule* and is embedded in adipose tissue. It is surrounded by the renal fascia (fig. 1098) and is more firmly attached to the latter than to the kidney.

The weight of the gland is given from 4 to 18 grams, undoubtedly liable to considerable physiological variation. The measurements vary from 40 to 60 mm. in length and 20 to 30 mm.

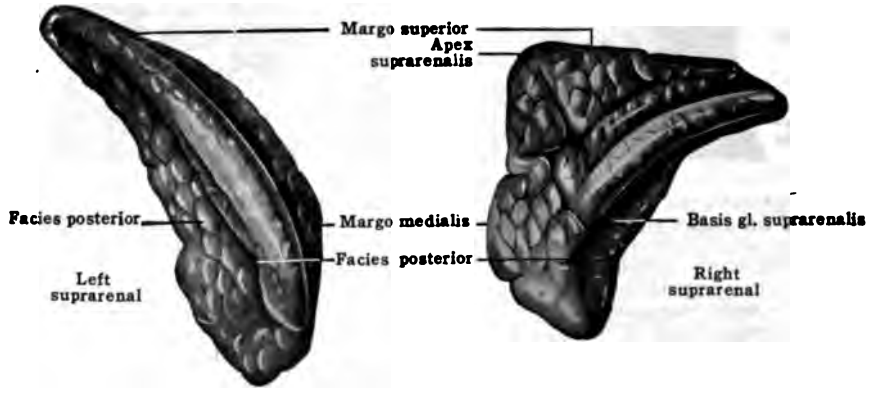
FIG. 1062.—THE SUPRARENAL GLANDS, VENTRAL VIEW.



in width. The gland is relatively large in the fetus and in the young. In malformations (anencephalic monsters, for instance), it is considerably enlarged. Its color is of a yellow or brownish tint. Its texture is rather firm.

Topography.—The suprarenal glands lie in the epigastric region (figs. 965, 1018, 1064), at about the level of the eleventh thoracic vertebra. The posterior surface rests against the lumbar area of the diaphragm. The anterior surface of the right gland touches the inferior vena cava medially, the liver laterally and (sometimes) the duodenum below. The left gland lies somewhat more cranially

FIG. 1063.—THE SUPRARENAL GLANDS, DORSAL VIEW.



and nearer the aorta, behind the lesser omental sac. Anteriorly it is in relation with the posterior surface of the stomach above, the posterior surface of the pancreas and the splenic vessels below, and (often) the renal surface of the spleen laterally.

Structure.— From the fibrous capsule, numerous trabeculæ are given off which pervade the gland and form septa between the groups and rows of cells. Within the capsule, the suprarenal is composed of two distinct portions, an external firmer, yellowish layer, the *cortex* [substantia corticalis], and an internal, softer layer, the *medulla* [substantia medullaris], which usually appears dark reddish-brown in color, on account of its large blood content. These two portions, the cortex and medulla, really represent two distinct glands which are different both physiologically and morphologically (see further under Development and Variations).

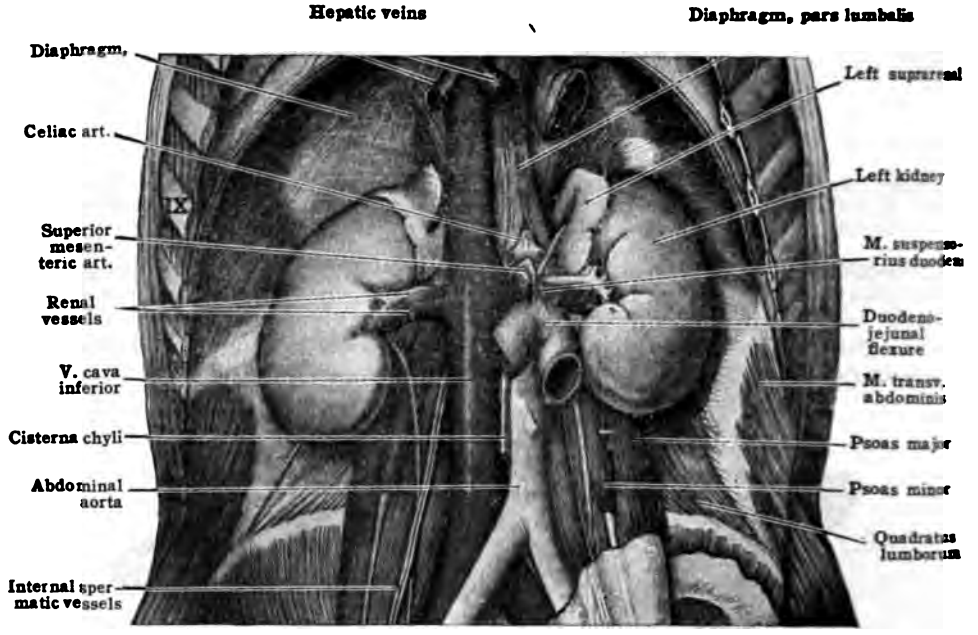
Blood-supply.—The blood-supply of the suprarenal gland is unusually abundant. Three arteries, the superior, the middle and the inferior suprarenal artery, approach the capsule and

penetrate into the interior. They are branches of the inferior diaphragmatic artery, aorta and renal artery respectively (fig. 570). All veins collect into one large **central vein**, lying in the medulla of the organ and passing out at the hilus as the **suprarenal vein**, which, on the right side, drains into the inferior vena cava, on the left side into the renal vein. Some arterial twigs form a network in the capsule, and special veins drain that area as tributaries to the inferior diaphragmatic veins, or veins of the adipose and fibrous capsule of the kidney.

The **lymph-vessels** of the suprarenal form a plexus directly under the capsule and a second one in the medulla. The peripheral plexus drains into vessels leaving the capsule; the central one into those following the central and suprarenal vein. On the right side, the lymph-channels connect ventrally with 2 or 3 lymphatic nodules near the aorta; and dorsally with a node near the crus of the diaphragm. On the left they drain ventrally into a node situated at the point of origin of the renal artery, and dorsally also into a node between the aorta and the crus of the diaphragm, or, following the splanchnic nerve through the diaphragm, into a mediastinal node lying between the aorta and the ninth thoracic vertebra. Some lymph-channels also drain into the subperitoneal network of the kidneys.

The **nerves** of the suprarenal gland, forming the **suprarenal plexus**, connect with the renal and celiac plexuses and the celiac ganglia.

FIG. 1064.—VENTRAL VIEW OF THE SUPRARENAL GLANDS, IN SITU. × ⅓. (From Toldt's Atlas.)



Development.—In the discussion of the development of the suprarenal gland, the two portions of the gland, cortex and medulla, have to be considered separately. It is the medullary portion which is derived from the ectodermal cells of the ganglionic crest, and which alone contains chromaffin (phæochrom) cells. Very early, such cells are split off from the nodules containing the sympathetic ganglion-cells, and migrate further ventrad, so as to lie lateroventrally to the aorta (paraganglia). Several such nodules, near the cranial end of the gonad, combine into a larger mass of cells, lying between the dorsal aorta and the dorsomedial border of the mesonephros. They come into close approximation to the group of mesoderm cells derived (at least the greater part) from that narrow strip of mesothelium of the body cavity between the dorsal mesentery and the genital ridge. There is, in embryos of 6 mm., an actual budding of mesothelial cells into the underlying mesenchyma, sometimes in tubular form, as occurs in pig embryos. These rapidly multiplying cells soon lose their connection with the mesothelium and attempt to form a complete layer of mesoderm cells around the ectoderm cells, derived from the sympathetic ganglia. In this way, the mass of the chromaffin cells, the medulla, is finally enclosed within the outer cortical layer. Comparatively large twigs of the dorsal aorta (mesonephric vessels) are seen to approach this mass very early. The fibrous capsule is formed rather late. For further details on the growth of the suprarenal glands, see DEVELOPMENTAL ANATOMY, p. 56.

Variations.—In lower forms, most of the anamnia, the two portions of the suprarenal glands are still separate as *interrenals* (cortical substance) and *adrenals* (medullary substance). In reptiles, the partial union of the two structures begins to appear. Therefore, it is not at all unusual, even in man, to find, in addition to the suprarenal glands proper, some accessory structures, made up of one or the other, or of both components. Only such nodules, which consist of cortex and medulla, are properly called **accessory suprarenal glands**. They are usually found near the cranial region of the kidneys, sometimes embedded in the cortex of the kidney or in the suprarenal itself. More often, one finds nodules made up of cortical tissue

only. These *accessory cortical* bodies have been found in more caudal regions of the abdominal cavity, and since, during development, the cortical (mesothelial tissue) is situated close to the germinal epithelium, such nodules may, with the descent of the gonad, be carried into the pelvis or even the scrotum. Such nodules, lying in the adventitia or the ligaments of the genital glands, the spermatic cord or the broad ligament of the uterus, at times have been the cause of a wrong diagnosis of true hermaphroditism, since they were mistaken for rudiments of the genital glands of the opposite sex. Still more often one finds, even in the pelvic region, scattered masses of the medullary substance, which are, however, *not* accessory suprarenals, but misplaced paraganglia. A complete absence of the suprarenal glands is rare and then only in cases of severe malformations. A hypoplastic condition is often found in connection with hypoplasia of the genital glands, and hyperplasia of the thymus and lymphatic structures (*status thymolymphaticus*).

THE CAROTID BODY

The **carotid body** [glomus caroticum] is a small, oval nodule, approximately 2 by 7 mm. in size, of paraganglionic (chromaffin) tissue, usually lying on the medial side of each common carotid artery, at or in the neighborhood of its branch-

FIG. 1065.—THE GLOMUS CAROTICUM (CAROTID BODY). (From Testut, after Princeteau.) 1, Carotid body; 2, 3, 4, common, external and internal carotids; 5, int. jugular; 7, inf. cervical sympathetic ganglion; 8, vagus.

ing into the external and internal carotids (fig. 1065). The connective tissue of the adventitia of these vessels adds to the formation of the capsule, from which elements penetrate into the interior of the nodule. Thus, the carotid body is rather closely attached to, and sometimes even partially embedded in, the tunica externa of the arteries.

It is richly supplied by fine *blood-vessels*. The arteries arise from the carotids, and the venules drain into the internal jugular vein or its tributaries. The *nerve-supply* is mainly sympathetic, coming from the inferior cervical ganglia. Branches have been described from the vagus and laryngeal nerve. The carotid body may consist of several small nodules, embedded in adipose tissue.

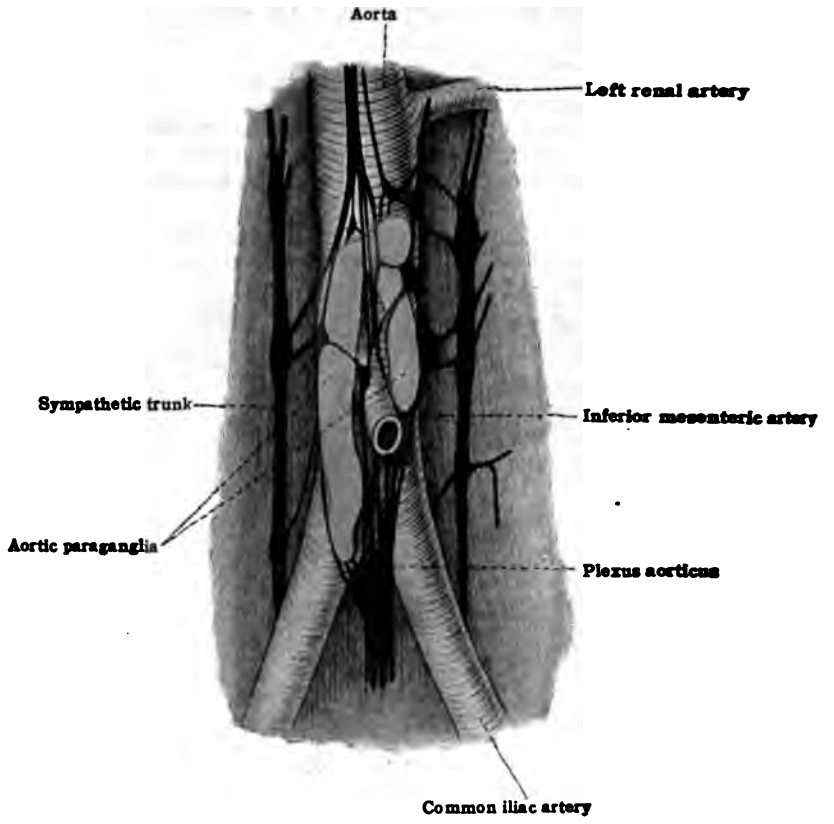
THE AORTIC PARAGANGLIA

The **paraganglia** proper are minute accumulations of chromaffin cells, lying inside or attached to the capsule of the ganglia of the sympathetic chain and of all the abdominal sympathetic plexuses.

The **aortic** or **lumbar paraganglia** (paraganglia lumbalia) represent a special group of chromaffin bodies, which develop from the sympathetic nodules and are, therefore, of ectodermal origin. While the rest of the chromaffin bodies are very small nodules, the carotid bodies being the largest of them, the right and left aortic, or abdominal paraganglia, attain a larger size. They may represent a fusion of several large chromaffin bodies into elongated, cylindrical masses, lying behind the peritoneum, ventrolaterally to the dorsal aorta, at about the level of

the origin of the inferior mesenteric artery (fig. 1066). Their size and extension is extremely variable. They may consist of a number of smaller nodules (as many as 70 have been counted). Often the right and left bodies are connected with each other. Their sympathetic nerve-supply comes from the abdominal aortic plexus. They are said to undergo retrogression after puberty.

FIG. 1066.—AORTIC PARAGANGLIA. (Zuckerkandl.)



THE HYPOPHYSIS

The **hypophysis cerebri** (pituitary gland) is an ovoid, somewhat flattened mass attached to the end of the infundibulum. The latter is an attenuated, funnel-shaped process of the tuber cinereum (see p. 832), which extends downward and forward (fig. 1068). The cavity of the infundibulum (infundibular recess) is a continuation of the cavity of the tuber cinereum and a part of the third ventricle; it may extend almost to the hypophysis (fig. 1067).

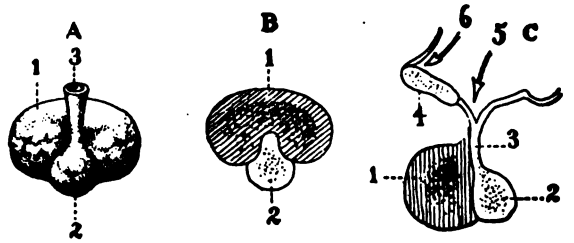
The hypophysis is lodged in the sella turcica of the sphenoid bone, where it is held down and roofed in by a fold of the inner layer of the dura mater, the *diaphragma sellæ*. It is surrounded by a dense, fibrous capsule and consists of two lobes, the larger *anterior*, glandular or buccal, lobe, possessing a concave posterior surface; and the smaller *posterior* or neural lobe, which is the terminal swelling of the infundibulum. Usually, the neural portion fits into the concavity of the glandular portion (hypophysis proper) as a ball into the hollow of the hand (fig. 1067, B). It is supplied by the *hypophyseal branches* of the internal carotid artery.

Development.—The entire body is of ectodermal origin, the anterior lobe arising from the ectoderm of the primitive oral cavity (3 mm. embryo), the posterior from the ectoderm of the neural tube. The posterior lobe develops as a ventral diverticulum of the diencephalon (see p. 56). Through the infundibulum, it retains its connection with the tuber cinereum. The anterior lobe develops as a dorsal diverticulum from the roof of the stomodeum (Rathke's pouch) and very soon (second month) loses its connection with the oral ectoderm. It then forms a closed vesicle. Remnants of its duct through the later sphenoid bone can be seen for some time and

may give rise to accessory glandular nodules, or cysts and tumors. It is claimed that at least one accessory nodule is often found forming the *pharyngeal hypophysis*. A persistent canal is occasionally found in the sphenoid bone (fig. 1069). In myxinoids and sharks, the duct into the oral cavity remains patent. Even in man, the adult hypophysis possesses a cavity, the rudiment derived from the embryonic buccal cavity.

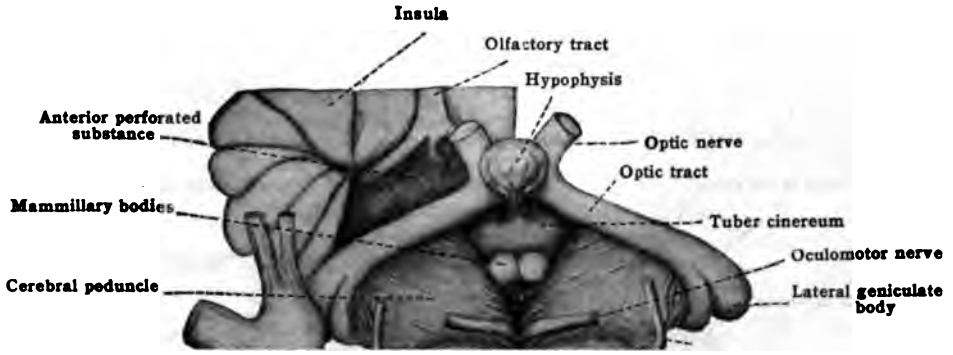
The structure of the anterior lobe of the gland is that of a typical organ of internal secretion. Its influence upon growth, differentiation and metabolism is well established. In cases of excessive growth of the skeleton (gigantism) and connective tissue (acromegaly) and late epiphyseal ossification (status thymicus), as well as in hypoplasia of the sex-glands, the anterior

FIG. 1067.—DIAGRAMS OF THE HYPOPHYSIS CEREBRI. (After Testut.) A, posterior view, B, frontal section; C, sagittal section. 1, anterior lobe; 2, posterior lobe; 3, infundibulum, 4; optic chiasma; 5, infundibular recess of 3d. ventricle; 6, optic recess. The infundibulum in C is somewhat too short.



lobe of the hypophysis is found to be enlarged or diseased. After removal of the thyroid gland a vicarious hypertrophy of the glandular lobe, with attempt of colloid-formation, may set in During menstruation, and still more during pregnancy, a normal temporary hyperplasia of this lobe is noticeable, sometimes to such an extent, that pressure may be exerted on the neighboring optic chiasma and temporary blindness may follow. That the neural portion plays an important rôle in metabolism (urinary excretion, sugar, etc.) is claimed by some physiologists. Anatomically, however, no basis for any secretion can be detected, except in the so-called *intermediate portion*, a part of the glandular lobe, lying between it and the neural lobe. For further details on topography and clinical relations, see p. 1342.

FIG. 1068.—HYPOPHYSIS AND RELATIONS. Inferior view.



THE PINEAL BODY

The **pineal body** [corpus pineale] or **epiphysis,** a part of the epithalamus, is a nodular or cone-shaped structure, lying in the transverse cerebral fissure, below the splenium corpus callosi, and extending in a caudal direction from the roof of the posterior extremity of the third ventricle (figs. 675, 706, 1070). It is connected to the medial surfaces of the optic thalami by two attenuated strips, the habenulæ. Its stem is attached just above the posterior commissure of the cerebrum, and its body rests in the groove between the superior quadrigeminate bodies (fig. 1071). The pineal body is covered by pia mater and is involved in a continuation of the tela choroidea of the third ventricle. It is surrounded by a dense capsule of fibrous tissue and consists of groups of epithelioid cells derived from the ependymal layer of the ventricle. Between these cells are frequently found accretions (brain-sand), consisting of mixed phosphates of calcium, magnesium, and ammonium, and of calcium carbonate, surrounding organic particles.

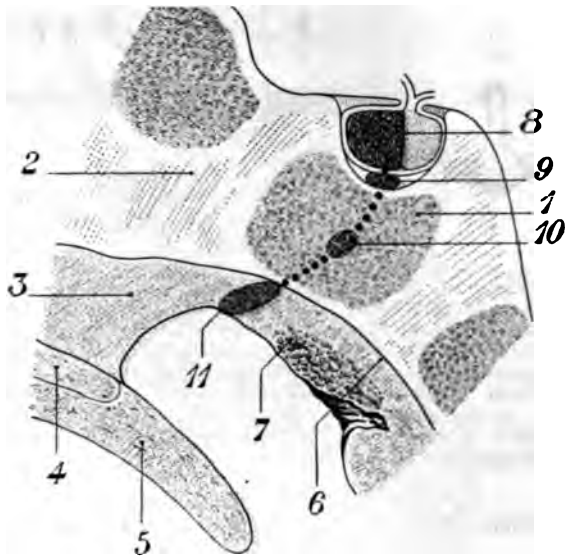
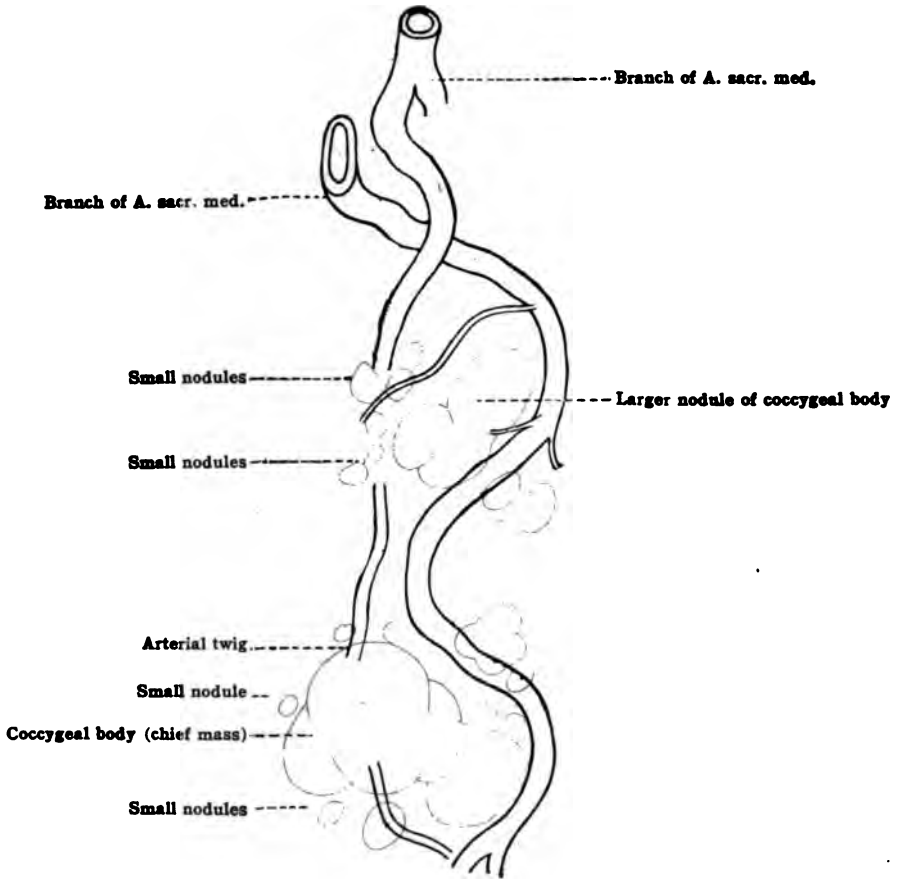


FIG. 1070.—PINEAL BODY AND RELATIONS. Superior view.

COCCYGEAL BODY

Ventral to the tip of the coccyx, between the tendons of the anterior sacro-coccygeal muscles, along the median sacral artery are one or more small, varicose nodules (usually there are several accessory nodules), called the **coccygeal body** [glomus coccygeum] (fig. 1071). It is apparently *not* a glandular organ and has nothing to do with the chromaffin system. However, its nature is entirely doubtful. The afferent artery forms a skein of anastomosing vessels, which drain into the median sacral vein. Around the endothelial tubes of the vessels, several layers of spheroidal cells are found, presenting the appearance of epithelioid cells.

FIG. 1071.—DIAGRAM SHOWING RELATIONS OF THE COCCYGEAL BODY AND ACCESSORY NODULES TO THE MIDDLE SACRAL ARTERY. (J. W. Thomson Walker.)



They are considered to be modified muscle-cells. Between these cell groups are found connective tissue and smooth muscle-fibers. It marks the termination of the median sacral artery, and thus takes the place of the rudimentary caudal vessel.

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SECTION XIV

CLINICAL AND TOPOGRAPHICAL ANATOMY

REVISED FOR THE SIXTH EDITION

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IN describing the clinical and topographical relations, the divisions of the body will be successively considered in the following order: head, neck, thorax, abdomen, pelvis, back, upper and lower extremities. For further details concerning the structure and relations of the various organs, the reader should consult the preceding sections devoted to the corresponding systems.

THE HEAD

The bony landmarks of the head will first be considered, followed by a separate description of the cranium and the face.

Bony landmarks.—These should be studied with the aid of a skull, as well as on the living subject. Beginning in front is the **nasion,** a depression at the root of the nose, and immediately above it, the **glabella,** a slight prominence joining the two **superciliary arches.** These points mark the remains of the frontal suture, and the junction of the frontal, nasal, and superior maxillary bones and one of the sites of a meningocele. In the middle line, behind, is the external occipital protuberance, or **inion,** the thickest part of the vault, and corresponding internally with the meeting-point of six sinuses. A midline joining the inion and glabella corresponds to the sagittal, and occasionally the frontal, suture, the falx cerebri, the superior sagittal sinus, and the longitudinal fissure of the brain. From the inion the **superior nuchal lines** pass laterally toward the upper and back part of the base of the **mastoid processes,** and indicate the first or so-called horizontal part of the transverse (lateral) sinus (fig. 1078).

The **transverse sinus** usually presents a varying curve upward and runs in the tentorium. The second or sigmoid portion turns downward on the inner surface of the mastoid, then forward, and lastly downward again to the jugular foramen, thus describing the double curve from which this part takes its name. In the jugular foramen the vessel occupies the posterior compartment; its junction with the internal jugular is dilated and forms the bulb. A line curved downward and forward from the upper and back part of the base of the mastoid, reaching two-thirds of the way down toward the apex, will indicate the second part of the sinus. The spot where it finally curves inward to the bulb would be about 1.8 cm. (¾ in.) below and behind the meatus. The two portions of the transverse sinus meet at the asterion laterally; at the entry of the superior petrosal sinus medially. The right transverse sinus, the larger, is usually a continuation of the superior sagittal sinus, and, therefore, receives blood chiefly from the cerebral cortex; the left, arising in the straight sinus, drains the interior of the cerebrum and the basal ganglia. Each transverse sinus receives blood from the temporal lobe, the cerebellum, diploë, tympanic antrum, internal ear, and two emissary veins, the mastoid and posterior condylar.

About 6.2 cm. (2½ in.) above the external occipital protuberance is the **lambda,** or meeting of the sagittal and lambdoidal sutures (posterior fontanelle, small and triradiate in shape). It is useful to remember, as guides on the scalp to the above two important points, that the lambda is on a level with the superciliary ridges, and the external occipital protuberance on one with the zygomatic arches.

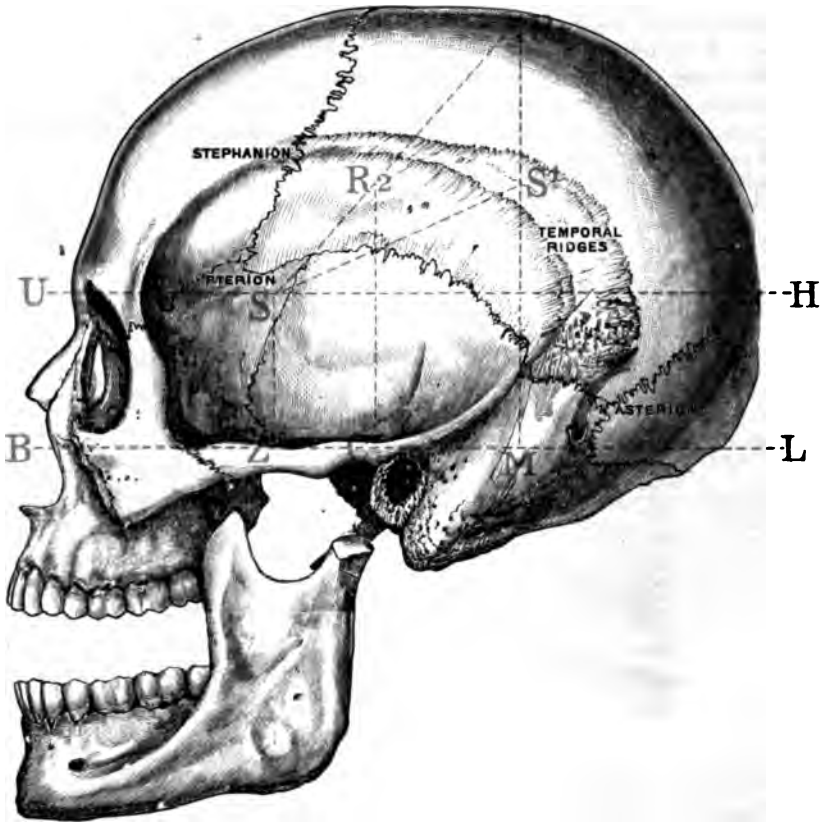
Below the external occipital protuberance, between it and the foramen magnum, an **occipital,** the commonest form of cranial **meningoceles,** makes its appearance. It comes through the median fissure in the cartilaginous part of the squamous portion of the bone.

further, corresponds to the anterior lateral fontanelle. On the side the **zygomatic arch,** the **temporal ridge,** and **external auditory meatus** tion. That important landmark, the **zygomatic arch,** wide in front formed by the zygomatic (malar), narrowing behind where it joins th gives off here three roots, the most anterior marked by the eminentia in front of the mandibular (glenoid) fossa, the middle behind this join posterior curves upward and backward to be continuous with the tem Within the zygomatic arch lie **two fossæ** separated by the infratemp goid) ridge: above is the **temporal,** with the muscle and deep temporal nerves; below is the **infratemporal** or **zygomatic** fossa, with the lower temporal muscle, the two pterygoids, the internal maxillary vessels, a dibular division of the fifth. To the upper border of the zygom attached the temporal fascia, to its lower, the masseter. Its upper b the level of the lower lateral margin of the cerebral hemisphere. A sponding to the middle root of the zygoma, immediately in front of and on a level with the upper border of the bony meatus, is called the point. Here the superficial temporal vessels and the auriculotem cross the zygoma, and a patient's pulse may be taken by the anesth lower end of the central (Rolandic) fissure lies 5 cm. (2 in.) vertically point. The **temporal ridge,** giving origin to the temporal fascia, sta zygomatic process of the frontal, and becoming less distinct, curves backward over the lower part of that bone, crosses the coronal sutur the parietal bone, curving downward and backward to its posterior inf Here it passes on to the temporal, and passing forward over the extern meatus, is continuous with the posterior root of the zygoma. Belo of the zygoma will be felt the mandibular joint, and when the mouth the condyle will be felt to glide forward on the eminentia articularis well-marked depression behind.

The **external auditory meatus,** measured from its opening on the concha to th is about 2.5 cm. (1 in.) in length; if from the tragus, 3.7 cm. (1½ in.). Its long ax medially and a little forward with a slight convex curve upward, most marked i Between the summit of this curve and the membrane is a slight recess in which fo may lodge. The lumen is widest at its commencement, narrowest internally. cartilaginous portion in line with the bony, the auricle should be drawn well upwa ward. In the bony portion the skin and periosteum are intimately blended, thu

blood-supplies to flaps taken from the forehead. Owing to the paper-like thinness of the bones on the medial wall of the orbit, e. g., lacrimal, ethmoid, and body of sphenoid, and the mobility of the skin, injuries which are possibly penetrating ones, as from a slate-pencil, etc., are always to be looked upon with suspicion. After a period of latency of symptoms, infection of the membranes and frontal abscess have often followed. Above the supraorbital margin is the superciliary arch, and higher still the frontal eminence [tuber frontale].

FIG. 1072.—THE SKULL, SHOWING KRÖNLEIN'S METHOD OF CRANIOCEREBRAL TOPOGRAPHY. (For explanation, see text p. 1340.)



THE CRANIUM

Under this heading will be considered the scalp, the bony sinuses, craniocerebral topography and the hypophysis.

The scalp.—The importance of the **scalp** is best seen from an examination of its **layers** (fig. 1073). These are—(1) **skin**; (2) **subcutaneous fat** and **fibrous tissue**; (3) the **epicranius** (occipitofrontalis) and **aponeurosis**; (4) the **subaponeurotic layer** of connective tissue; (5) the **pericranium.**

The first three layers are connected and move together. The thick skin, supported by the dense fibrous subcutaneous layer and epicranial aponeurosis, is well adapted to protect the underlying cranium from the effects of trauma, and in this connection the mobility of the first three layers on the subaponeurotic areolar tissue is important. A scalp wound does not gape widely unless it involves the epicranial aponeurosis, in which case it involves the subjacent **'dangerous area'** of the scalp, so-called because pus in this layer may spread widely underneath the scalp and even give meningeal infection by spreading through the diploic or emissary veins. In the process of scalping (whether performed by the knife or by the hair being caught in machinery), separation takes place at this subaponeurotic layer which is loose, delicate and devoid of fat. The numerous **sebaceous glands** frequently give rise to retention cysts in the scalp.

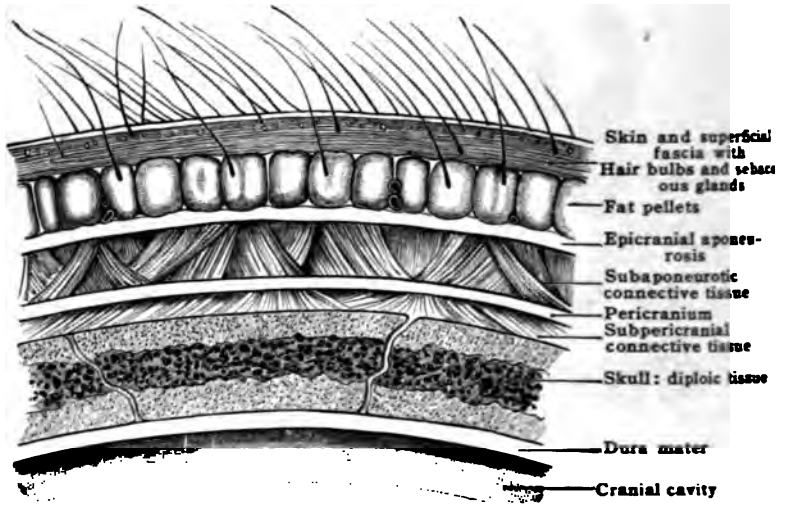
The **epicranius and aponeurosis** have been described elsewhere (p. 371).

The **pericranium** differs from periosteum elsewhere in that it gives little nourishment to the bone beneath, which derives most of its blood-supply from

the meningeal vessels. After necrosis of the skull there is no tendency to th formation of an involucrum of new subperiosteal bone as in the long bones. Th pericranium is firmly adherent to the sutures of the skull bones, so that an subpericranial effusion of blood or pus is limited by the sutures.

Of the **vessels of the scalp,** the *arteries*, arising in the anterior region fro the internal, in the posterior from the external carotid, are peculiar in the position. Thus they lie superficial to the deep fascia, which is here represente by the aponeurosis (fig. 1073). From this position arises the fact that a lar flap of scalp may be separated without perishing, as it carries its own bloo vessels. From the density of the layer in which the vessels run they cann retract and are difficult to seize, hemorrhage thus being free. Finally, fro their position over closely adjacent bone, ill-applied pressure may easily lead t sloughing. A practical point with regard to the veins is given below. Th *lymphatics* from the front of the scalp drain into the anterior auricular an parotid, those behind into the posterior auricular, occipital and deep cervic nodes. The **nerves** are derived from all three divisions of the trigeminus, fro

FIG. 1073.—SECTION THROUGH THE SCALP, CRANIUM AND DURA MATER. (Tillaux.



the facial (motor) and also from three branches of the second and third cervic (fig. 805). The supply from the fifth explains the neuralgia in acute iritis, glau coma, and herpes frontalis, and also the pains shooting up from the front of th ear in late cancer of the tongue.

The emissary veins.—These are communications between the sinuses within and the veins outside the cranium. Most of them are temporary, correspondin to the chief period of growth of the brain. Thus in early life, when the develop ment of the brain has to be very rapid, owing to the approaching closure of it case, a free escape of blood is most essential, especially in children, with the sudden explosions of laughter and passionate crying.

The gravity of these emissary veins and their free communications with others are show by the readiness with which they become the seat of thrombosis, and thus of blood-poisonin in cranial injuries, erysipelas, infected wounds of the scalp, and necrosis of the skull. The include the following (cf. pp. 950):

1. Vein through the foramen cecum, between the anterior extremity of the superior sagitt sinus and the nasal mucous membrane. The value of this temporary outlet is well seen in th timely profuse epistaxis of children. Other more permanent communications between the sk cavity and nasal mucous membrane pass through the ethmoid foramina. The fact that t nasal mucous membrane is loose and unsupported on the nasal conchæ (turbinate bone allows its vessels to give way readily, and thus forms a salutary safeguard to the brain, wardi off many an attack of apoplexy. 2. Vein through the mastoid foramen, between the transver lateral sinus and the posterior auricular and occipital veins. This is the largest, the mo constant, and the most superficial of the emissary veins. 3. Vein through the poster superior angle of the parietal between the superior sagittal sinus and the veins of the scal 4. Vein through the condyloid foramen between the transverse (lateral) sinus and the de veins of the neck. 5. Vein through the hypoglossal canal between the occipital sinus and t

deep veins of the neck. 6. Ophthalmic veins communicating with the cavernous sinus and the angular vein. These veins may be the source of fatal blood-poisoning, by conveying out of reach septic material, in acute periostitis of the orbit, or in osteitis, of dental origin, of the jaws. 7. Minute veins through the foramen ovale between the cavernous sinus and the pharyngeal and pterygoid veins. 8. Communications between the frontal diploic and supraorbital veins, between the anterior temporal diploic and deep temporal veins, and between the posterior temporal and occipital diploic veins and the transverse sinus. In addition to the veins specially mentioned, the scalp and sinuses communicate by numerous diploic veins, by those in the intersutural membrane, and through sutures before their obliteration, as already explained.

Structure of cranium.—Two layers and intervening cancellous tissue. Each layer has special properties. The **outer** gives thickness, smoothness, and uniformity, and, above all, elasticity. The **inner** is whiter, thinner, less regular—e.g., the depressions for vessels, Pacchionian bodies, dura mater, and brain. **The diploë,** formed by absorption after the cranium has attained a certain thickness, reduces the weight of the skull without proportionately reducing its strength, and provides a material which will prevent the transmission of vibrations.

A blow on the head may fracture the internal layer only, the external one and diploë escaping. This is difficult to diagnose, and thus it is impossible to judge of the severity of a fracture from the state of the external layer. This may be whole, or merely cracked, while the internal shows many fragments. It is usual to find more extensive splintering of the inner than of the outer layer (table.)

The average **thickness** of the adult skull-cap is about 5 mm. (⅕ in.). (Holden.) The thickest part is at the external occipital protuberance, where the bone is often 1.8 cm. (¾ in.) in thickness. The thinnest part of the skull vault is over the temporal part of the squamous. The extreme fragility of the skull here is partly compensated for by the thickness of the soft parts; these two facts are always to be remembered in the diagnosis of a fracture of the skull here, after a slight injury. Other weak spots are the medial wall of the orbit, the cerebellar fossæ, and that part of the middle fossa corresponding to the glenoid cavity.

Anatomical conditions tending to minimise the effects of violence inflicted upon the skull.—(1) The **density and mobility of the scalp.** (2) The **dome-like shape of the skull.** This is calculated to bear relatively hard blows and also to allow them to glide off. (3) **The number of bones** tends to break up the force of a blow. (4) The **sutures** interrupt the transmission of violence. (5) The **intersutural membrane** (remains of fetal periosteum) **acts,** in early life, as a linear buffer. (6) **The elasticity of the outer layer** (table). (7) **The overlapping of some bones,** e. g., the parietal by the squamous; and the alternate bevelling of adjacent bones, e. g., at the coronal suture. (8) **The presence of ribs, or groins,** e. g., (*a*) from the **crista galli** to the internal occipital protuberance; (*b*) from the root of the nose to the **zygoma;** (*c*) the temporal ridge from orbit to mastoid; (*d*) from mastoid to mastoid; (*e*) from external occipital protuberance to the foramen magnum. (9) **Buttresses,** e. g. zygomatic processes and the greater wing of the sphenoid. (10) The **mobility** of the head upon the spine.

THE BONY SINUSES

Frontal.—When well developed, the frontal sinuses may reach 5 cm. (2 in.) upward and 3.7 cm. (1½ in.) laterally, occupying the greater part of the vertical portion of the frontal bone. (Cf. pp. 131 and 1235). When very small, they scarcely extend above the nasal process. In any case, they are rarely symmetrical. The average dimensions of an adult frontal sinus are 3.7 cm. (1¼ in.) in height, 2.5 cm.(1 in.) in breadth, and 1.8 cm. (¾ in.) in depth. (Logan Turner.) The sinuses are separated by a septum. The posterior wall is very thin. Each sinus narrows downward into the infundibulum. This is 'deeply placed, at the back of the cavity, behind the frontal (nasal) process of the maxilla and near the medial wall of the orbit. Its termination in the middle meatus is about on a level with the palpebral fissure.' (Thane and Godlee.) Its direction is backward.

The communication of these sinuses with the nose accounts for the frontal headache, the persistence of polypi and ozena, and the fact that a patient with a compound fracture opening up the sinuses can blow out a flame held close by.

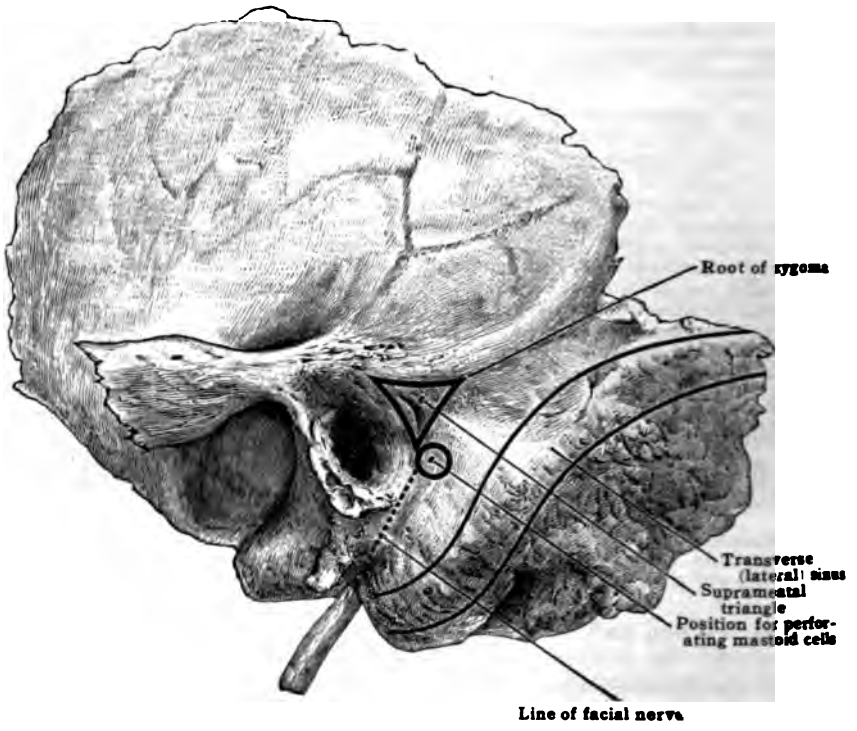
To open the frontal sinus, while the incision which leaves the least scar is one along the shaved eyebrow, superficial laterally so to avoid the supraorbital nerve and vesels, running a little downward at the medial end, it is always to be remembered that, where the sinuses are little developed, this or a median incision may open the cranial cavity. To avoid this complication the sinus should always be opened at a spot vertically above the medial angle.

The development of these by the twentieth or twenty-fifth year may render a fracture here much less grave in the adult than would otherwise be the case, the inner layer (table), if now separated from the outer, protecting the brain. Mr. Hilton showed that the absence of any external prominence here does not necessarily imply the absence of a sinus, as this may be formed by retrocession of the internal layer. Again, prominence of the superciliary and frontal eminences does not necessarily point to the existence of a sinus at all, being due merely to a heaping up of bone.

The mastoid cells are arranged in two groups;—(A) The **upper, or antrum,** present both in early and late life, horizontal in direction, closely adjacent to and communicating with the tympanum. (B) The **lower, or mastoid cells proper.** This group is not developed in early life.

A. **Tympanic antrum** (fig. 1075).—This is a small **chamber lying** behind the tympanum, into the upper and back part of which (**epitympanic recess**) it opens (cf. p. 147). Its size varies, especially with age. **Almost as large at birth,** it reaches its maximum (that of a pea) about the **third or fourth year.** After this its size usually diminishes somewhat, owing to the development of the encroaching bone around it. Its **roof,** or tegmen, is merely the backward continuation of the

FIG. 1074.—TEMPORAL BONE, SHOWING SUPRAMEATAL TRIANGLE. (BART.)
The lower part of the transverse sinus is here placed too far back to be relied upon with constant accuracy.



tegmen tympani. The level of this is indicated by the **posterior root of the zygoma.** 'The level of the floor of the adult skull at the tegmen antri is, on an average, less than one-fourth of an inch above the roof of the external osseous meatus; in children and adolescents, from one-sixteenth to one-eighth of an inch.' (Macewen.) In early life, when the bony landmarks, e.g., the suprameatal crest are little marked, the level of the upper margin of the bony meatus (suprameatal triangle, fig. 1074) will be the safest guide to avoid opening the middle fossa.

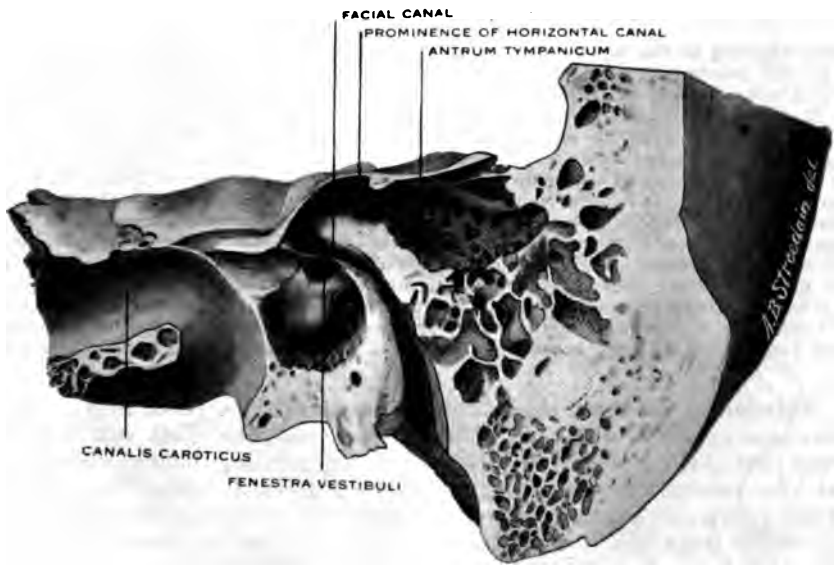
The **lateral wall** of the antrum is formed by a plate descending from the squamous bone. This is very thin in early life, but as it develops by deposit under the periosteum, the depth of the antrum from the surface increases. Macewen gives the average of the depth as varying from one-eighth to three-fourths of an inch.

The thinness of the outer wall in early life is of practical importance. It allows of suppuration making its way externally—subperiosteal mastoid abscess. This will be facilitated by any delay in the closure of the petro- and mastosquamosal sutures, by which this thin plate blends with the rest of the temporal bone. Further, by the path of veins running through these sutures or their remnants, infection may reach such sinuses as the inferior petrosal. The sutures normally close in the second year after birth.

Through the **floor,** the antrum communicates with the lower cells of the mastoid. This floor is on a lower level than the opening into the tympanum, and thus drainage of an infected antrum is difficult, fluid finding its way more readily into the lower cells. **Behind** the mastoid antrum and cells is the bend of the sigmoid part of the transverse (lateral) sinus, with its short descending portion (figs. 1074, 1078). The average distance of the sinus from the suprameatal triangle is 1 cm. (⅖ in.). It may be further back; on the other hand, it may come within 2 mm. (1/12 in.) from the meatus, and even overlap the outer wall of the antrum.

The exact position of the antrum, a little above and behind the external auditory meatus is represented by Macewen's 'suprameatal triangle.' This is a triangle bounded by the posterior root of the zygoma above, the upper and posterior segment of the bony external meatus below, and an imaginary line joining the above boundaries (fig. 1074). 'Roughly speaking, if the orifice of the external osseous meatus be bisected horizontally, the upper half would be on the level of the mastoid antrum. If this segment be again bisected vertically, its posterior half would again correspond to the junction of the antrum and middle ear, and immediately behind this

FIG. 1075.—SECTION THROUGH MASTOID PROCESS, ANTRUM AND TYMPANIC CAVITY. (Dr. Geo. E. Shambaugh.)



lies the suprameatal fossa.' (Macewen.) When opening the antrum through this triangle, the operator should work forward and medially, so as to avoid the transverse sinus (fig. 1074, 1078); while, to avoid the facial nerve (fig. 1075), he should hug the root of the zygoma and the upper part of the bony meatus as closely as possible. The level of the base of the brain will be a few mm. above the posterior root of the zygoma (fig. 1076) and about 6 mm. (¼ in.) above the roof of the bony meatus. (Macewen.)

B. The lower **mastoid cells** are developed later than is the antrum, and vary much in their contents. The condition of the mastoid cells varies very widely. They may be numerous (fig. 1075) or few. In the latter case they are replaced by diploë, or by bone which is unusually dense, without necessarily any pathological change. Hence mastoids have been classified as pneumatic, diploëtic, or sclerosed.

As part of the surgical anatomy of this most important region, the different paths by which infection of the tympanum and antrum may travel should be glanced at. The most important are:—(1) **Upward**: either by advancing caries or by infection of veins going to the superior petrosal sinus, or through the tegmen to the membranes; an abscess forming in the temporal lobe, usually the middle and back part. (2) **Backward**: the transverse (lateral) sinus and cerebellum (abscess of the front and outer part of the lateral lobe) are reached in the same ways as those given above, the mastoid vein being the one chiefly affected here. Macewen has shown that the bony wall of the sinus, like those of the tegmen and the aqueduct of Fallopius, may be naturally imperfect. (3) **Downward**: where the vertical cells are well developed mischief may reach the mastoid notch and cause deep-seated inflammation beneath the sternomastoid. (v. Bezold's abscess.) (4) **Lateralward**: the explanation of this, in early life, has been given above. (5) **Medialward**: the facial nerve, or by the fenestra ovalis; the labyrinth is now in

danger. When the internal ear and auditory nerve are affected, infection finds another ju to the cerebellar fossa.

The **sphenoidal sinuses** are less important surgically, but these points should be rem bered:—(1) Fracture through them may lead to bleeding from the nose, which is thus bro into communication with the middle fossa; (2) the communication of their mucous membra with that of the nose may explain the inveteracy of certain cases of polypi and ozæna; and in the frontal sinuses very dense exostoses are sometimes formed. Before any operat attack on these sinuses is undertaken, their most important relations should be remembe Thus above are the olfactory and optic nerves, the hypophysis (see p. 1342), and front of the po Externally lie the cavernous sinus and superior orbital (sphenoidal) fissure. Below is the r of the nose.

The relations of the various paranasal sinuses, including the **ethmoidal** and **maxill sinuses** are considered more in detail in connection with the sections on OSTEOLOGY and es cially the RESPIRATORY SYSTEM (pp. 1233).

CRANIOCEREBRAL TOPOGRAPHY

To make as clear as possible the points of practical importance which have late years, been put on a definite basis, and which the surgeon may have to re and act upon at very short notice, craniocerebral topography will be spoken under the following headings: A. **Relation of the brain as a whole to the sk** B. **Localization and relations of the chief sulci and gyri to the skull.**

Before alluding to the above, it is necessary to say distinctly that the following surf markings and points of guidance are only approximately reliable, for the following reas (1) In two individuals of the same age and sex the sulci and convolutions are never preci alike. (2) The relations of the convolutions and sulci to the surface vary in different indi uals. For age differences, cf. figs. 745 and 746. (3) That as the surface area of the s and outer aspect of the skull are greater than the surface area of the brain, and as the convex do not tally, lines drawn on the scalp or skull cannot always correspond precisely to cere convolutions or sulci. It results from the above that when a definite area of the surface is to correspond accurately in any individual to a definite area of the brain surface, this re has been correlated from many examinations; and that as surface-markings, shape, and proce of skull and arrangement of surface are all liable to variations in different individuals. surgeon must allow for these variations by removing more than that definite area of s which is said to correspond exactly to that part of the brain which he desires to expose. detailed relations of craniocerebral topography are not emphasized so much as formerly, h ever, for large flaps are now turned down so as to expose larger areas of the brain for ex ination.

A. **Relation of the brain as a whole to the skull** (figs. 1076, 1077).—To tr *the lower level of each cerebral hemisphere* on the skull, the chalk would start fr the lower part of the glabella; thence the line representing the lower borders of t frontal lobe pursues a course, slightly curved upward, about 0.8 cm. ($\frac{1}{3}$ i above the supraorbital margin; next, crossing the temporal crest about 1.2 c ($\frac{1}{2}$ in.) above the zygomatic (external angular) process, it passes not quite ho zontally but descending slightly to the region of the pterion (Sylvian point) the temporal fossa about 3.7 cm. ($1\frac{1}{2}$ in.) behind the zygomatic process. Fr this point the line of the level of the brain, now convex forward and correspondi to the anterior extremity of the temporal lobe, would dip down, still within t great wing of the sphenoid, to about the center of the zygoma. Thence the li of the lower border of the temporal lobe would travel along the upper border this process about 6 mm. ($\frac{1}{4}$ in.) above the roof of the external auditory meat (fig. 1076), and thence just above the base of the mastoid and the posterior i ferior angle of the parietal, and so along the linea nuchæ suprema, and correspon ing to the tentorium and horizontal part of the transverse (lateral) sinus, tot external occipital protuberance.

The **upper margin of each hemisphere** would be represented by a line drav from just below the glabella, sufficiently to one side of the midline to allow f the falx and superior sagittal sinus, to the inion. The *cerebellum* occupies th posterior cranial fossa, below the cerebral hemisphere, and behind the ear (fig 1076, 1077).

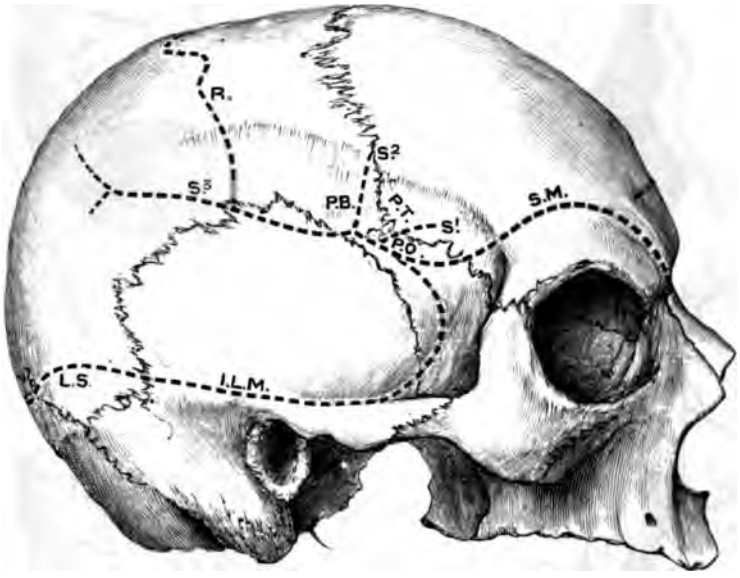
B. **Localization and relations of the chief sulci and gyri.**—It will be well fir to indicate the position of the chief sutures which mark off the parietal bon under which lies that part of the brain which is most important to the surgeon- the motor area. The upper limit of the bone will be indicated by the line alread spoken of as giving the upper margin of the hemisphere—the **sagittal line,** c **sagittal suture.** The anterior limit of the parietal bone, formed by the coron **suture,** may be traced thus: The point where it leaves the sagittal suture (th

bregma) will be found by drawing a line from a point just in front of the external auditory meatus (the preauricular point) (fig. 1072) straight upward on to the vertex; from this point a line drawn downward and forward to the middle of the zygomatic arch would indicate that of the coronal suture. Under this suture lie the posterior extremities of the three frontal convolutions; for the frontal lobe lies not only under the frontal bone, but extends backward under the anterior part of the parietal, the central sulcus (fissure of Rolando), which separates the frontal from the parietal lobe, lying from 3.7 to 5 cm. (1½ to 2 in.) behind the coronal suture at its upper extremity and about 2.5 cm. (1 in.) at its lower.

The squamoparietal suture, which marks the lower border of the anterior two-thirds of the parietal bone, is not so easy to define, owing to the irregularity and variations of its curve. Its highest point is usually 4.3 cm. (1¾ in.) above the zygoma.

FIG. 1076.—THE OUTLINE OF THE CEREBRUM IN RELATION TO THE SUTURES. (Cunningham.)

S.M. Superciliary margin of the cerebrum. I.L.M. Inferolateral margin of the cerebrum. L.S. Position of highest part of the arch of the transverse sinus. R. Central sulcus (Fissure of Rolando). s^1. Anterior horizontal limb of lateral fissure. s^2. Anterior ascending limb of lateral fissure. s^3. Posterior horizontal limb of lateral fissure P.B. Opercular portion of the inferior frontal convolution. P.T. Triangular portion of the inferior frontal convolution. P.O. Orbital portion of the inferior frontal convolution.



The lambdoid suture, which forms the posterior boundary of the parietal bone, will be marked out by a line which starts from a point (lambda) about 6.2 cm. (2½ in.) above the external occipital protuberance, and runs downward and forward to a point on a level with the zygoma, 3.7 cm. (1½ in.) behind and 1.2 cm. (½ in.) above the center of the meatus.

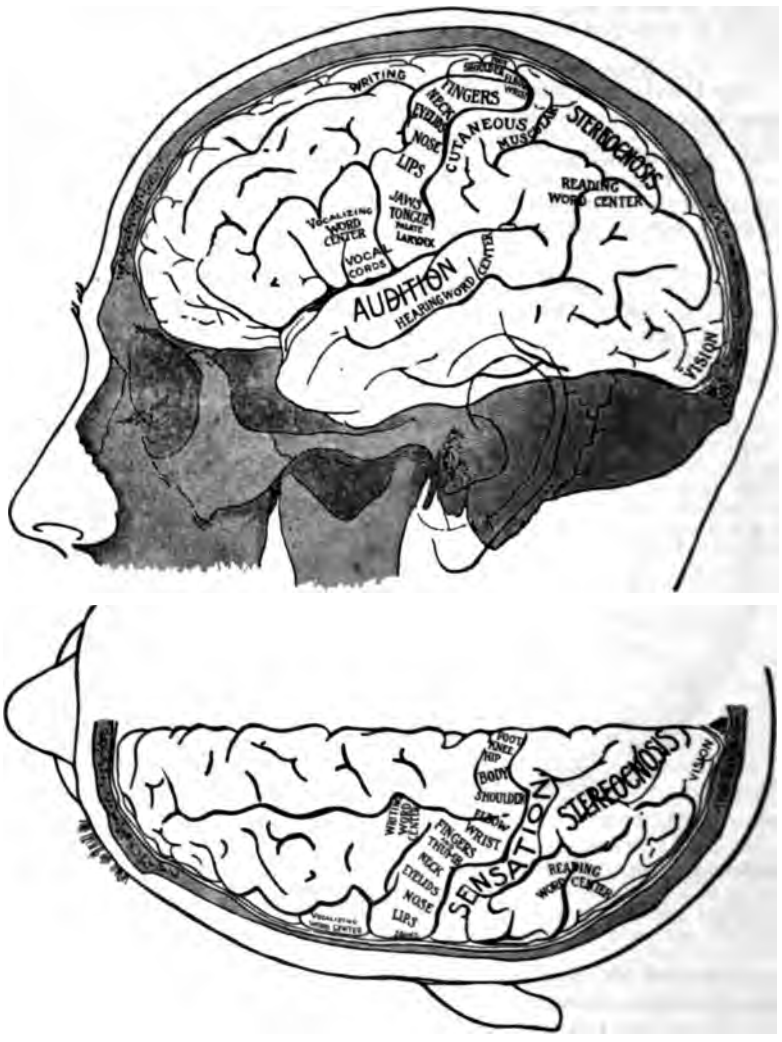
The position of the chief sulci (fissures) will now be given;—

Lateral (Sylvian) fissure (fig. 1076).—The point of appearance of this, on the outer side of the brain, practically corresponds to the pterion (fig. 1072)—a point which lies in the temporal fossa, about 3.7 cm. (1½ in.) behind the zygomatic process and about the same distance above the zygoma. From this point the lateral fissure, which here separates the frontal and parietal from the temporal lobe, runs backward and upward, ascending gently, at first in the line of the squamoparietal suture, then crossing this suture about its center and thence, ascending more rapidly, it climbs up to the temporal ridge, to end 1.8 cm. (¾ in.) below the parietal eminence. Its termination is surrounded by the supramarginal convolution, to which the parietal eminence corresponds with sufficient accuracy. Such being the surface-marking of the chief or posterior horizontal limb of the lateral fissure (s^3, fig. 1076), it remains to indicate briefly the two shorter limbs which bound the inferior frontal convolution, which, on the left side, contains the center for speech (Broca's convolution), and corresponds to a point lying three fingers' breadth vertically above the center of the zygo-

matic arch. (Stiles.) Of these, the anterior horizontal (s^1, fig. 1076) runs fo ward across the termination of the coronal, just above the line of the spheno parietal suture. The ascending limb (s^2, fig. 1076) runs upward for about 2 cm. (1 in.) just behind the termination of the coronal suture, or 3.7 cm. ($1\frac{1}{2}$ in behind the zygomatic process.

The central sulcus (fissure of Rolando).—This most important fissure, i front of which, in the precentral convolution of the frontal lobe, lie the moto

FIG 1077.—CEREBRAL TOPOGRAPHY AND LOCALIZATION. (Cushing, from Keen's Surgery.)



centers for the opposite side of the body, is situated under the parietal bone It may be marked out with sufficient precision in the following way (Thane) The sagittal line, from glabella to external occipital protuberance, is bisected and a point 1.2 cm. ($\frac{1}{2}$ in.) behind the center represents the superior Rolandic point. From this point a line drawn downward and forward 9 cm. ($3\frac{3}{4}$ in.) long at an angle of $67\frac{1}{2}°$ with the sagittal line (i.e., $\frac{3}{4}$ of a right angle) will represent the central sulcus. The lower extremity of this line is known as the inferior Rolandic point.

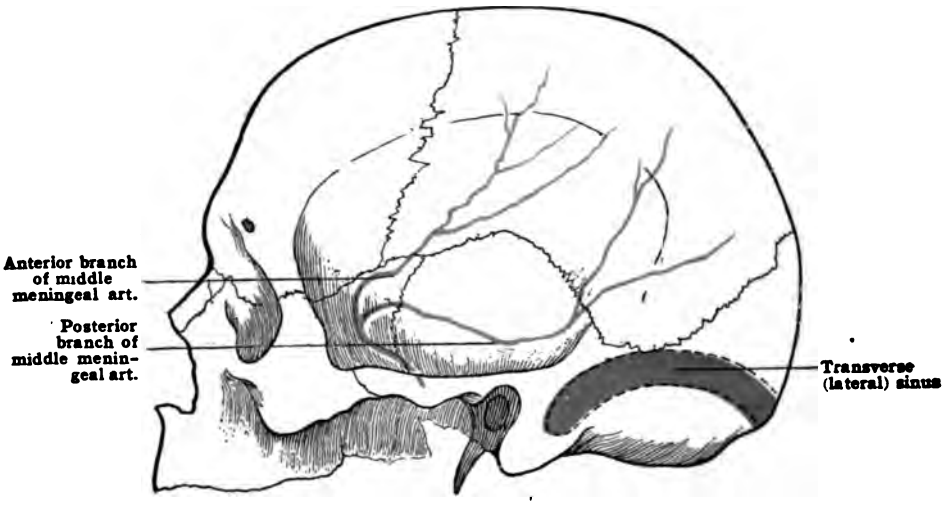
This method is open to the objection that it only applies to the average adult skull, and not to skulls of all sizes. To obviate this difficulty the method of Krönlein may be employed in addition (fig. 1072). Reid's base line BL is drawn through the lower border of the orbit and the upper border of the external acoustic meatus. Parallel to this an upper horizontal line UH is

marked out at the level of the upper margin of the orbit. Three lines vertical to the base line are now drawn, (1) at the posterior border of the mastoid process MR_1 (2) through the condyle of the lower jaw (CR_2), and (3) from the midpoint of the zygoma (ZS). The point R_1, where the first vertical joins the sagittal suture is the superior Rolandic point. The point S where the third vertical ZS cuts the line UH marks the junction of the three limbs of the lateral fissure. A line joining R and S will cut the second vertical CR_2 at the inferior Rolandic point, R_2.

The posterior limb of the lateral fissure also may be represented by a line bisecting the angle R_1SH and ending behind at the point S^1 where it cuts the vertical MR_1.

Reid's base line (fig. 1072, BL) is of importance in craniocerebral topography. The sigmoid portion of the *transverse (lateral) sinus* is at a point on the base line ¾ of an inch behind the center of the meatus. The transverse portion of the sinus is at a point an inch behind the meatus and ¼ of an inch above the base line. The *mastoid antrum* is at a point formed by the meeting of Reid's base line with a vertical line through the posterior border of the meatus (in the suprameatal triangle, fig. 1074). The trephine opening for *cerebral abscess* (temporosphenoidal) is ¾ of an inch above the base line at the posterior border of the meatus. The trephine opening for *cerebellar abscess* should be made an inch and a half behind the meatus on Reid's base line and ¼ of an inch below it. The relation to the lateral ventricle is mentioned below.

FIG. 1078.—LATERAL VIEW OF THE SKULL, SHOWING THE TOPOGRAPHY OF THE MIDDLE MENINGEAL ARTERY AND THE TRANSVERSE SINUS.



Some further *points in the surgical anatomy of the cranium* must be considered. The *middle meningeal artery*, entering the middle cranial fossa by the foramen spinosum, grooves the great wing of the sphenoid and divides into two branches (fig. 1078). The anterior grooves the anterior inferior angle of the parietal bone, and is then continued upward and slightly backward between the coronal suture and central sulcus, almost to the vertex; the posterior branch takes a lower level, running backward under the squamous bone to supply the parietal and anterior part of the occipital bones. If a skull, bisected anteroposteriorly, be held up to the light, it will be seen how thin are the bones over the chief branches of this vessel, thus accounting for the slight violence sometimes sufficient to rupture it. The groove it occupies in the parietal is sometimes converted into a canal. A wounded artery retracting here may be very difficult to secure. The veins which accompany the artery and which lie lateral to it in the groove are thin-walled and sinus-like before they open into the sphenoparietal sinus, another explanation of the obstinacy of this hemorrhage. According to the point of rupture, three hematomata should be remembered (Krönlein), anterior or frontotemporal; middle, or temporoparietal; and posterior, or parietooccipital. The first two are much the most frequent, and exposure of the pterion, with free removal of the adjacent bones will suffice for dealing with them.

Drainage of the lateral ventricle.—(1) Where the anterior fontanelle is closed, Poirier and Keen have opened the inferior cornu through the middle temporal convolution, the pin of the trephine being placed 3.1 cm. (1¼ in.) behind the external auditory meatus, and about the same distance above Reid's base line. The needle should here be directed to a point about 5 cm. (2 in.) above the opposite ear. (2) Kocher's point for draining the lateral ventricle is taken over the frontal lobe 2.5 cm. from the median line and 3 cm. in front of the upper Rolandic point. The needle is passed downward and a little backward to a depth of 4 or 5 cm.

Puncture of the corpus callosum is employed to lessen intracranial pressure in cases of inoperable or unlocalized brain-lesions where there is an internal hydrocephalus. A communication is thus established between the ventricles and the subdural space. The anterior and middle thirds of the corpus are the best sites as the corpus is thinnest and the lateral ventricle on one or the other side is sure to be opened. The callosum is usually punctured at a point a finger's breadth behind the bregma and to the side in order to avoid the superior sagittal sinus.

Up to this point the **outside** of the cranium has been mainly considered; it remains to draw

attention to some of the chief points in the surgical anatomy of the interior, especially of t base. The three fossæ are of paramount importance in fractures. In the anterior fo the delicacy of parts of the floor, the connection of this with the nose and orbit, and the ex adaptation of its irregular surface to that of the frontal lobes, no 'water-bed' intervening, the chief points. Thus the slightness of a fatal fissure, the frequent presence of bruising af a blow perhaps on the occiput, which has been considered to have caused only concussion, characteristic palpebral hemorrhage, and the infection of a fracture here are all explain together with the possibility and gravity of a fracture here from a severe blow on the nose. the middle fossa the frequency of fractures is explained by the facts that while here, as in other fossæ, a fracture often radiates down from the vertex, the overlying vault being a reg often struck, the base is weakened by numerous foramina and fissures. Further, the resist power of the petrous bone must be lessened by the cavities for the internal ear, the caro and, to a less degree, by the jugular fossa. For fluids to escape through the external mea the dura, the prolongation of the arachnoid into the internal meatus, the membrani tymp and probably the internal ear, must all be injured. The presence of the middle meningeal art (fig. 1078) and the cavernous sinus in this fossa must also be remembered, especially in s operations as that on the Gasserian ganglion. Posterior fossa: It is not sufficiently recogni that fractures here are, owing to the anatomy of the parts, in some respects the most import of all. It is here that a small fissure-fracture, ultimately fatal, with severe occipital and fro bruising and some intradural hemorrhage, has been so often overlooked, especially in drunken. This is explained by the supposed strength of the bone, this being really very thi places, by the thickness of the soft parts, and the abundance of hair. Further, there is no v apparent escape of cerebral contents as in the anterior and middle fossæ. Blood, etc., n trickle into the pharynx far back, or a deep-seated ecchymosis coming up after two days, un the muscles about the mastoid process, may call attention to the damage within.

Dura mater.—The outer layer of this membrane acts as a periosteum, by bringing blo vessels to the bone, while the inner layer supports the brain. The influence of its partitions a its damping effect on vibrations is great in blows on the head. Its varying adhesions, accord to site and age, must be remembered. Thus while it is intimately connected over the b with its adhesions to the different foramina, it is more loosely connected with the vault, a shown in middle meningeal hemorrhage. In early and later life the closeness of its connecti with the bones is also more marked. It is united to the inter-sutural membranes.

Finally, the existence of the cerebrospinal fluid with its power of lessening the evil of brations and its aid in regulating intracranial pressure, must be borne in mind. The ch collections, in which the subarachnoid meshwork is almost absent, are met with in front a behind the medulla. That in front, also lying under the pons, Hilton's 'water-be ,' sen a prolongation forward to the optic chiasma, but does not extend under the frontal or tempo lobes. The collection behind lies between the medulla and under surface of the cerebellu Here, by the foramen of Magendie, the intraventricular cavities communicate with the su arachnoid space of the brain and spinal cord.

The hypophysis cerebri.—The hypophysis (pituitary body) has assumed ne clinical importance because of recent experimental and clinical studies. It li in the sella turcica (figs. 1068–1070) and consists of three parts: the pars anteri and pars intermedia, both of which are derived from buccal ectoderm, and t pars nervosa which is composed of nervous tissue, a downgrowth from the flo of the third ventricle. Its structure is described under GLANDS OF INTERNA SECRETION, p. 1326.

Apart from the general skeletal and nutritional changes (acromegaly and Fröhlich's sy drome), which are caused by alteration in the function of the gland, pressure-effects up neighboring structures, especially upon the optic nerve and adjacent bones, are noted as t gland enlarges. The anterior lobe as it enlarges is apt to erode and expand the floor of the sel pushing toward the sphenoidal sinus. Interpeduncular tumors on the other hand widen t entrance to the sella, causing destruction of the clinoid processes. The enlargements may detected by lateral radiograms. The normal size of the adult hypophyseal fossa is 10 to 12 m from before backward and 8 mm. from above downward.

There are three surgical approaches to the hypophysis. In one, employed by Cushin Kanavel and Halsted, a sublabial incision is made in the vestibule of the mouth and through the mucosa is separated from each side of the nasal septum back to the sphenoidal sinus. submucous resection of the septum is then made, the floor of the sphenoidal sinus is remove the hypophyseal fossa is opened and a part of the gland removed. The frontal approach to t hypophysis (McArthur and Frazier) is used by many because of the lessened risk of infectio In this operation a plastic operation is performed upon the frontal bone, the optic foramen located and the dura incised at this level to permit of exposure of the hypophysis. In Heue operation a large flap is turned down on the side and front of the skull and an intradural a proach is employed. Text-books upon operative surgery or special articles dealing with the should be consulted for details.

THE FACE

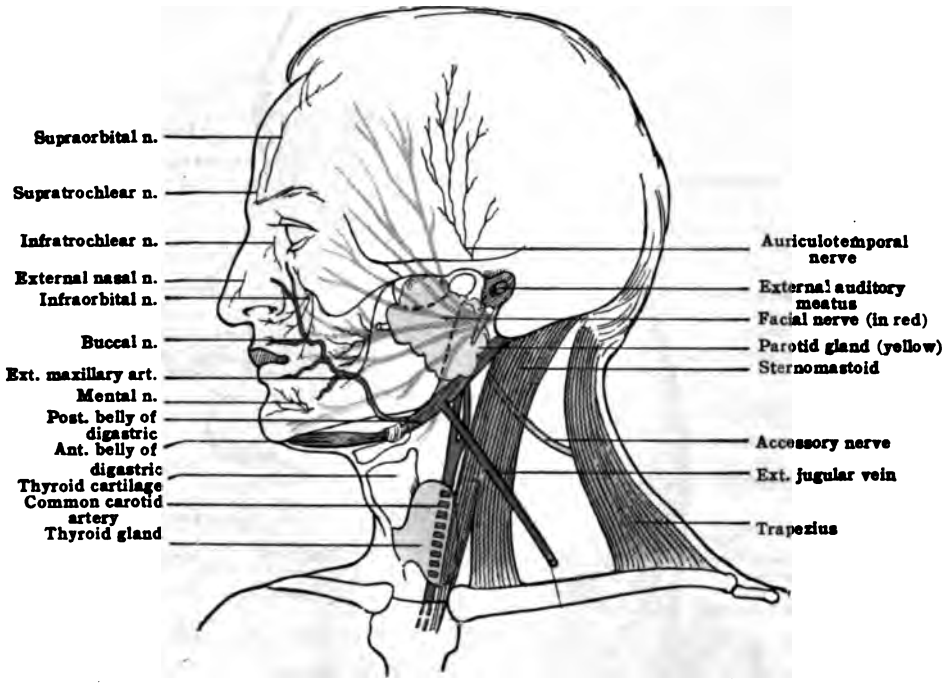
The topics included under this heading are the arteries, parotid region, nerve mandible and maxilla, orbit, mouth, palate and nose.

The outline of the different bones nasal, upper and lower jaws, zygomati and zygoma can be readily traced. The last mentioned and the glabella a

alluded to on pp. 1331 and 1332; and the canine fossa should be identified as one of the antral routes. The delicacy, laxity, and vascularity of the skin are of great importance in all operations, while the abundance of large gland orifices accounts for the frequency of lupus here.

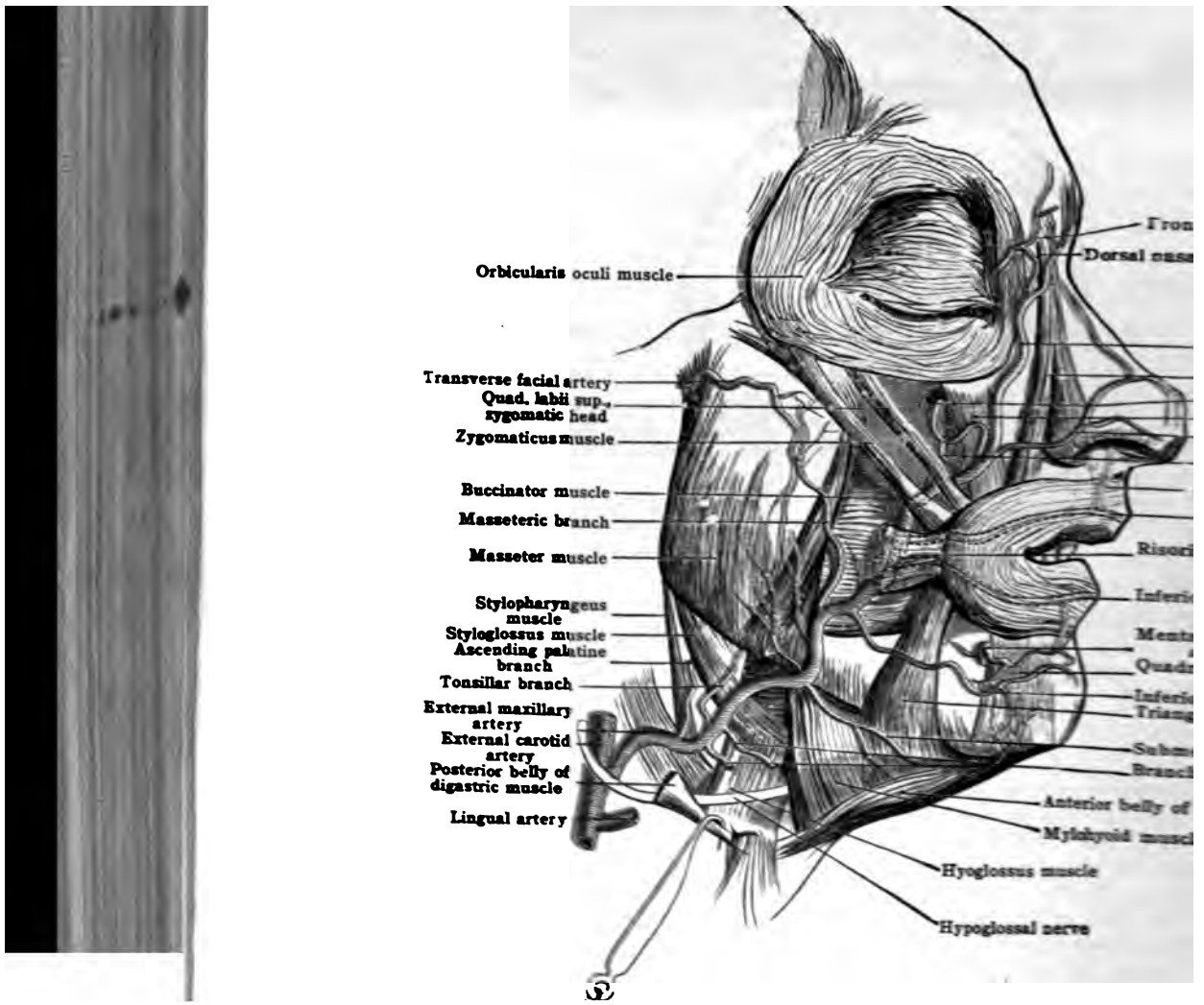
Arteries.—The **supraorbital artery** can be felt beating just above its notch (junction of medial with lateral two-thirds of supraorbital margin); the small **frontal artery** is of importance, as it nourishes the flap when a new nose is taken from the forehead; the **superficial temporal,** accompanied by the auriculotemporal nerve, can be felt where it crosses the root of the zygoma just in front of the tragus, its anterior branch about 3.1 cm. (1¼ in.) above and behind the zygomatic process of the frontal; the **occipital,** accompanied by the great occipital nerve (fig. 494), pulsates to the medial side of the center of a line drawn from the occipital protuberance to the mastoid process; the **posterior auricular,** rather deeply, between the auricle and the mastoid process. The **external carotid** lies behind

FIG. 1079.—SURFACE RELATIONS OF VESSELS AND NERVES IN LATERAL VIEW OF THE FACE AND NECK.



the ascending ramus of the mandible. The **external maxillary** (facial) (figs. 1079, 1080) crosses the jaw just in front of the masseter; if divided, both ends must be ligated here. It can be felt again a little behind the angle of the mouth, just beneath the mucous membrane (where it gives off the labial branches, which can also be felt, lying deeply, if the lip is taken between the finger and thumb); and again by the side of the nose, as it runs up to the medial angle (canthus) of the eye. The small angular branch is, from its position, always troublesome to secure. To trace the course of the **external maxillary** artery a line should be drawn from a point a little above and lateral to the tip of the great cornu of the hyoid to the lower part of the anterior border of the masseter, and thence to one lateral to and above the angle of the mouth, and so onward, lateral to the angle of the nose, up to the medial angle. The **anterior facial vein** (fig. 562) takes a straight course behind the tortuous external maxillary artery. The absence of valves and its communication by the angular and ophthalmic veins with the cavernous sinus, and, by the deep facial, with the pterygoid plexus, are of grave importance in infective thrombosis. The external jugular vein will be mentioned later.

Parotid region.—A line drawn from the lower border of the meatus to a point midway between the nose and upper lip gives the level of the **parotid** (Stenson's)


Orbicularis oculi muscle
Transverse facial artery
Quad. labii sup., zygomatic head
Zygomaticus muscle
Buccinator muscle
Masseteric branch
Masseter muscle
Stylopharyngeus muscle
Styloglossus muscle
Ascending palatine branch
Tonsillar branch
External maxillary artery
External carotid artery
Posterior belly of digastric muscle
Lingual artery
Hyoglossus muscle
Hypoglossal nerve

and sternomastoid; *in front* the gland and socia parotidis overlap the posterior part of the masseter, to a variable degree.

Sensory nerves.—The cutaneous nerve areas of the face are shown in figs. 805, 1079. The **supraorbital** nerve, the main sensory branch of the ophthalmic, emerges from the orbit with its companion artery through the notch (occasionally a foramen) at the junction of the medial third and lateral two-thirds of the supraorbital margin. A line drawn from the supraorbital notch downward across the interval between the bicuspid teeth will cross the **infraorbital foramen** from which emerges the **infraorbital nerve,** the main terminal division of the maxillary, at a point 1 cm. below the orbital margin. The mental foramen, the point of exit of the *mental nerve*, a branch of the inferior alveolar, is found on a prolongation of the same line midway between the upper and lower margins of the mandible in the adult.

In the infant in whom the alveolar element of the jaw is relatively large, the mental foramen is nearer the lower margin, while in the edentulous jaw of old age it is found much nearer the upper margin. In trephining to expose the inferior alveolar (dental) nerve, one of the common seats of neuralgia and one in which a peripheral operation is justified from the results, the ascending ramus is opened midway between its anterior and posterior borders, on a level with the last molar.

The **semilunar (Gasserian) ganglion** lies at a depth of 5.5–6 cm. (2¼ in.) under the eminentia articularis. In exposing it for the purpose of excision for intractable neuralgia the following structures are encountered: (1) Skin and superficial fascia with branches of the superficial temporal artery; (2) temporal fascia and muscle with deep temporal vessels; (3) squamous bone and great wing of sphenoid, which are trephined, the floor of the middle fossa being gouged away; (4) middle meningeal vessels and dura mater. By elevating the dura mater and superimposed temporal lobe, and securing the middle meningeal artery, the ganglion is exposed, lying in a separate compartment [cavum Meckelii] of the dura, which contains cerebrospinal fluid. The motor nerve of the muscles of mastication lies on the lower and medial aspect of the ganglion, and should not be divided. Division of the sensory root of the ganglion is a simpler operation than removal of the ganglion and the results are more satisfactory.

Injection of the mandibular nerve with alcohol, by means of a long stout hypodermic needle is practised in cases of intractable neuralgia as an alternative to excision of the semilunar ganglion. A vertical line is drawn on the cheek downward from the junction of the posterior and middle thirds of the zygomatic arch, and the needle is entered on this line at a point 1.5 cm. from the lower border of the zygoma. It is directed upward and medially so as to pass through the lowest part of the mandibular notch. If the mouth is opened the notch is depressed and more room gained. The needle impinges first against the inferior surface of the great wing of the sphenoid bone, and when the point is lowered a little it engages in the foramen ovale at a depth of 4–4.5 cm. In most cases the needle can be passed through the foramen ovale into the semilunar ganglion. (Harris. Lancet, Jan. 23, 1912.)

The **maxillary nerve** may be injected by passing a needle along the floor of the orbit from its inferolateral angle in a direction backward and slightly medially to the foramen rotundum which lies 4.5 cm. from the surface.

Facial nerve.—In the petrous bone the course of this nerve is first outward and forward, then, having entered the facial canal, backward and downward along the medial wall of the tympanum, above the fenestra ovalis. Emerging from the stylomastoid foramen the nerve takes first the line of the posterior belly of the digastric, running forward and a little downward from the anterior border of the mastoid where this meets the auricle (Godlee.) Entering at once the posterior part of the parotid, it crosses the neck of the mandible at the level of the lower border of the tragus (figs. 770, 1079).

The frequent paralysis of this nerve may thus depend upon—(1) cerebral causes; (2) disease of or injury to the petrous portion; (3) affections after its exit—Bell's paralysis. A diagnosis may be arrived at by attention to the following. In *cerebral disease* the lower part of the face is chiefly affected, the eyelids usually escaping. In paralysis due to involvement of the upper motor centers the orbicularis oculi, frontal and corrugator muscles are not affected. Hemiplegia of the opposite side of the body and paralysis of the sixth nerve are usually present. In all the other forms the whole side of the face is paralyzed. In *petrous paralysis*, owing to involvement of the chorda tympani, there may be interference with the saliva and taste, affecting especially the anterior part of the tongue. The auditory nerve may also be affected. Here and in (3) there will be a history of disease or injury. In complete paralysis the smooth side of the face and forehead, the absence of power of expression, to frown, to blow, or whistle, the open eyelids and epiphora, and subsequent liability to mischief in the cornea, the dropping of the angle of the mouth and dribbling of saliva, the interference with mastication from paralysis of the buccinator, are the chief points. For the relations of the facial nerve and parotid gland, see p. 1146.

Mandible.—Dislocation of the mandibular joint is referred to on p. 260. In the usual **dislocation,** from muscular action, the jaw is suddenly brought forward against the anterior part of the capsule, which tends, by the action of the

depressors, to give way; the elevators then pull up the **mandible**, a sequence t must be remembered in reduction. In the commonest **fracture** of the mandibl unilateral, near the mental foramen—the larger anterior **fragment** will be pu by the depressors downward and medially, the smaller **posterior** one upw and usually lateral to the other fragment.

Maxilla.—The boundaries of the **maxillary sinus** (**antrum**) are of much portance. The base of this irregularly pyramidal cavity corresponds to middle and inferior meatuses on the lateral wall of the **nose**; toward the up and back part is the opening into the middle meatus. The **apex** runs later toward the zygomatic process. The roof is formed by the **orbital plate** with infraorbital nerve and vessels anteriorly; the floor by the **junction of the alve** arch, carrying the first molars (and often the bicuspids), **with the hard pal** It may be pierced by the roots of the second bicuspid or **first and second m** teeth. Anteriorly, the antrum is in relation with the **canine fossa**; posteric with the zygomatic fossa. The cavity, present at birth, **increases gradually** to the twelfth year. (For further details, see p. 1235).

The chief paths of infection are through the teeth (especially the **first and second mo** the nose, and frontal sinus. The obstinacy of inflammation here is explained by the site of opening, high up on the medial wall, and thus inadequate drainage, by the imperfectly m locular cavity of the interior and its rigid walls. The chief sites for *opening the antrum* are— through the sockets of the first or second molars; (*b*) through the canine fossa, after the ref tion of mucous membrane has been detached, midway between the roots of the teeth and infraorbital foramen (this path gives more room); (*c*) through the inferior meatus of the n

THE ORBIT AND EYE

The **bony orbit** (figs. 842–845, 975) is a pyramidal fossa with its **base** at t orbital margin and its **apex** at the optic foramen. The medial walls of the tw orbits are approximately parallel, but the lateral walls diverge as they are trac forward and lie at right angles to each other. The thin **floor** which is form mainly by the maxilla and corresponds to the roof of the maxillary sinus, readily destroyed by growths extending up from the sinus and in the proce pressure on the infraorbital nerve is apt to cause pain referred to the cheek. Th **roof** formed by the orbital plate of the frontal bone is also thin, and foreign bodie thrust into the orbit may perforate it and enter the frontal lobe of the cerebrum The **medial wall** is chiefly constituted by the lacrimal and lamina papyracea o the ethmoid, both very thin bones.

Injuries of the medial wall such as may be associated with fractures of the nose bring th ethmoidal air cells into communication with the cellular tissue of the orbit. The latter may thu be distended with air on attempting to blow the nose. This wall is readily destroyed by mal ignant growths of the nose.

The **lateral wall** is formed in its anterior third by the zygomatic bone, whic separates the orbit from the zygomatic fossa. The posterior **two-thirds** formed by the sphenoid bone separate the orbit from the temporal lobe of the brain i the middle cranial fossa. The orbit communicates with the **cranium** by the optic foramen, which transmits the optic nerve and ophthalmic **artery** and by th superior orbital fissure through which pass all the other vessels and nerves of th orbit.

In cases of fracture of the base of the skull involving the anterior clinoid process, a traumati communication (arteriovenous aneurysm) may be formed between the internal carotid arter and cavernous sinus, behind the apex of the orbit, giving rise to pulsating exophthalmos.

The **orbital margin** is larger in the transverse than in the vertical direction and consequently there is more space on either side than above and below be tween it and the eyeball, which is nearly spherical. The eyeball lies nearer to th medial than to the lateral margin and hence foreign bodies more commonly penetrate the orbit to the lateral side of the eye.

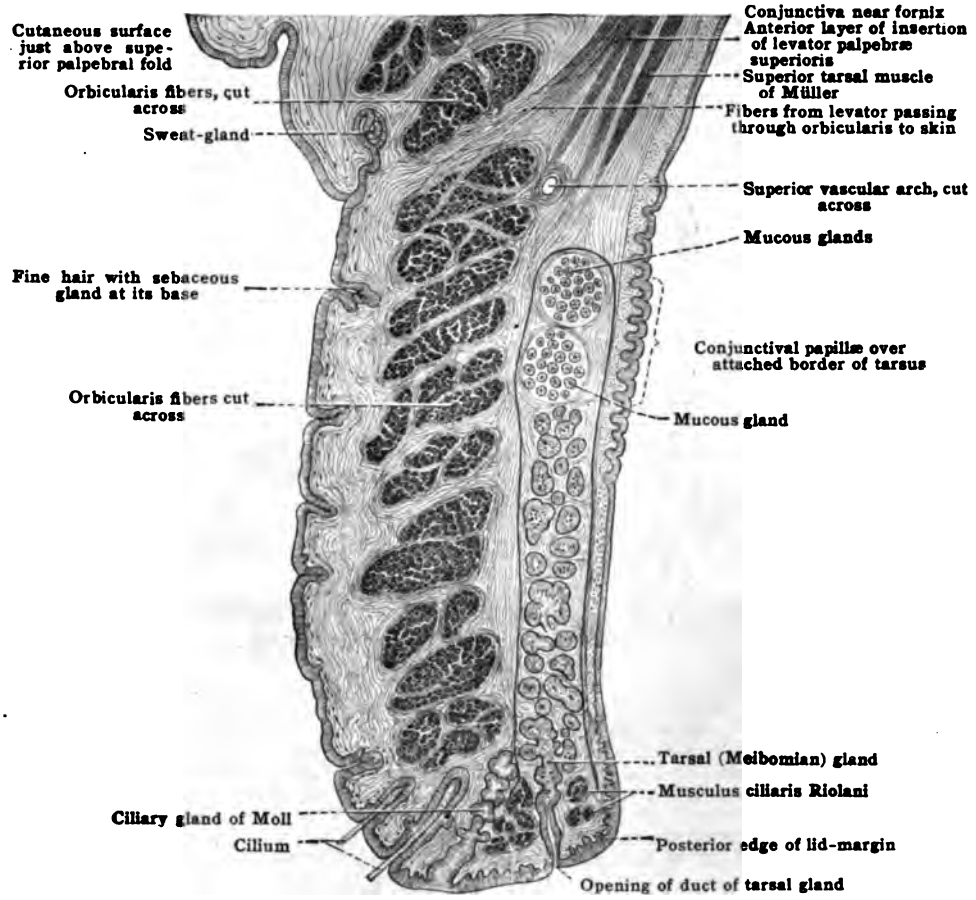
Behind the **fascia bulbi**, the eyeball rests on a mass of **soft loose orbital fa** (figs. 847, 848) in which foreign bodies may be hidden for a considerable time.

The structure of the eyelids.—The different layers (**fig. 1081**) are of mucl practical importance. (1) The **skin** is delicate and fatless, and contains pigment the object of this being to protect the eye from bright light. It helps to explai the 'dark circles' of later life. (2) **Subcutaneous areolar tissue.** Owing to its looseness and delicacy, this is very liable to infiltration, as in **edema and erysipelas**

(3) **Orbicularis oculi.** Paralysis of this, the palpebral portion, leads to epiphora, the puncta being no longer kept in their normal backward direction against the conjunctiva. (4) **Palpebral fascia,** reaching from the orbit to the tarsal cartilage. This is usually strong enough to prevent hemorrhage, due to fractured base of skull, becoming subcutaneous. (5) **Levator palpebræ.** (6) **Tarsal plate,** consisting of densely felted fibrous tissue. (7) **Tarsal** (Meibomian) **glands, lashes, and sebaceous follicles.**

Localized inflammation starting in any of these last three structures, especially the last, will cause a 'stye.' The frequency with which the lid-border is the seat of that most troublesome chronic inflammation, blepharitis, and its result, 'blear eye,' is explained by these anatomical points. Its circulation is terminal and slow; half skin and half mucous membrane, it is moister and more liable to local irritation than the skin; while its numerous glands readily participate in any inflammation.

FIG. 1081.—SAGITTAL SECTION THROUGH THE UPPER EYELID. (After Waldeyer and Fuchs.)


Cutaneous surface just above superior palpebral fold
Orbicularis fibers, cut across
Sweat-gland
Fine hair with sebaceous gland at its base
Orbicularis fibers cut across
Ciliary gland of Moll
Cilium
Conjunctiva near fornix
Anterior layer of insertion of levator palpebræ superioris
Superior tarsal muscle of Müller
Fibers from levator passing through orbicularis to skin
Superior vascular arch, cut across
Mucous glands
Conjunctival papillæ over attached border of tarsus
Mucous gland
Tarsal (Meibomian) gland
Musculus ciliaris Riolani
Posterior edge of lid-margin
Opening of duct of tarsal gland

(8) **The conjunctiva.** To trace this important membrane, the lids should be everted, when the following will be noted. The conjunctiva over the tarsal part of the lid is closely adherent, and through it a series of nearly straight, parallel, light yellow lines and granules, the tarsal glands, can be seen. Owing to their position here (fig. 1081) and to avoid scarring, a tarsal cyst is always opened on its conjunctival surface.

Beyond the tarsi, the palpebral conjunctiva is thicker and freely movable owing to the abundant lax submucous tissue. Underlying vessels are visible here. Leaving the eyelid the conjunctiva is reflected onto the eyeball at the **fornix** (cf. fig. 845). Into the lateral part of the upper fornix open the ducts of the lacrimal gland (fig. 854). The bulbar conjunctiva is continued over the front of the eyeball to the corneal margin. It is thin and contains fine vessels which are distinguished from subjacent episcleral vessels by the fact that they move with the conjunctiva.

These **conjunctival vessels**, derived from the lacrimal and palpebral arteries, become easi visible in conjunctivitis. In deep inflammation affecting the iris and ciliary body, the episcle branches of the anterior ciliary arteries (which are derived from the muscular and lacrim arteries) become engorged and are visible as a pink circumcorneal zone of congestion, deep situated under the conjunctiva. These branches take a large share in the nutrition of the corne and are responsible for the vascularity of *pannus* and the '*salmon-patches*' of interstitial kerati

The **conjunctival nerves** for the upper lid and bulbar part of the membrane, and the nerv to the cornea, are supplied by the ophthalmic division of the trigeminal. The maxillary di sion of this nerve supplies the lower palpebral conjunctiva.

The differing structure of the palpebral and ocular portions has important bearings. Th the palpebral conjunctiva is thick, highly vascular and sensitive. To this vascularity we ow the chemosis, or hot, red, tense swelling of purulent ophthalmia. The exquisite suffering the same disease, or that caused by a foreign body, is explained by the numerous nerve-papill and end-bulbs. To the thickness and abundance of the connective tissue are due the contra tion and permanent thickening which may occur in granular lids. The so-called granulation met with in this disease on the palpebral conjunctiva, are really little nodules of hypertrophie lymphoid follicles, or mucous glands, which abound here.

FIG. 1082.—THE LACRIMAL APPARATUS AND NASOLACRIMAL DUCT. (Bellamy.)
(Bristles are introduced into the puncta lacrimalia.)

Immediately under the bulbar conjunctiva, between it and the sclerotic, lies the anterior part of the **fascia bulbi** (of Tenon). This fibrous membrane forms a sheath for the posterior five-sixths of the eyeball, and is intimately connected with the sheaths of the extrinsic muscles and through the **check ligaments** with the orbital walls (figs. 847, 848). Together with the conjunctiva it must be opened in the operation of tenotomy for strabismus, and after division of a rectus tendon the muscle retains some control over the eye through its connection with the fascia bulbi. In enucleation of the eyeball both conjunctiva and fascia bulbi are divided around the cornea, where they are intimately blended. In removal of the upper jaw the attachment of the suspensory ligament of this fascia must always be left if possible, for otherwise the eyeball will tend to fall forward and the cornea suffer from its exposure (Lockwood). Finally the cavity between the two layers of the capsule is continuous with the extensions of the cere bral membranes along the optic nerve, i. e., with the subarachnoid space.

For an account of the intrinsic and extrinsic muscles of the eye the reader is referred to the section on the EYE. Reference may be made here, however, to the part played by certain fiber of the **cervical sympathetic** system (cf. fig. 744). Emerging from the cord at the first and second thoracic segments, the communicating fibers pass up the sympathetic chain in the neck to cell-stations in the superior cervical ganglion. Thence continuing onward through the caro tid canal and superior orbital fissure, they supply (1) the dilator muscle of the iris, (2) the un striped muscle element in the eyelids, and (3) smooth muscle-fibers, described by Sappey in the check ligaments and fascia bulbi. Paralysis of the cervical sympathetic nerve in the neck, usually in its lowest part, by trauma or the pressure of a malignant growth, causes there fore (1) narrowing of the pupil, (2) narrowing of the palpebral fissure (pseudoptosis), and (3 enophthalmos. These symptoms may be observed in fractures of the spinal column involving the lower cervical vertebræ.

The **lacrimal gland** lies in a hollow at the superolateral angle of the orbit protected by the zygomatic process of the frontal bone. It is not palpable nor mally. Its lower or palpebral portion rests on the lateral third of the fornix

conjunctiva, into which the numerous ducts open, and it may be seen through the conjunctiva on everting and raising the upper lid.

The **position of the lacrimal puncta** should be noted; owing to their backward direction, the lids must be previously everted. The puncta are kept open by a minute fibrous ring.

Each is situated on a minute papilla. Close to the medial angle, in addition to the puncta and papilla, should be noted the caruncula lacrimalis, with its delicate hairs, and the plica semilunaris, which corresponds to the third eyelid of certain birds.

The **lacrimal sac** is a most important part of the lacrimal apparatus, from its disfiguring diseases; it lies in a bony groove, between the nasal process of the maxilla and the lacrimal bone. The medial palpebral ligament crosses it a little above its center (figs. 854, 1082). Thus two-thirds of the sac are below the ligament, and in suppuration the opening is made below it also. The angular artery ascends on the nasal side of the sac.

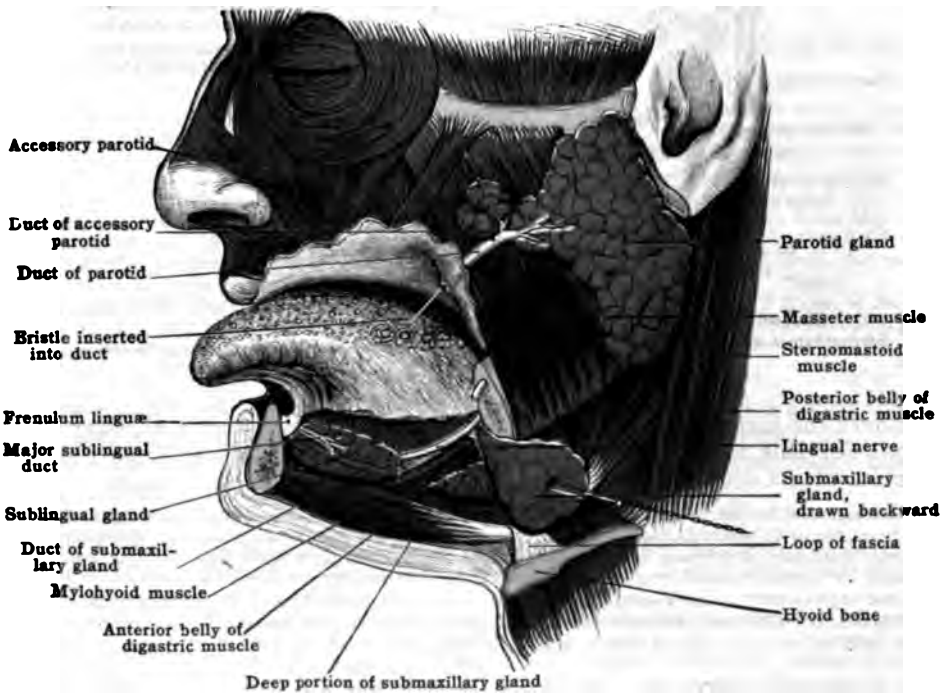
The **manipulation of a probe along the lacrimal passages** should thus be practised:—the lower lid being drawn laterally and downward by the thumb, the probe is passed vertically into the punctum, then turned horizontally and passed on till it reaches the medial wall of the sac. It is then rotated somewhat forward, raised vertically, and pushed gently along the duct downward, and a little lateralward and backward, till the floor of the nose is reached, the operator aiming, as it were, for the site of the first molar tooth. The *nasolacrimal duct* extends from the lower end of the lacrimal sac to the inferior meatus of the nose and is about 1.2 cm. (½ in.) in length.

If the eyes are opened naturally, the greatest part of the cornea, behind it the iris, with the pupil in the center, on either side of the cornea some of the sclerotic, the semilunar fold, and caruncle can be seen. For further details, see section on the EYE.

THE MOUTH

The lips.—When the whole thickness of the lip is incised the labial artery will be found lying near the free margin, internal to the orbicularis muscle, and

FIG. 1083.—SIDE OF THE FACE AND MOUTH CAVITY, SHOWING THE THREE SALIVARY GLANDS.



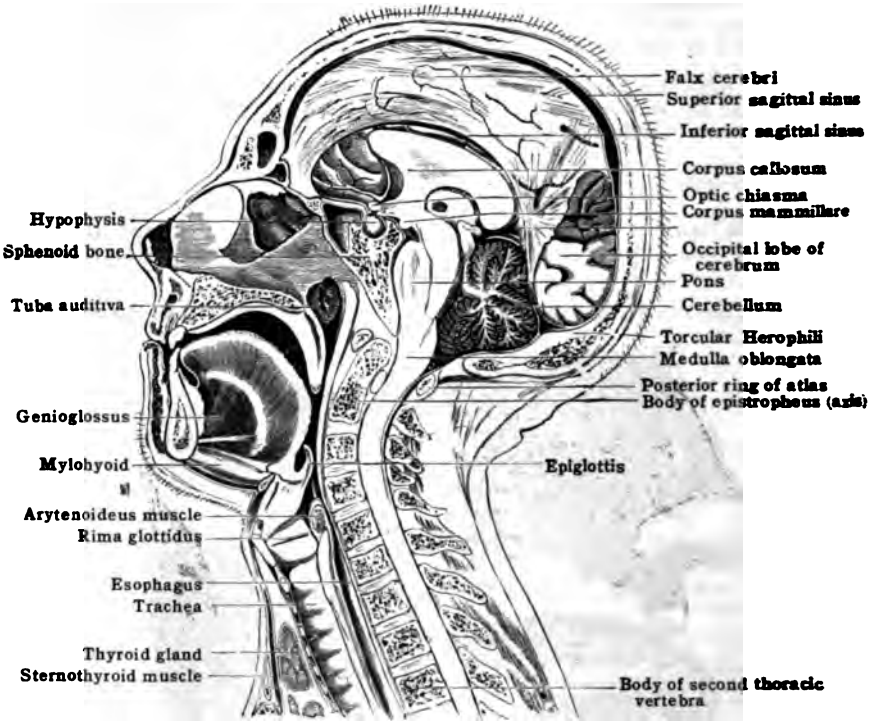
between it and the mucosa. There is a very free anastomosis between the arteries of the opposite sides.

If the tongue be raised, the under surface is seen to be smooth and devoid of papillæ. In the middle line is the **frenulum** (figs. 884, 1083). When division of this is really required (which is not often) in tongue-tie, the scissors should be kept close to the bone, in order to avoid the ranine vessels.

Of these, the veins can be seen just to one side; the arteries are close by, but deeper. Farther out are two more or less distinct fringed folds, the plicæ fimbriatæ, running from behind forward and, like the frenulum, disappearing before the tip. Between these and the frenulum are the small apical mucous glands of Nuhn or Blandin. A retention cyst of this gland is called a ranula, as it resembles a frog's belly in the floor of the mouth. Further back, at the junction of the mucous membrane and the alveoli, are two other projections of the mucosa, the sublingual; under these are the sublingual glands, the ranine veins, and, more deeply, Wharton's duct (in which salivary calculi are occasionally found) and the termination of the lingual nerve. The majority of the ducts of the sublingual gland (Rivinian) open on the sublingual ridges. A single larger one, Bartholin's, opens with that of Wharton, or close to it, on either side of the frenulum (fig. 1083).

The **submaxillary gland** can be felt nearer the angle of the jaw, lying between its fossa and the mucous membrane, especially if pressure is made from outside. The attachment of the **genioglossi** can be felt behind the symphysis: the division of the muscles allows the **tongue** to come well out of the mouth; but when both have to be divided, the tongue loses much of its steadiness, and may easily fall

FIG. 1084.—MIDSAGITTAL SECTION OF THE HEAD AND NECK. (Braune.)



back over the larynx during the administration of the anesthetic or, later on, in sleep. For this reason, in removal of one-half of the mandible, part of this muscular attachment should always be left, if possible.

Turning now to the dorsum of the tongue (figs. 889, 1083), this shows two distinct parts: one, the anterior two-thirds, *the buccal*, is rich in papillæ; the other, the posterior, the *pharyngeal*, contains abundant lymphoid follicles like the tonsil. This part possesses peculiar sensibility, as shown by movements of tongue and palate when a depressor is placed too far back. The two parts are separated by the V-shaped arrangement of the vallate papillæ, with the apex turned backward. Immediately behind the apical vallate papilla is a small pit, the foramen cecum which represents the upper remains of the thyroglossal tract, and may be the seat of lingual thyroid growths. While the tongue is mainly a muscular organ, the fine fatty connective tissue in the septum and between the muscular bundles is the seat of that dangerous condition, acute glossitis, and of gummatous infiltration. While the mouth is widely open, the pterygo-mandibular ligament can be seen and felt beneath the mucous membrane, behind the last molar tooth. Just below and in front of the lower attachment of this ligament the lingual nerve can be felt lying close to the bone below the last molar. The simplest and surest method of dividing the nerve here, to give relief from pain in incurable carcinoma of the tongue, is to draw the tongue out of the mouth and expose the nerve where it lies superficially under the mucous membrane thus made prominent between the side of the tongue and the gums, the center of the incision being opposite to the last molar tooth. (Roser, Létiévant.) In cancer of the tongue pain is often referred up the auriculotemporal nerve to the ear and side of head.

Behind the last molar tooth can be felt the **coronoid process,** and higher up, just behind and medial to the tooth, the **pterygoid hamulus of the sphenoid.** This process is a landmark to the site of the greater palatine foramen, which lies just in front of it, and which transmits the greater palatine branch of the descending palatine artery, together with the anterior palatine nerve. The vessel and nerve run forward in grooves on the lower surface of the palatine process of the maxilla, giving off anastomosing branches toward the middle line, and join at the incisive foramen with the nasopalatine artery.

Their position must be remembered in raising the flaps during the operation for closure of a cleft in the hard palate. To ensure the vitality of the flaps the incisions must be made lateral to the vascular arch, close to and parallel with the upper alveolus, and should not extend beyond a point opposite to and just medial to the last molar tooth, for fear of encroaching upon the posterior palatine canal.

When the teeth are clenched, there is still a space, communicating between the mouth and pharynx behind the molar teeth, which admits a medium-sized catheter. When a patient breathes deeply through the mouth and the head is thrown back, the soft palate is raised, the arches (pillars) separated; the uvula and fauces, with the anterior and posterior palatine arches, with their attachments, the tonsils, and the back of the pharynx are exposed.

This portion of the pharyngeal mucous membrane would lie over the lower part of the second and the upper part of the third cervical vertebra, the anterior arch of the atlas corresponding to the level of the posterior nares, and the body of the epistropheus (axis) to the level of the soft palate (fig. 1084). If finger be introduced past the soft palate to this part of the spine and turned upward and downward, it is possible, with the aid of an anesthetic, to examine the upper four or five and, in children, six vertebræ, as far as the anterior surfaces of their bodies. The part of the column which is accessible to a straight instrument introduced through the mouth is very limited, extending, in the adult, from the lower border of the axis to the middle or lower part of the fourth cervical vertebra; in the child, owing to the small size of the face, it comprises the bodies of the axis and of the third cervical vertebra.' (Thane and Godlee, from Chipault.) The distance from the incisor teeth to the commencement of the esophagus at the cricoid cartilage is 15 cm. (6 in.) in the adult, and the distance from the teeth to the cardiac orifice of the stomach is 48 to 50 cm. (16 or 17 in.)

The *lymphatic drainage* of the face, mouth, and tongue is given on pp. 744 and 749.

The finger may be introduced through the mouth into the pharynx, especially if the parts are rendered insensitive by local anesthetics. Inferiorly may be felt the root of the tongue, the epiglottis and the arytenoepiglottideon folds. If if the finger be turned upward into the nasal pharynx and then forward, it will feel the choanæ (posterior nares), separated by the vomer. The other boundaries of these are, laterally, the medial pterygoid plate and palate bones; above, the basisphenoid; and below, the horizontal plate of the palate bone and the inferior nasal spine. Within each nostril would be felt the posterior ends of the two lower nasal conchæ (turbinate bones); above and behind is felt the basilar process of the skull, the vault of the pharynx, and the bodies of the upper cervical vertebra (fig. 1084).

The **size of the choanæ,** in the bony skull 2.5 cm. (1 in.) vertically by 1.2 cm. (½ in.), and the presence of any adenoids, are especially to be noted. The **richness of the nasopharynx in glandular structures,** its proneness to inflammation, and of this inflammation to spead to other parts,—e. g., the tympanum,—are well known.

The palate.—Between the diverging anterior or glossopalatine arches (pillars) of the soft palate is the **isthmus faucium,** through which the mouth opens into the oral pharynx. It is bounded above by the free margin of the palate and the uvula, laterally by the anterior (glossopalatine) arches, and below by the dorsum of the tongue. The coverings of the hard palate are chiefly mucous membrane, glands, and periosteum. These are intimately blended by fibrous septa, as in the superficial layers of scalp and palm of the hand. Hence the readiness with which necrosis takes place here.

Hare-lip and cleft palate.—Failure of union between the medial nasal process and the maxillary process of the embryo gives rise to the deformity known as **hare-lip** (cf. p. 1138).

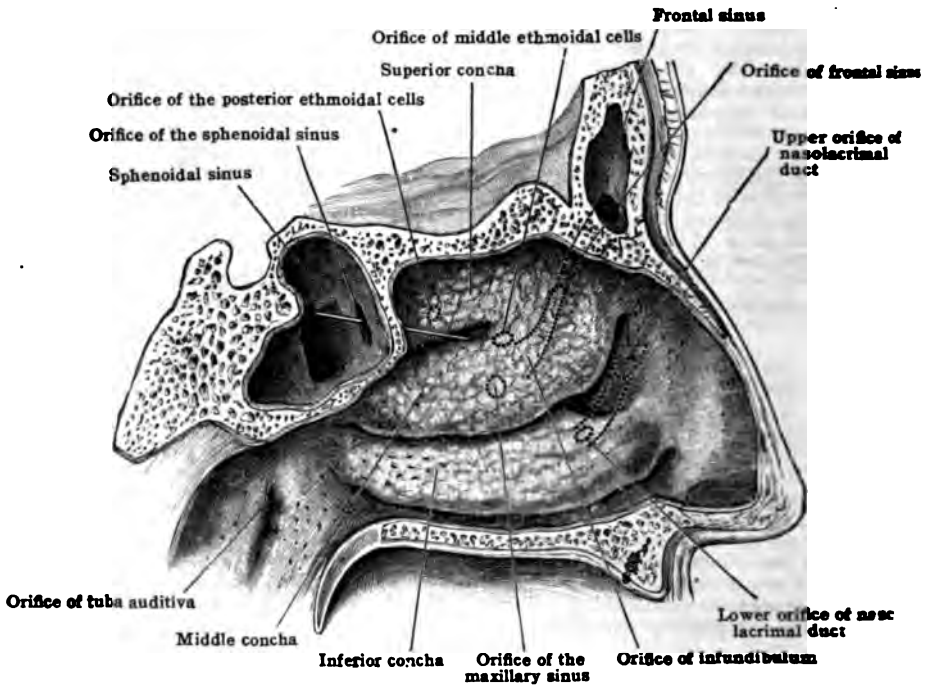
The palate is developed from three primitive processes growing down from the basis cranii, viz., (1) the medial nasal process forming the premaxilla which lies in front of the anterior palatine foramen and bears the four incisor teeth, (2) and (3) the maxillary process of either side. The slighter cases of failure to unite affect only the soft palate which is the last part to fuse. Complete alveolar cleft palate, which occurs combined with hare-lip and may be unilateral or bilateral, represents more serious non-union. In this condition the lateral incisor may be found either on the medial or on the lateral side of the cleft, which is explained by the fact that this tooth is developed in the groove between the two processes (Keith).

In paring the edges of a cleft soft palate, the following structures would be successively cut through:—(1) Oral mucous membrane; (2) submucous tissue, with vessels, nerves, and glands; (3) glossopalatine muscle; (4) aponeurosis of tensor palati; (5) anterior fasciculus of pharyngopalatine; (6) levator palati and uvular muscles; (7) posterior fasciculus of pharyngopalatine; (8) submucous tissue, vessels, nerves, and glands; (9) posterior mucous membrane. The soft palate is thicker than it seems, the average in an adult being 6 mm. (¼ in.). The muscles widening a cleft are the tensor and levator, while the superior constrictor closes it in swallowing. Of the *arteries* of the palate, from the external maxillary (facial), ascending pharyngeal, and internal maxillary, the largest is the descending palatine branch of the last. This emerges from the posterior palatine canal close to the medial side of the last molar tooth.

THE NOSE AND PHARYNX

On the face the outline of the nasal bones can be easily traced, and below them the lateral nasal cartilages, flat and also somewhat triangular. Below these are the greater alar cartilages, curved and so folded back that each forms a lateral and a medial plate. Of these, the medial meet below the septal cartilage to form the tip of the nose, while the lateral curve backward, and, together with dense masses of cellular tissue and fat and accessory cartilages, form the ala.

FIG. 1085.—SECTION OF THE NOSE, SHOWING THE CONCHÆ (TURBINATES) AND MEATUSES WITH THE OPENINGS IN DOTTED OUTLINE.



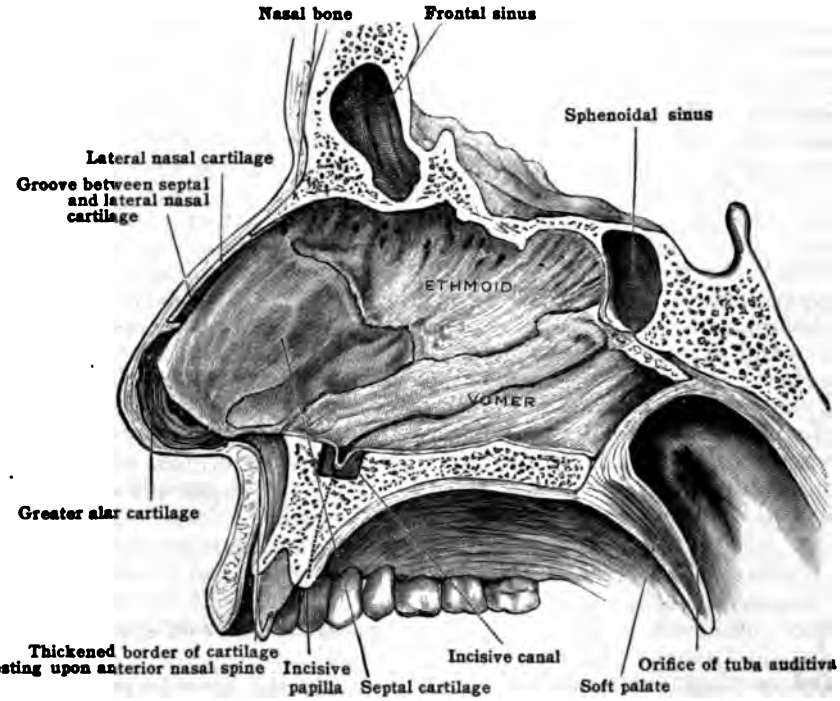
With the speculum, especially if the head be thrown back and the tip of the nose drawn up, the lower part of the septum, floor of the nose, and greater portion of the inferior concha (turbinate) can be seen. On throwing the head further back, with a good light the lower margin of the middle concha can also be made out. This is much higher up and nearly on a level with the root of the nasal bone. The septum often deviates to one side. The mucous membrane over it is, in health, dull red in color; that over the inferior concha is thicker. The anterior extremity of the latter bone is about 1.8 cm. (¾ in.) behind the nasal orifice, while the opening of the nasolacrimal duct is about 2.5 cm. (1 in.) behind and about 1.8 cm. (¾ in.) above the floor, concealed by the anterior extremity of the inferior concha. The opening into the maxillary sinus (antrum) is situated in about the center of the middle meatus and 2.5 cm. (1 in.) above the floor.

The olfactory area of the mucous membrane extends over the highest conchæ (possibly also somewhat lower) and corresponding portions of the septum. The respiratory portion is more vascular and thicker, especially over the conchæ. It is firmly adherent to the periosteum and perichondrium. The veins, especially

over the lower concha, form a dense plexus, closely resembling cavernous tissue. This fact explains the severity of epistaxis, and, together with the drainage of blood into out-of-the-way veins, such as the sphenopalatine and ethmoidal, accounts for the serious results which may follow on a firmly impacted and infected plug. The boundaries of the choana (posterior nares) have been given above.

Nasal septum.—The structure of the skeletal element of the septum, which consists of the septal cartilage, the vertical plate of the ethmoid and the vomer, is shown in fig. 1086. Slight deviations of the septum to one side are common in adults, and involve mainly the cartilage and the ethmoid bone, the vomer being but little affected as a rule.

FIG. 1086.—SECTION SHOWING BONY AND CARTILAGINOUS SEPTUM.
The dotted line indicates the course of the incisive (anterior palatine) canal.



The convexity is most commonly on the right side, and occlusion of the nares on that side with unsightly deflection of the whole nose, results in some cases during the transition from the infantile to the adult facial conformation. Too extensive removal of the bony septum in the operation of submucous resection for the relief of this condition may cause sinking in of the bridge of the nose. More often, however, this is due to the destructive effect of congenital syphilis.

Accessory sinuses.—The communications of these paranasal air sinuses with the nasal fossa are of great clinical importance. The **sphenoidal sinus** opens high up into the sphenoethmoidal recess. **The posterior ethmoidal sinuses** open into the superior meatus under cover of the superior concha. The infundibulum of the **frontal sinus, the anterior** and **middle ethmoidal** and the **maxillary sinus** all communicate with the middle meatus under cover of the middle concha. The orifice of the **maxillary sinus** lies at the lowest part of the hiatus semilunaris into the front and upper end of which the frontal sinus opens. Consequently infected fluid may trickle down from the latter into the maxillary sinus. The orifice of this sinus is placed high up in its medial wall so that fluid does not drain away from it readily in case of infection. When the head is held forward in a stooping position some of the pus or mucus may escape from the nostrils, since in this position the fluid contents more readily reach the orifice. For further details concerning the sinuses, see RESPIRATORY SYSTEM.

The **nasolacrimal duct** which carries the tears into the nose opens into the front and upper part of the inferior meatus under cover of the inferior concha.

Nasopharynx.—About 1.2 cm. (½ in.) behind the posterior extremities of the inferior conchæ, just above the level of the hard palate (fig. 1048), on the side of the nasopharynx, are the openings of the *tubæ auditivæ* (**Eustachian tubes**). Oval in shape, these are bounded above and behind by the prominence of the cartilage [torus tubarius], which is wanting below, thus facilitating the entry of a catheter. The lower part of the tube contains in early life lymphoid tissue; enlargement of this explains the deafness in certain cases of adenoids. At the upper part of the nasopharynx, on the posterior wall, extending down laterally as far as the tubæ auditivæ, is the collection of lymphoid tissue known as the **pharyngeal tonsil,** which when hypertrophied, plays a large part in 'nasopharyngeal adenoids.' From the periosteum of the basisphenoid and basioccipital arise nasopharyngeal fibromata. For digital exploration of the pharynx through the mouth, see p. 1351.

Pharyngeal hypophysis (fig. 1069).—In the nasopharyngeal mucosa, a few mm. behind the posterior border of the vomer, a group of glandular cells may be found on microscopical examination in all cases (Haberfeld), corresponding in histological appearance with the pars anterior of the hypophysis. These cells are a remnant of the primitive bud that grows toward the brain in front of the buccopharyngeal membrane to form the pars anterior of the hypophysis. In some cases of pituitary disorder they give rise to a palpable tumor in the nasopharynx.

Oral pharynx.—The **palatine tonsils** are located in the side walls of the oral pharynx (figs. 880, 889). They are separated externally by the superior constrictor and pharyngeal aponeurosis from the ascending pharyngeal and internal carotid arteries. The latter vessel lies about 2.5 cm. (1 in.) behind and to the lateral side of the tonsil. When serious hemorrhage follows operations here, it usually comes from one of the numerous tonsillar branches (fig. 492). The extent to which the tonsil is covered by the anterior arch (pillar), how far it projects upward beneath the soft palate or downward into the pharynx, have all important bearings on the mode of removal. Its position corresponds to a point a little above and in front of the angle of the jaw. The lateral surface, enclosed by an imperfect capsule and separated from the superior constrictor by connective tissue, explains how an enlarged tonsil can be dragged medialward by a vulsellum, and enucleated after an incision in the mucous membrane around. It is in this connective tissue that severe infective inflammation, e.g., after scarlet fever or an imbedded pipe-stem, may set up hemorrhage or spreading cellulitis, retropharyngeal or otherwise.

THE NECK

The topics considered in the neck are the landmarks, thyroid gland, sternomastoid, clavicle, triangles and cervical ribs.

Bony and cartilaginous landmarks.—The body of the *hyoid* is nearly on a level with the angles of the jaw, and the interval between the third and fourth cervical vertebræ (fig. 1084). With the head in the usual erect position it lies a little higher than the chin. It divides the front of the neck into supra- and infrahyoid regions, convenient for remembering the distribution of the deep fascia. On either side of the body are the greater cornua, with the lesser cornua attached to their upper borders at the junction with the body. The upper borders of these are the guides to the lingual arteries. The outline and mobility of the body and the greater cornua are easily determined by relaxing the deep fascia and pushing the bone over to the opposite side. Below the hyoid is the *thyrohyoid space*, which corresponds with the epiglottis and the upper aperture of the larynx. Thus, if the throat be cut above the hyoid, the mouth will be opened and the tongue cut into; if the thyrohyoid space be cut, the pharynx would be opened and the epiglottis wounded near its base. In the former case the lingual and external maxillary are the most likely vessels to be wounded; in thyrohyoid, the commonest cut-throat, the superior thyroid vessels, and the superior laryngeal nerve. The *laryngeal prominence* and thyroid notch begin about 2.5 cm. (1 in.) below the hyoid and are much more distinct in men than in women or children. The prominence is not marked before puberty, and thus forms a less distinct landmark for tracheotomy, especially in children with short fat necks.

The cricoid, on the other hand, is always to be made out. It corresponds in horizontal plane to the following: (1) The sixth cervical vertebra, (2) The junction of pharynx and œsophagus: from the narrowing of the tube here, foreign bodies may lodge at this point and cause dyspnœa by pressing on the air-tube in front. The cricoid is taken as the center of the incision

in esophagotomy, and also for ligature of the common carotid. (3) The junction of larynx and trachea. (4) The crossing of the omohyoid over the common carotid. (5) The middle cervical ganglion. Above the cricoid is the cricothyroid membrane. In laryngotomy, the deepest part of the incision should be kept to the middle line for fear of injuring the cricothyroids, and as near the cricoid as possible, so as to avoid the neighborhood of the vocal folds (cords) and the small cricothyroid vessels. The space is always small, and, after middle life, increasingly rigid.

The distance between the cricoid and the manubrium is only about 3.7 cm. (1½ in.). When the neck is stretched, about 1.8 cm. (¾ in.) more is gained. Thus, as a rule, there are not more than seven or eight tracheal rings above the sternum. Of these, the second, third, and fourth are covered by the isthmus of the thyroid gland.

The parts met with in the midline—(*a*) above, and (*b*) below, the isthmus—high and low tracheotomy—should be borne in mind: (*a*) Skin, superficial fascia, branches of transverse cervical and inframandibular nerves, lymphatics, cutaneous arteries, anterior jugular veins—with their transverse branches smaller above—deep fascia, sternohyoids, cellular tissue, superior thyroid vessels, and pretracheal layer of deep fascia. The importance of this last is twofold, as, first, the tube in tracheotomy may be passed between it and the trachea, and after a wound in this region this layer, continuous with the pericardium, may conduct discharges, into the mediastina. (*b*) The surface structures are much the same, but the anterior jugular veins and their transverse branches are much larger. The inferior thyroid veins, are also larger. A thyroidea ima may be present, and the innominate artery, especially in children, may be 1.2 cm. (½ in.) above the sternum. The trachea is also smaller, deeper, and less steadied by muscles. The *thymus*, too, in young children (fig. 1087), may prove a difficulty. Thus, in children, the high operation, incising the cricoid and cricotracheal membrane, if needful, is to be preferred. The cricoid is, however, not to be incised, if possible; the higher the tube is inserted, the greater the irritation.

The suprasternal notch, between the sternal heads of the sternomastoids in on a level with the disk between the second and third thoracic vertebræ. Just below the level of the cricoid cartllage, on deep pressure at the anterior border of the sternomastoid the transverse process of the sixth cervical vertebra may be felt. It is known as Chassaignac's carotid tubercle, and the common carotid may be compressed against it. Compression below it will command the vertebral artery as well.

The **thyroid gland** (figs. 1052–1056) enclosed in a capsule of deep fascia derived from the pretracheal layer (fig. 1054) is closely connected by this to the upper trachea and larynx. The upper somewhat pointed extremity of each lateral lobe reaches to the upper and back part of the thyroid cartilage: here enter the superior thyroid vessels. The lower layer and rounded extremity reaches to the fifth or sixth tracheal ring: its posterior and lower aspect is in relation to the inferior thyroid vessels and the recurrent nerve: the lateral lobe, posteriorly, also overlaps the carotid sheath, which may be infiltrated in malignant disease of the thyroid. The thyroidea ima has been mentioned above.

The thyroid isthmus in the adult is opposite to the second, third, and fourth tracheal rings. At its upper border is an arterial arch formed by the superior thyroids; over the anterior surface of the gland and isthmus the inferior thyroid veins take origin in a plexus. The upper border of the thymus (fig. 1087) may be in relation with the lower border of the isthmus. From the upper border of the latter, the pyramidal lobe, especially on the left side, is often present, reaching by a pedicle to the hyoid. The pyramidal lobe, when present, is the persistent remnant of the thyroglossal duct, and occasionally cystic outgrowths persist obstinately as remnants of this duct, in the middle line, above, behind, and below (the commonest form) the hyoid bone.

In short-necked people the thyroid is relatively lower in relation to the sternum, and enlargements of the gland are apt to become mainly intrathoracic. The presence of an intrathoracic or retrosternal goiter may be determined by X-ray examination. An enlargement of the thyroid is liable to give trouble by pressure on (1) the trachea, which is compressed laterally between the lateral lobes; (2) the esophagus; (3) the internal jugular vein and carotid artery; (4) the recurrent laryngeal or cervical sympathetic nerves.

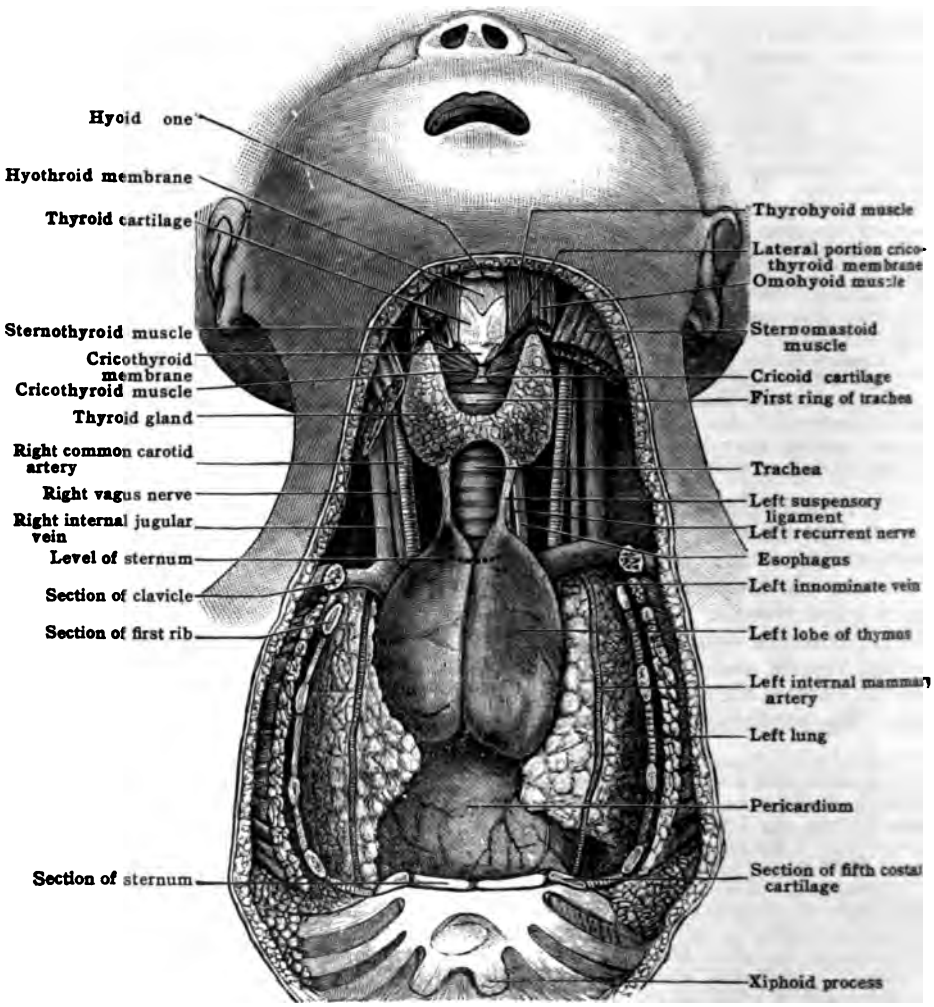
Parathyroids.—These small glands, about the size of a pea, vary somewhat in number and situation (fig. 1057). There are usually four—two behind each lateral lobe. The upper glands lie imbedded in the capsule of the thyroid about the junction of the middle and upper thirds of the lateral lobes on the posterior aspect. The lower pair lie nearer the lower poles of the lateral lobes, sometimes separated from them by a distinct interval. Excision of all the parathyroids gives rise to tetany in animals.

The **sternomastoid** (figs. 1079, 1088) is the landmark for several important operations. Its medial border, the thicker and better marked of the two, overlaps the carotids: the common carotid corresponding, as far as the upper border of the thyroid cartilage, with a line drawn from the sternoclavicular joint to midway between the mastoid process and the angle of the jaw. The artery can be best compressed above the level of the cricoid, as here it is less deeply covered. The student should recall the deep relations of the sternomastoid, which he may

classify as vessels, nerves, muscles, glands, and bones: or, according to their position, (1) those above the level of the angle of the jaw: (2) those between the angle of the jaw and the omohyoid: (3) those below the omohyoid.

Of the two heads of the sternomastoid the sternal is the thicker and more prominent, the clavicular the wider. A stab through the interval which lies between the two heads might wound the bifurcation of the innominate on the right side, and the common carotid on the left, the internal jugular vein, vagus, and phrenic nerves, according to the direction of the wound. Injury of the sternomastoid during child-birth, followed by scar-tissue formation, may give rise to wry-neck.

FIG. 1087.—THYMUS AND THYROID GLAND IN A CHILD AT BIRTH.



The anterior jugular vein (fig. 552), commencing in branches from the submaxillary and submental regions, descends at first in the superficial fascia between the midline and anterior border of sternomastoid, perforates the deep fascia just above the clavicle, here entering Burns's space (p. 1362): it then curves laterally to pass beneath both origins of the sternomastoid a little above the clavicle, to end usually in the external jugular.

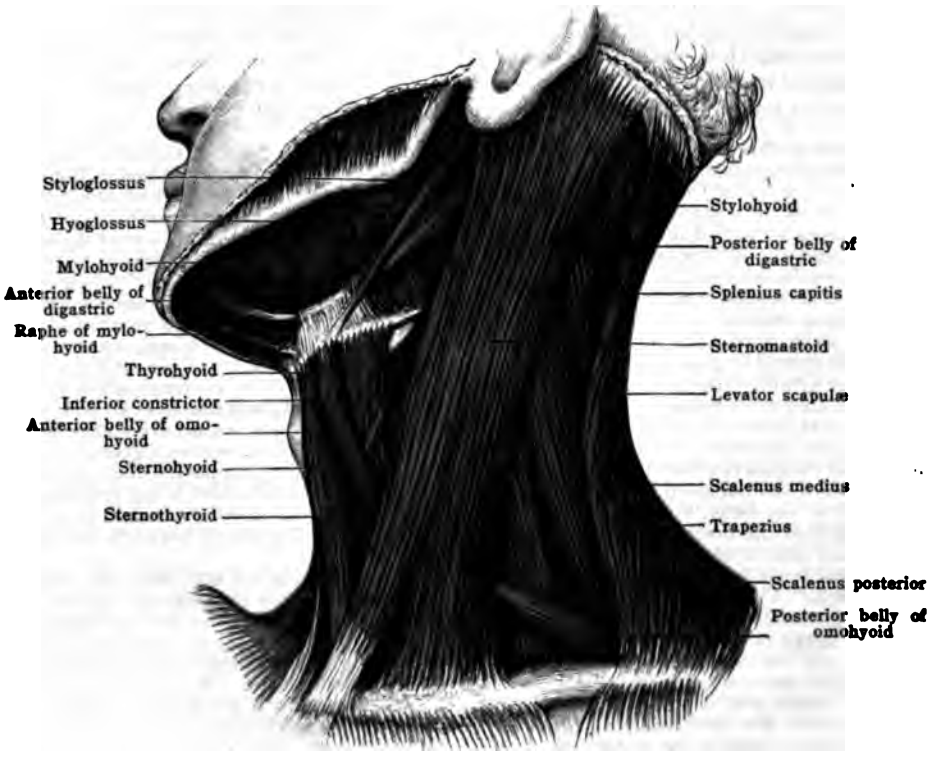
When distended, a large communicating branch between it and the common facial, which runs along the anterior border of the sternomastoid, must always be remembered in operations for removal of glands, etc. The varying level at which the external jugular crosses the lateral border of the clavicular origin must be remembered in such operations as tenotomy. These veins vary in size inversely to each other; the anterior jugulars are joined by numerous transverse branches and become larger below. They have no valves.

Of the chief arteries to the sternomastoid, that from the superior thyroid will be divided [illegible]rature of the common carotid; that from the occipital runs with the spinal accessory nerve.

Behind the sternoclavicular joint lies the commencement of the innominate veins, the bifurcation of the innominate artery on the right, and the common carotid artery on the left; deeper still lie the pleura and lung.

The clavicle.—This bone can be felt beneath the skin in its whole length. It forms the only bony connection between the upper limbs and the trunk. As one traces it laterally toward the acromial end, it rises somewhat, particularly in children and in subjects of good muscular development. The skin over it is thin but very mobile, and consequently is not often wounded. The most important posterior relations of this bone are, passing from the medial end laterally, the subclavian vein, the subclavian artery, and the cords of the brachial plexus as they lie on the first rib (cf. fig. 562).

FIG. 1088.—ANTERIOR AND LATERAL CERVICAL MUSCLES.



The subclavian vein occupies the angle between the first rib and the clavicle, and hence is, as a rule, the first structure compressed in growths of this bone. The artery lies on a deeper plane behind the midpoint of the clavicle, and the nerve cords extend a little further laterally. The subclavius muscle forms a protective cushion between the bone and these important structures, and this accounts for the rarity of injury to them in fracture of the clavicle. Behind the medial half of the clavicle the apex of the lung extends upward into the neck to a height of 2.5–3.7 cm. (1–1½ in.), and consequently is liable to be wounded by a stab in the root of the neck.

Cervical triangles.—In front of the sternomastoid on each side is the **anterior triangle,** which is **subdivided into three smaller triangles** by the digastric muscle above, and the anterior belly of the omohyoid below (figs. 1079, 1088). These smaller triangles are called, from above, the submaxillary, the superior and inferior carotid triangles. The **submental triangle** is an additional small unpaired area bounded on either side by the anterior belly of the digastric, and posteriorly by the body of the hyoid.

The **submaxillary** or **digastric triangle** is bounded above by the mandible, and a line drawn back to the mastoid process: behind, by the stylohyoid and posterior belly of the digastric, and in front by the anterior belly of the digastric.

This space contains the submaxillary gland, and embedded in the gland is the external maxillary (facial) artery, the facial vein lying superficial to the gland; deeper than the gland are the submental vessels and the mylohyoid vessels and nerve. Posteriorly, and separated from

the above structures by the stylomandibular ligament, which subdivides the triangle into a sub maxillary and parotid part, is the upper part of the external carotid artery running up into the parotid gland, where it gives off its two terminal and the posterior auricular branches. Mor deeply lie the internal jugular vein, internal carotid artery, and the vagus. The floor of th triangle is formed by the mylohyoid, hyoglossus, and superior constrictor. The lingual arter may be tied here, or, better, in order to get behind the dorsalis linguæ, close to its origin, by a incision similar to that for exposing the external carotid. The lingual artery is most easil ligated in Lesser's triangle, which is formed by the *hypoglossal nerve* above and the two belli of the digastric below. The artery is covered by the fibers of the hypoglossus. The hypo glossal nerve is also a guide to the carotids and the occipital artery at the lower border of th digastric.

The **superior carotid triangle** (cf. figs. 488 and 1088) is bounded above by th digastric, below by the omohyoid, and behind by the sternomastoid. It contain the upper part of the common carotid and its branches, the external being at firs somewhat anterior to the internal. The external may be differentiated from th internal carotid by remembering that the latter gives off no branches in the nec All the branches of the external carotid, save the three just given, are found i this space, together with their veins, the internal jugular vein, the vagus an sympathetic nerves, and, for a short distance, the accessory, together wit those nerves which lie in front of and behind the carotids.

Ligature of the common carotid is usually performed at the 'seat of election,' where th vessel is more superficial, *above the omohyoid.* An incision with its center opposite the crico is made 7.5 cm. (3 in.) long in the line of the carotid artery. The deep fascia along the a terior border of the sternomastoid having been divided, the cellular tissue beneath is opened u the omohyoid identified and drawn down or divided. The sternomastoid is next drawn we laterally, and the artery felt for. At this stage, such veins as the communication betwee the common facial and the anterior jugular and the superior and middle thyroids may giv trouble. The sheath is next opened well to the medial side, opposite to the cricoid cartilag the ascending cervical, when seen, being avoided. If the internal jugular be distended, it ma be drawn aside with a blunt hook, or pressure made lightly in the upper angle of the woun The needle should be passed from the lateral side in very close proximity to the lateral and bac part of the artery, as so to avoid the vein and vagus. Ligature *below the omohyoid* is rendere more difficult by the presence of the anterior jugular, the pretracheal muscles, an overlappin thyroid gland, especially if enlarged, the greater depth of the artery, especially on the left sid and, here also, the closeness of the internal jugular. The *collateral circulation* is given at p. 136 Ligature of the external carotid, otherwise difficult, is rendered very simple by first exposing th bifurcation of the common carotid artery, the incision similar to the last being prolonged up ward. Here the facial and lingual veins and hypoglossal nerve cross the trunk, over whic also lie some of the deep cervical glands. The ligature is usually placed between the superi thyroid and lingual branches.

Allusion must here be made to the **chief structures liable to be met with in operation on the neck.** These are the **internal jugular,** the **accessory,** and **phrenic nerves, the vagu** and **hypoglossal,** the **thoracic duct,** low down and deep on the left side, the **esophagus** an **recurrent nerve** in difficult operations on the thyroid gland. Of these, the **internal jugular** i in some ways, the most important. Glands, tuberculous or carcinomatous, are often adherei to its sheath, especially those which drain the submaxillary group. When this condition present or suspected, it is always well to begin the dissection low down in the inferior carot triangle, where the structures are probably normal and the landmarks easy to identify. I infective thrombosis of the transverse sinus the internal jugular is often tied opposite to th cricoid cartilage, being either divided between two ligatures, or, if the thrombus has extende downward, as much of the vein as is possible is removed. This vein contains only a single pa of valves low down in the neck. In all operations here on it and the other two jugulars, th risk of entry of air is to be remembered. The accessory and phrenic nerves are alluded to p. 1360.

The **inferior carotid** (muscular or tracheal) **triangle** is bounded above by th omohyoid, behind by the sternomastoid, and in front by the middle line of th neck (fig. 1088). It contains the lower part of the carotid sheath and its con tents, with, behind it, the inferior laryngeal nerve and inferior thyroid vessel and to the medial side the trachea, thyroid gland, and esophagus. More deepl are the vertebral vessels; on the left side is the thoracic duct.

The position of the **branches of the external carotid (fig. 488) should be r** membered. The greater cornu of the hyoid and the ala of the thyroid are lan marks for the origin of most of them.

The **superior thyroid,** arising just below the level of the great cornu of the hyoid bon passes downward and forward to the back part of the thyroid cartilage and upper part of th thyroid body. Many of its branches are important in surgery. The superior laryng perforates the thyrohyoid membrane. The sternomastoid passes laterally into the midd of the muscle, across the carotid sheath. The cricothyroid crosses the space of the same nam just below the lower border of the thyroid cartilage. The small hyoid branch runs to the low border of the hyoid bone. Anastomosing branches of the superior thyroid form an arch alon the upper border of the isthmus. The lingual artery arises from the parent trunk, opposite th

tip of the greater cornu of the hyoid, and passes forward just above the greater cornu, crossed by the hypoglossal, and thence to the side of the tongue. In the first part of its course, before it reaches the hyoglossus, it is curved, at first ascending, and then, having descended slightly, before it reaches the hyoglossus, and while it lies under it, its curve is gentle, with the concavity upward; beyond the hyoglossus, as it lies on the muscles of the tongue beneath the mucous membrane, it is tortuous. The **lingual vein,** it will be remembered, does not run with its artery, but lies superficial to the hyoglossus. It receives the two small venæ comitantes which run with the lingual itself just before it crosses the common carotid. The line of the **external maxillary (facial) artery** (fig. 1080), which often arises with the lingual, has been given on p. 1343. The **occipital artery;** starting on the same level as the facial (i.e., at a point a little above and outside the tip of the greater cornu of the hyoid bone), follows a line drawn upward and laterally, first to the interval between the transverse process of the atlas and the mastoid process, the former bone being felt just below and in front of the tip of the latter; thence, lying in the occipital groove of the mastoid, the artery ascends gradualy, enters the scalp, together with the great occipital nerve, a little medial to a point midway between the external occipital protuberance and the mastoid process, to follow, tortuously and superficial to the aponeurosis, the line of the lambdoid suture.

The surface marking of the **digastric** and **omohyoid,** which subdivide the anterior triangle into the three smaller subtriangles above described, should be noted. The line of the **posterior belly of the digastric** corresponds to one drawn from the apex of the mastoid process to a point just above the junction of the great cornu and body of the hyoid bone; and from this spot, which gives the point of meeting of the two tendons, one slightly curving upward to a point just behind the symphysis menti, would give that of the **anterior belly.**

To trace the **omohyoid,** a line should be drawn from the lower margin of the side of the hyoid bone obliquely downward, so as to cross the common carotid opposite the cricoid cartilage and thence curving laterally under the sternomastoid at the junction of its middle and lower thirds, and then onward and still laterally parallel with and a little above the clavicle, as far as its center.

Posterior triangle.—This lies behind the sternomastoid (figs. 1079, 1088), bounded posteriorly by the trapezius and inferiorly by the clavicle. It is subdivided by the posterior belly of the omohyoid into a larger, upper *occipital* and a smaller lower *subclavian* triangle. The latter corresponds to a surface depression, the supraclavicular fossa. Here the brachial plexus may be felt, and, by pressure downward and backward immediately behind the clavicle, just lateral to and behind the lateral margin of the sternomastoid, the subclavian artery can be compressed upon the first rib.

The supraclavicular fossa should be opened out by depressing the arm, and parts relaxed by carrying the shoulder forward and turning the head to the same side. The subclavian artery curves upward and laterally from behind the sternoclavicular joint to disappear behind the center of the clavicle, the highest point of the curve being 1.2 to 2.5 cm. (½ to 1 in.) above the bone. The artery on the left side lies more deeply than the right, and does not rise so high into the neck. The subclavian vein lies at a lower level, separated by the scalenus anterior, and under cover of the clavicle. Into the above curve rise the pleura and lung. The pleura may be expected to rise 2.5 cm. (1 in.) above the clavicle, behind the clavicular head of the sternomastoid.

The **transverse scapular** and **transverse cervical vessels** run laterally, parallel with the clavicle. The former lies behind the bone and subclavius; the latter also runs laterally in a transverse direction, across the root of the neck, but on a slightly higher plane, and thus a little above the clavicle. In aneurism of the axillary artery these vessels may form the main part of the collateral circulation and in exposing the subclavian artery for purposes of ligation they should be carefully preserved.

Ligature of the third part of the subclavian is best performed by an angular incision, the horizontal portion along the center of the clavicle, and the vertical one along the posterior border of the sternomastoid, with partial division of this and the trapesius when closely adjacent. The chief points to bear in mind are the venous plexus into which the external jugular, transverse cervical, transverse scapular, and cephalic veins enter; the omohyoid and division of the fascia which ties this to the clavicle; identification of the lateral margin of the scalenus anterior and the scalene tubercle; care of the transverse scapular artery and the descending branch of the transverse cervical. The needle is passed from above downward so as not to include the lowest cord of the brachial plexus, the vein, if distended, being depressed with a blunt hook. If the nerve to the subclavius be seen, it must be uninjured, as it occasionally forms an important part of the phrenic. The *collateral circulation* is given at p. 1360.

Crossing the sternomastoid, a little obliquely, in a line drawn from a point just below and behind the angle of the jaw which marks its origin in the union of the posterior part of the internal maxillary and the posterior auricular veins to the center of the clavicle, runs the **external jugular vein** (fig. 552). Above, it lies between the platysma and deep fascia, and is accompanied by the group of superficial cervical nodes (p. 742). About 3.7 cm. (1½ in.) above the clavicle it perforates the deep cervical fascia, its coats being blended with the opening. Gentle pressure with a finger at this point renders the vein above clearly visible. The dilated part between this point and the subclavian vein is called the sinus, and is marked by two valves, neither of which is usually perfect.

Opening into the external jugular, in the middle or lower third of its course, is the posterior external jugular, a vessel which begins in the occipital region superficially and runs down in front of the anterior border of the trapezius, across the posterior triangle.

The **accessory nerve** (fig. 1079), having crossed the transverse process of the atlas at a point lying a little below and in front of the apex of the mastoid, enters the anterior border of the sternomastoid at about the junction of the upper and middle thirds of the muscle. Having traversed the muscle obliquely, it leaves it usually at a point a little lower down, pursues a similar course across the posterior triangle and disappears under the anterior border of the trapezius, to enter into the subtrapezial plexus with the third and fourth cervical nerves.

Above it is accompanied by a branch from the occipital, below by the transverse cervical artery. It is always seen in thorough operations on the upper deep cervical glands. The nerve is resected in spasmodic torticollis, and in recent years inveterate facial paralysis has been treated by anastomosing the facial to this nerve or the hypoglossal. A line drawn from midway between the tip of the mastoid and the angle of the mandible along the above given course of the nerve would denote its position. The guides for the spinal accessory should be carefully studied. It is not infrequently injured or divided in operations in the posterior triangle of the neck. Division of the nerve may give rise to drop shoulder

Just above the center of the sternomastoid, the **small occipital, great auricular,** and **cutaneous cervical nerves** emerge, the first passing upward and backward to the scalp, the second upward and forward across the upper part of the sternomastoid to the ear, and the last turning straight forward to the front of the neck. The small occipital and great auricular are often in intimate association with the accessory at its exit from the muscle. At this point also care must be taken not to injure the nerve in removal of glands from the posterior triangle.

The **phrenic nerve** (figs. 501, 1091), taking its largest root from the fourth cervical, begins deeply about the level of the hyoid bone: thence descending under the sternomastoid, and, passing obliquely medially across the scalenus anterior (the posterior borders of the above two muscles roughly correspond to each other in the lower part of the neck), it descends under the subclavian vein and clavicle to enter the thorax.

When the internal jugular is distended, its lateral border will be liable to overlap this nerve. The relations of the *scalenus anterior* should be noted here. In addition to the phrenic, which runs with a slight obliquity medially and is in close contact with the muscle, the following structures cross it mediolaterally: the subclavian vein and termination of the external jugular, the transverse scapular and transverse cervical vessels, and the omohyoid. At its medial margin are the thyrocervical trunk and vertebral arteries, and over them, the internal jugular. Behind it are the subclavian artery, the brachial plexus, and pleura.

The level of the **brachial plexus** (upper border) would be given by a line drawn from the cricoid cartilage to the center of the clavicle. The lowest, medial cord (eighth cervical and first thoracic, giving off chiefly the ulnar, medial head of median, and medial antibrachial cutaneous) is just above and behind the subclavian artery. Its importance in ligature of the artery has been referred to (p. 1359).

In paralysis of the newly born, after some violent manipulation, it is usually the upper and lateral cord (fifth nerve, and axillary and median chiefly) which suffers, elevation and abduction at the shoulder and flexion at the elbow-joint being lost. Upper radicular brachial palsy known as Erb's palsy, while palsy arising from injury of the lower roots of the brachial plexus is known as Klumpke's palsy.

Collateral circulation after ligature of the common carotid (fig. 1089).—This takes place by means of (1) the free communication which exists between the opposite carotids, both without and within the cranium; and (2) by enlargement of the branches of the subclavian artery on the same side as that on which the carotid has been tied. Thus, outside the cranium, the superior and inferior thyroids are the chief vessels employed. Within the cranium the vertebral replaces the internal carotid.

Collateral circulation after ligature of the second and third parts of the subclavian (fig. 1089).—Here the following three sets of vessels are those chiefly employed:—

The transverse scapular, the transverse cervical,	with	The thoracoacromial, infra- and supra-scapular, and circumflex scapular
The superior intercostal, the aortic intercostals, and the internal mammary,	with	The lateral thoracic and subscapular arteries
Numerous unnamed branches passing through the axilla from branches of the subclavian,	with	Branches of the axillary.

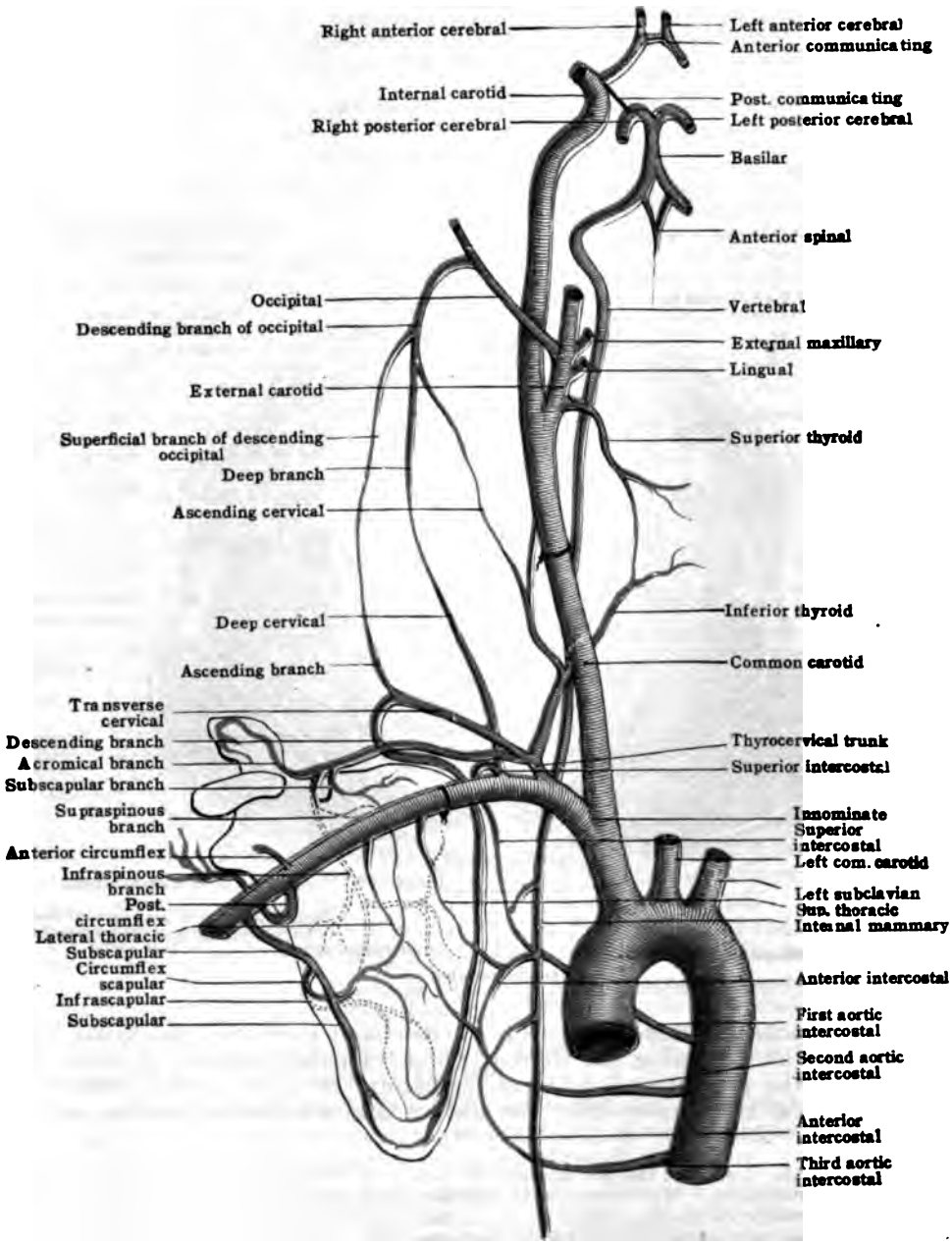
Deep cervical fascia.—The arrangement of this must be remembered—(*a*) above, and (*b*) below, the hyoid bone. The latter is far more important (fig. 381

(*a*) **Arrangement above the hyoid bone.**—Here two chief processes can be made out:—one, continuous with that in front of the sternomastoid, traced upward from the hyoid bone

encloses the submaxillary gland, passing over the mylohyoid, and, ascending, is connected with the lower border of the mandible, gives off the masseteric and parotid fasciæ, and is attached to the lower border of the zygoma, and, more posteriorly, to the mastoid and linea nuchæ suprema. (ii) A special process, which forms the stylomandibular ligament, is important in its power of checking overaction of the external pterygoid. By both these processes the ante-

FIG. 1089.—THE COLLATERAL CIRCULATION AFTER LIGATURE OF THE COMMON CAROTID AND SUBCLAVIAN ARTERIES.

(A ligature is placed on the common carotid and on the third portion of the subclavian artery.)



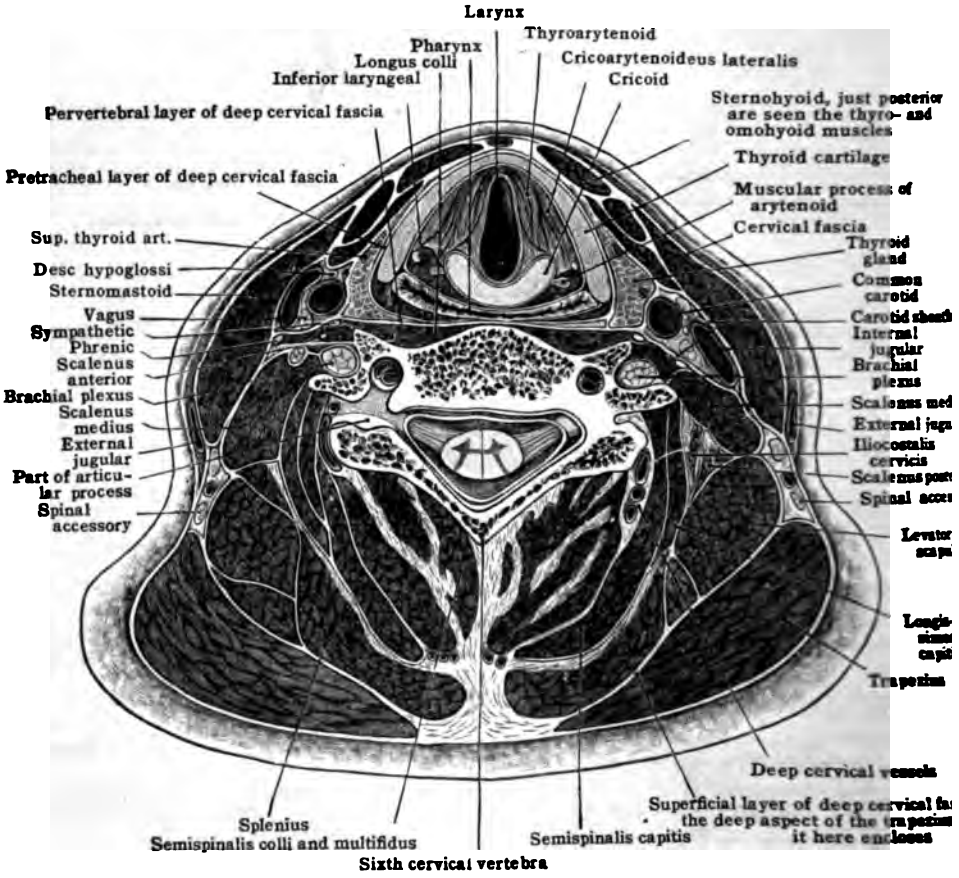
rior border of the sternomastoid is tied firmly forward to the mandible about its angle, and more deeply to the styloid process. This renders all operations under the upper part of the muscle, e. g., the removal of glands, extremely difficult.

(*b*) **Below the hyoid bone** (figs. 381, 1090).—The importance of the fascia here is much greater. **Four layers** must be remembered: (1) **Superficial**; (2) **pretracheal**; (3) **prevertebral**; (4) **carotid.** (1) **Superficial:** This starts from

the ligamentum nuchæ, encases the trapezius, forms the roof of the poster triangle where it is perforated by branches of the superficial cervical nerves a the external jugular vein. Passing on it encloses the sternomastoid and, pass over the anterior triangle, it meets its fellow in the middle line.

Thin behind, it is thickened anteriorly. Behind this thickened union lie the ant jugular veins. Below, at a varying distance below the thyroid cartilage, this layer div into two, attached to the front and back of the manubrium. Between these (Burn's spa lie some fat, a small gland, a communicating branch between the anterior jugulars and a se portion of the veins, and the sternal heads of the sternomastoids. The sheath to the depres of the hyoid bone is partly derived from this layer, partly from the next. Laterally, this la gives a sheath to the posterior belly of the omohyoid, is attached to the clavicle, and pass on, is continuous with the sheath to the subclavius and coracoclavicular fascia.

FIG. 1090.—SECTION OF NECK THROUGH THE SIXTH CERVICAL VERTEBRA. (Braune



(2) **Pretracheal or middle.** This lies under the depressors of the hyoid, e the trachea, also encasing the thyroid gland. Farther laterally it helps, gether with the prevertebral, to form the carotid sheath. Traced downw the pretracheal layer passes over the trachea into the thorax (middle me tinum).

As it descends, it encases the left innominate vein, and ends by blending with the fi layer of the pericardium. Hilton suggested that the attachment of this fascia above, and of the central tendon of the diaphragm below, to the pericardium served to keep this sac stretched, and so prevented any pressure of the lungs upon the heart.

(3) **Prevertebral.** This layer passes over the longus colli and capitis up to the base of the skull, and downward over the longus colli behind the esoph into the posterior mediastinum. Laterally it helps to form the carotid sh and, lower down, gives a sheath to the subclavian artery and so to the axil

(4) **The carotid sheath.** This is formed by septa from i, ii, and iii, meeting u the sternomastoid (fig. 1090).

The following **uses** and **important points** with regard to the anatomy of the deep cervical fascia should be noted:—(A) It **forms certain definitely enclosed spaces** in which pus or growths may form, and by the walls of which these morbid structures may be tied down and thus rendered difficult of diagnosis, while their increasing pressure may embarrass the air-passages, etc. Thus: (1) In the first space, which lies between the first layer and the skin, the structures met with, the platysma and superficial branches of the cervical plexus, are unimportant. Any abscess here is prone to extend, but superficially. (2) In the second space, between the superficial and middle layers, lies a narrow space containing loose cellular tissue and lymphatic glands. Suppuration here is very common, but usually comes forward. (3) This is the largest and most important of all. From its contents it has been called the **visceral compartment.** (Stiles.) It is bounded in front by the middle, and behind by the prevertebral layer. Its contents are—larynx, trachea, esophagus, thyroid, carotid sheath, glands; and below, brachial plexus, subclavian artery, and abundant loose cellular tissue for the movements of the neck. Suppuration is somewhat rarer here; but either pus or growth, if confined in this space, may have baneful effects, from pressure, or from their tendency to travel behind the sternum. (4) This space between the prevertebral layer in front and muscles behind, is very limited. Retropharyngeal abscess forms here, and the dyspnea it causes is thus explained. The origin of such abscesses is chiefly twofold, either in one of the highest deep cervical nodes, e. g., from infection of the nasopharynx (p. 751), or from disease of the upper cervical vertebræ. In the former cases (Stiles, Chiene) the suppuration will be *in front* of the prevertebral fascia, pointing toward the pharynx; in the latter *behind* the above fascia, spreading laterally, behind the carotid sheath. In making his incision, now along the posterior border of the sternomastoid, the surgeon should keep close to the transverse processes of the vertebræ, to avoid opening the visceral compartment and infecting the structures in it. (B) The deep cervical fascia gives **sheaths** or **canals** to certain veins which perforate it, e. g., the external jugular. These are thus kept patent, and a ready passage of blood ensured from the head and neck. Further, this fact accounts for the readiness with which air may enter veins, in operations low down in the neck. The carotid sheath is another and different instance. (C) It **helps to resist atmospheric pressure.** (D) Hilton's suggestion as to **its action on the pericardium** has already been mentioned.

The lymphatic nodes of the head and neck have already been described. (See Section VII, LYMPHATIC SYSTEM.)

THE THORAX

The bony landmarks of the thorax will be discussed first, followed by the structures of the thoracic wall, the lungs and pleura, and finally the heart and pericardium.

Bony landmarks.—The top of the sternum (figs. 203, 983, 1084) usually corresponds to the disk between the second and third thoracic vertebræ, and is distant about 6.2 cm. (2½ in.) from the vertebral column. In the newborn child it corresponds to the middle of the first thoracic vertebra (Symington). If traced downward, the subcutaneous sternum presents a ridge (sternal angle of Louis) at the junction of the manubrium and body, and the second costal cartilages on either side: this ridge usually corresponds to the disk between the fourth and fifth thoracic vertebræ. At the lower extremity of the sternum the xiphoid cartilage usually retires from the surface, presenting the depression of the epigastric angle or 'pit of the stomach.' This is opposite to the seventh costal cartilages and corresponds to the tenth thoracic vertebra behind.

Parts behind manubrium.—There is little or no lung behind the manubrium, the space being occupied by the trachea and large vessels, as follows:

The left innominate vein crosses behind the sternum just below its upper border. Next come the great primary branches of the aortic arch. Deeper still is the trachea, dividing into its two bronchi opposite to the sternal angle. Deepest of all is the esophagus. About 2.5 cm. (1 in.) below the upper border of the sternum is the highest part of the aortic arch, lying on the bifurcation of the trachea. (Holden). (Fig. 1091).

Sternoclavicular joint (fig. 315).—The expanded end of the clavicle and the lack of proportion between this and the sternal facet, on which largely depends the mobility of the joint, can easily be made out through the skin.

The strength of the joint, considerable when the rarity of dislocation compared with fracture of the clavicle is considered, depends mainly on its ligaments, the buffer-bond meniscus, the costoclavicular ligament, which checks excessive upward and backward movements, and the fact that the elastic support of the first rib comes into play in strong depression of the shoulder as in carrying a weight. The relative weakness of the anterior ligament determines the greater frequency of anterior dislocation of the clavicle at this joint. Behind the joint lie, on the right side, the innominate artery, right innominate vein, and pleura; on the left, the left innominate vein, the left carotid, and the pleura.

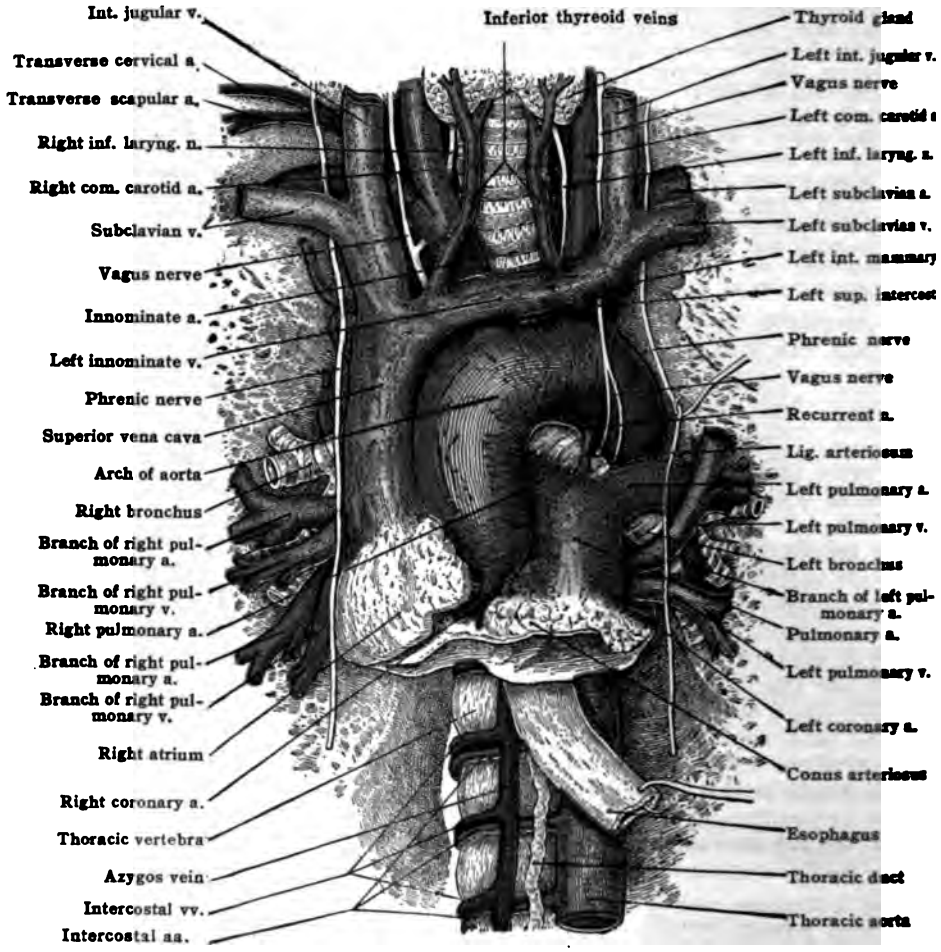
Acromioclavicular joint (figs. 319, 320).—On tracing the clavicle laterally, it is found to rise somewhat to its articulation with the acromion. This joint has

very little mobility, and owes its protection to the strong conoid and trapez ligaments near by. Owing to the way in which the joint-surfaces are bevell that of the clavicle looking obliquely downward, and resting upon the acromi upward displacement of the clavicle is more frequent.

Ribs.—In counting these, the position of the second is denoted by the tra verse ridge (sternal angle) at the junction of the manubrium and body of t sternum. It is well always to count ribs from this point and never from below. the twelfth rib varies in size and may be obscured by the sacrospinalis musc

FIG. 1091.—THE ARCH OF THE AORTA, WITH THE PULMONARY ARTERY AND CHIEF BRANC OF THE AORTA.

(Modified from a dissection in St. Bartholomew's Hospital Museum.)



The *nipple* in the male, lies between the fourth and fifth, nearly an inch late to their cartilages. The lower border of the great pectoral corresponds to t fifth rib. The seventh, the longest of the ribs, is the last to articulate by cartilage with the sternum. When the arm is raised, the first three digitatic seen of the serratus anterior correspond to the fifth, sixth, and seventh ribs. T ninth rib is the most oblique. The eleventh and twelfth can be felt lateral the sacrospinalis. Owing to the obliquity of the ribs, their sternal ends are o much lower level than their vertebral extremities.

'Thus the first rib in front corresponds to the fourth rib behind, the second to the si the third to the seventh, the fourth to the eighth, the fifth to the ninth, the sixth to the te and the seventh to the eleventh. If a horizontal line be drawn round the body from before ba ward at the level of the inferior angle of the scapula, while the arms are at the sides, the l would cut the sternum in front between the fourth and fifth ribs, the fifth rib at the nipple li and the ninth rib at the vertebral column.' (Treves.) The most frequently broken are

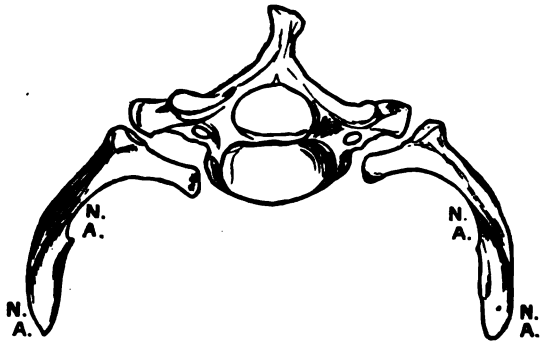
sixth, seventh, and eighth. The upper four and the two lowest ribs are best covered by soft parts, and, in the case of the former, the shoulder and arm take off some of the violence that would otherwise reach them. The way in which the ribs are embedded in the soft parts (fig. 1093), and the fact that the fragments are often held in place by the periosteum, account for the difficulty which is often met with in detecting crepitus. The intercostal spaces are wider in front than behind. The three upper are the widest of all.

Cervical ribs.—It occasionally happens that the rib-element of the seventh cervical vertebra, normally fused with the true transverse process, is segmented off as a separate, though usually rudimentary, rib. This anomaly is generally bilateral (fig. 1092). It occurred in 3 of 260 subjects (1.16 per cent.) examined by Wingate Todd (Jour. Anat. and Physiol., vol. 47, 1913). (See also p. 177.)

The anterior extremity of a cervical rib may, according to the degree of its development (1) lie free among the scalene muscles; (2) be connected with the sternum by a ligamentous prolongation; (3) articulate with the upper surface of the first thoracic at about its center by a synchondrosis, or (4) form a complete rib, articulating by a costal cartilage with the sternum.

The lowest trunk of the brachial plexus formed by the eighth cervical and first thoracic roots, the subclavian artery and less commonly the subclavian vein, curve over the upper surface of these ribs or over a ligament stretched from the first rib to the tip of the cervical rib. The abnormality owes its clinical importance to the pressure effects produced on the nerves

FIG. 1092.—CERVICAL RIBS, VIEWED FROM ABOVE. (× ½.) NN, IMPRESSION FOR LOWEST TRUNK OF BRACHIAL PLEXUS. AA, IMPRESSION FOR SUBCLAVIAN ARTERY. (T. WINGATE TODD.)



(especially the ulnar) in a small proportion of the cases. This pressure is manifested by (1) pain, going on to anesthesia down the medial side of arm, forearm and hand; (2) paralysis of the intrinsic muscles of the hand, producing the *main en griffe*, and to a less extent of the muscles of the forearm; (3) vascular effects (anemia, gangrene, etc.), manifested chiefly in the hand. Todd has shown that these vascular effects are not due to mechanical pressure on the subclavian artery by the cervical rib as was formerly supposed, but are trophic lesions of the sympathetic (vasomotor) nerves. The vasomotor nerves to the arm mainly come from the second thoracic root by the communication it gives to the lowest cord of the brachial plexus, and so are exposed to pressure from the rib.

The symptoms associated with cervical ribs usually develop about the 18th. year. Todd has shown that similar symptoms may be produced occasionally by a first thoracic rib in cases where the brachial plexus has migrated caudad. In the living patient, unless a radiogram be taken showing all the vertebræ up to the base of the skull, it is not possible with precision to ascertain with which vertebra the highest rib present articulates.

Structures found in an intercostal space.—(1) Skin; (2) superficial fascia, with cutaneous vessels and nerves; (3) deep fascia; (4) external intercostal; (5) cellular interval between intercostals, containing trunks of intercostal vessels and nerves; (6) internal intercostals; (7) thin layer of fascia; (8) subpleural connective tissue; (9) pleura (fig. 1093).

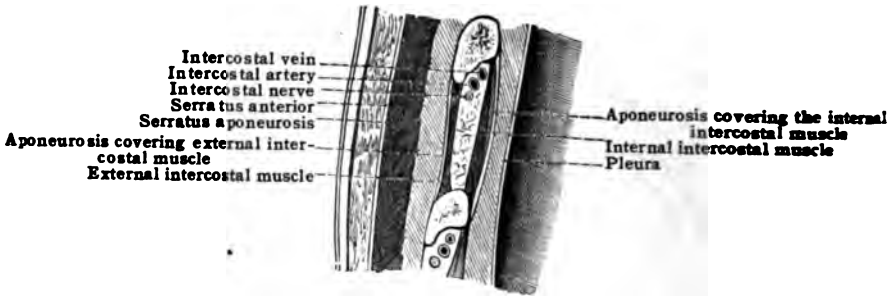
The *intercostal arteries* are nine aortic and two from the superior intercostal. An aortic intercostal having given off its dorsal branch, lying beneath the pleura, crosses the space obliquely upward to gain the lower border of the rib above, enters the costal groove at the angle, and runs forward between the intercostal muscles to anastomose with the anterior intercostals from the internal mammary or musculophrenic. Hence the rule of making the incision in empyema above the upper margin of the lower rib and in front of the angle. Along the dorsal branch a vertebral abscess may track backward.

Internal mammary artery (fig. 506).—This descends behind the clavicle, the costal cartilages, and the first six spaces, about 1.2 cm. (½ in.) from the edge of the sternum. In the sixth intercostal space it divides into musculophrenic and

superior epigastric arteries. Its venæ comitantes uniting join the innomi vein of the same side. A punctured wound of the artery is most easily secur the second and third spaces: below, resection of part of a costal cartilage wi needed.

Structures passing through the upper aperture of the thorax (388A, 98 If a section is made passing through the manubrium sterni, upper border o first rib, and upper part of the first thoracic vertebra, the following struct are met:—(1) **In the middle line.** Sternohyoid and sternothyroid muscles. their sheaths of deep cervical fascia, cellular tissue in which are the remains o thymus gland, the inferior thyroid veins, the trachea and tracheal fascia. esophagus, and longus colli muscles. Between the trachea and esophagus the recurrent nerves. (2) **On each side.** The apex of the lung, covered pleura, deep cervical fascia, and membranous cervical diaphragm ('Sibs fascia') derived from the scalenes, rises about 3.7 cm. (1½ in.) above the first Between it and the trachea and esophagus lie the following: the internal m mary artery, the phrenic nerve: on the right side, the innominate vein and art with the vagus between the two, the cardiac nerves, and the right lymph duct. On the left side are the common carotid and subclavian arteries, with left vagus between them, the cardiac nerves and the thoracic duct. Furth back and on each side are the trunk of the sympathetic, the superior interco artery, and the first thoracic nerve.

FIG. 1093.—SECTION OF THE SIXTH LEFT INTERCOSTAL SPACE, AT THE JUNCTION OF T ANTERIOR AND POSTERIOR THIRDS. (Tillaux.)



The mamma (figs. 80–83).—This lies chiefly on the pectoralis major s slightly on the rectus abdominis and serratus anterior. It is usually describ as reaching from the second to the sixth rib, and from the sternum to the anter border of the axilla. It is most important to remember that the breast is ofte much more extensive structure than would be included in the above very limit description. Thus—(1) the gland is not encapsuled at its periphery, its tis branching and breaking up here to become continuous with the superficial fas (Stiles.) (2) The retinacula cutis contain lymphatics and, sometimes, mamm tissue. (3) There is a lymphatic plexus, and, often, minute lobules of gl tissue, in the pectoral fascia. (Heidenhain.) Fully one-third of the wh mamma lies posterior and lateral to the axillary border of the pectoralis major that it reaches almost to the midaxillary line. That part of the upper and late quadrant known as the axillary lobe is of especial importance from its rea ing into close vicinity with the anterior pectoral group of axillary nodes (p. 7 In the male the nipple is usually placed in the fourth space, nearly 2.5 cm. (1 i lateral to the cartilages of the fourth and fifth ribs. On the nipple itself open fifteen or twenty ducts which dilate beneath it, and then diverge and break for the supply of the lobules. The skin over the areola is very adherent, p mented, and fatless. Here also are groups of little swellings corresponding large sebaceous follicles and areolar glands. The skin over the breast is fre movable, and united to the fascia which encases the organ, and thus to the int lobular connective tissue, by bands of the same structure—the retinacula cu Under the breast, and giving it its mobility, is a fatty areolar layer, the seat submammary abscess.

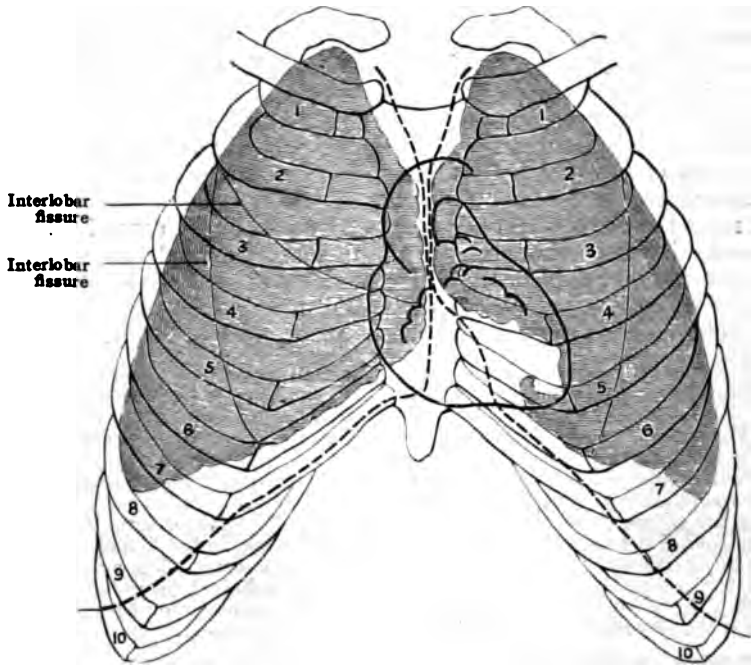
The nerves which supply the breast are the anterior cutaneous branches of the sec third, fourth, and fifth intercostal nerves, and the lateral branches of the last three. connection of these trunks serves to explain the diffusion of the pain often observed in pai

affections of the breast. Thus pain may be referred to the side of the chest and back (along the above intercostal trunks), over the scapula, along the medial side of the arm (along the intercostobrachial nerve), or up into the neck. The gland is supplied by the following **arteries**: the aortic intercostals of the second, third, fourth, and fifth spaces, similar intercostal branches from the internal mammary, which runs outward, two small branches to each space, perforating branches from the same vessel, one or two given off opposite to each space, the long thoracic and external mammary (when present) from the axillary.

The **lymphatics of the breast** require special attention. They follow along the milk-ducts to form the subareolar lymphatic plexus, from which the main lymphatic channels pass outward to communicate with the pectoral, subscapular, axillary and central nodes of the axilla.

There are three subsidiary or secondary lymphatic channels of the brest: (1) Groszman's path passes directly backward through the pectoralis major to communicate with lymph nodes (Rotter's) beneath the pectoralis minor. (2) Lymphatics which follow the perforating branches of the internal mammary to communicate with the mediastinal nodes and pleural lymphatics. (3) The paramammary route of Gerota, which may account for liver metastases and skin metastases in the upper abdominal wall. The lymphatics of the skin also anastomose across the front of the chest. For further details and figures, see pp. 756.

FIG. 1094.—OUTLINE OF THE HEART, ITS VALVES, THE LUNGS (SHADED), AND THE PLEURA. (Holden.) (Cf. figs. 481 and 1013.)



In **removal of the breast** elliptical incision will usually suffice if employed on wide lines and if attention be paid to the following points:—(1) Those details in the surgical anatomy already referred to, especially those bearing on the extensiveness of this organ, and the proportionate difference between seen and unseen disease. (2) The importance of removing in one continuous piece the whole breast, all the skin over it, the costosternal part of the pectoralis major, the pectoralis minor, the axillary fat, and lymphatics.

Surface form and relations of the lungs.—To map out the lung, a line should be drawn from the apex, a point about 2.5 cm. (1 in.) or less above the clavicle, a little lateral to the sternoclavicular articulation, obliquely downward, behind the sternoclavicular joint to near the center of the junction of the manubrium and body of the sternum (sternal angle). Thence, on each side a line should be drawn slightly convex as far as a similar point on the sternum lying opposite the articulation of the fourth chondrosternal joint. On the right side the line may be dropped as low as the sixth chondrosternal joint; on the left the incisura cardiaca may be shown by drawing a line lateralward to the parasternal line (midway between sternum and nipple) thence curving downward and medially to the sixth costal cartilage, a little lateral to its chondrosternal junction (fig. 1094). Thus the lower part of the anterior surface of the right ventricle is not covered by lung. The lower border of the lung will be marked on the right side by a line drawn from the sixth chondrosternal articulation across the side of the

chest down to the tenth thoracic spine. The lower border of the left lung wi follow a similar line, starting on a level with the sixth chondrosternal join In the nipple-line the lung crosses the sixth rib, in the midaxillary line the eigh and opposite the angle of the scapula (the arms being close to the sides), the ten rib. The position of the great fissure in each lung may be ascertained appro mately by drawing a line curving downward and forward from the second thora spine to the lower border of the lung at the sixth costal cartilage: and the small (horizontal) fissure of the right lung extends from the middle of the foregoing the junction of the fourth costal cartilage with the sternum. It will be seen fr the above that there is little lung behind the manubrium. The connective tis here between the lung margins contains the thymus, large up to the age of puber and, later, its remains. The hilus (root) of the lung is referred to on p. 12 For further details on the topography of the lungs, see p. 1265.

The border of the **pleura** (fig. 1094), following much the same line as the lu above and in front, reaches lower down laterally and behind. Thus the t sacs starting from about 2.5 cm. (1 in.) above the medial third of the clavi converge toward the sternal angle (p. 1260); meeting here, they descend ve cally, the left overlapping the right slightly, to the fourth chondrosternal joi Hence the *right* sac descends behind the sternum to the sternoxiphoid junct and sixth chondrosternal joint. Thence, as it curves backward on the chest, cr ing the eighth rib close to the parasternal line (*vide supra*), the tenth in the m axillary, the eleventh in the line of the angle of the scapula, and thence toward twelfth thoracic vertebra. On the *left* side the pleura parts company from right at the level of the fourth chondrosternal junction, deviating laterally s downward across the fourth and fifth interspaces: it then turns again sligh medially to meet the sixth costal cartilage. Thus, as in the case of the lung, to a less extent, there is a small area of the pericardium, and, under it, the ri ventricle uncovered by the pleura. Over the side and back of the chest, along diaphragmatic reflection, the left pleura reaches a little lower than the rig For further details on the topography of the pleura, see p. 1260).

The *deepest part of the pleural sac* is where the reflection crosses the tenth rib or tenth sp in the midaxillary line. From this it ascends slightly as it curves back to the spine. (C ningham.) *The relations of the pleura to the last rib* are of much importance to the surgeo operations on the kidney. In the case of a twelfth rib of ordinary length, the pleural reflect crosses it at the lateral border of the sacrospinalis; when a rudimentary last rib does not re the lateral border of this muscle, an incision carried upward into the angle between the eleve rib and the sacrospinalis will open the pleural sac. (Melsome.)

For **tapping the pleura** there are two chief sites:—(1) The sixth or seventh space in fr of the posterior fold of the axilla. (2) The eighth space behind, in the line of the angle of scapula. For **the incision of an empyema** the first is usually chosen. The overlying soft pa are not thick, the interspace is wide enough, drainage is sufficient (especially if part of seventh or eighth rib be resected), and this site is free from the objection that the angle of scapula overlaps the seventh and eighth ribs, unless the arm is raised.

Surface form and relations of the heart (figs. 481, 1097).—The upper limit the heart (base) is defined by a line crossing the sternum a little above the upp border of the third costal cartilage, reaching about 1.2 cm. ($\frac{1}{2}$ in.) to the rig and about 2.5 cm. (1 in.) to the left of the sternum. Its apex point is in t fifth space, 3.7 cm. ($1\frac{1}{2}$ in.) below the male left nipple, and 2.5 cm. (1 in.) to t medial side. This point will be about 7.5 cm. (3 in.) from the midline. T right border (right atrium) will be given by a line, slightly convex laterally, dra from the right extremity of the upper border to the right sixth chondroster joint. If another line, slightly convex upward, be drawn onward from this po across the last piece of the sternum, just above the xiphoid cartilage, to the ap it will give the lower border (margo acutus of right ventricle), which rests on t central tendon of the diaphragm. The left border (margo obtusus of left vent cle) will be given by a line, convex to the left, passing from the left extremity the upper border to the apex-point. This line should be 7.5 cm. (3 in.) from t middle of the sternum at the level of the fourth costal cartilage. The base of t heart is opposite four of the thoracic vertebræ, viz., the sixth, seventh, eight and ninth. The apex and anterior or sternocostal surface have been mentione The inferior or diaphragmatic surface (chiefly left atrium and left ventricle) re upon the diaphragm, mainly the central tendon, to which the intervening pe cardium is connected, and is thus adjacent to the liver and a small portion of t stomach.

If a circle 5 cm. (2 in.) in diameter be described around a point midway between the left nipple and the lower end of the body of the sternum, it will define with sufficient accuracy for practical purposes that part of the heart which lies immediately behind the chest wall, and which is uncovered by lung and (in part) by pleura. (Latham.)

The valves.—The **pulmonary valves** (the highest and most superficial) lie, in front of the aortic, behind the third left chondrosternal joint, and opposite to the upper border of the third costal cartilage. The **aortic valves** lie behind and a little below these, opposite to the medial end of the third intercostal space, and on a level with the lower border of the third left costal cartilage. The **atrioventricular openings** lie at a somewhat lower level than that of the aortic and pulmonary. Thus the **tricuspid valves** lie behind the middle of the sternum at the level of the fourth intercostal space; and the **mitral valves,** the most deeply placed of all, lie a little to the left of these, behind the left edge of the sternum and the fourth left costal cartilage (fig. 1094: also cf. fig. 481).

'Thus these valves are so situated that the mouth of an ordinary-sized stethoscope will cover a portion of them all, if placed over the juncture of the third intercostal space, on the left side, with the sternum. All are covered by a thin layer of lung; therefore we hear their action better when the breathing is for a moment suspended.' (Holden.)

The pericardium.—This fibroserous sac, occupying the middle mediastinum, is triangular in outline. Here its fibrous layer gives investment to the large vessels, except the inferior cava. It is also continuous with the deep cervical fascia. The base, connected with the diaphragm, has been referred to above. In front an area of variable size (fig. 1094), owing to the divergence of the left pleura, is in contact with the left half of the lower part of the sternum, and more or less of the medial ends of the fourth, fifth, and sixth costal cartilages, here forming the posterior boundary of the anterior mediastinum. Behind, the pericardium is the anterior boundary of the posterior mediastinum, and is in close contact with the esophagus and aorta.

Paracentesis of pericardium.—While the seat of election must here remain an open question, each case requiring a decision for itself, the one most suitable on the whole is the fifth left space, avoiding injury to the internal mammary artery and the pleura, of which the line of reflection has been shown to vary.

In **incision of the pericardium** to establish free drainage, a portion of the fifth or sixth left costal cartilage should be carefully resected, the internal mammary artery tied, the transversus thoracis (triangularis sterni) scratched through, and the pleural reflection pushed aside.

Relation of vessels to the wall of the thorax.—**Aortic arch.**—The ascending part of the aorta reaches from a spot behind the sternal border, on a level with the third left costal cartilage, to the upper border of the second right cartilage; thus it passes upward, backward, and to the right, and is about 5 cm. (2 in.) long. The transverse part then crosses backward to the left behind the sternum (the highest part of the arch being about 2.5 cm. below the notch), reaching from the second right costal cartilage to the lower border of the fourth thoracic vertebra on the left side. This part recedes from the surface, and, with the next, cannot be marked out on the surface. The third, or descending part, the shortest of the three, reaches from the lower border of the fourth to that of the fifth thoracic vertebra.

FIG. 1094 will remind the reader of many of the pressure symptoms which may accompany an **aneurysm of the aortic arch;** e.g., pressure on the left innominate vein, the three large arteries, trachea, and left bronchus, recurrent nerve, esophagus, and thoracic duct. In **aneurysm of the thoracic aorta,** pain, usually unilateral, referred to the corresponding intercostal nerves, is a common pressure symptom.

The pulmonary artery lies behind the left side of the sternum and its junction with the second and third costal cartilages.

Innominate artery.—A line drawn from the top of the arch, about 2.5 cm. (1 in.) below the sternal notch, and close to the center, to the right sternoclavicular joint, will give the line of this vessel.

Left common carotid.—This vessel will be denoted by a line somewhat similar to the above, passing from the level of the arch a little to the left of the last starting-point to the left sternoclavicular joint.

Left subclavian artery.—A line from the end of the transverse arch, behind the left of the sternum, straight upward to the clavicle, delineates the vertical thoracic course of the long left subclavian artery; its thoracic portion lies behind the left carotid.

Innominate veins.—The **left,** 7.5 cm. (3 in.) long, extends very obliquely from the left sternoclavicular joint, behind the upper part of the manubrium, to a point 1.2 cm. (½ in.) to the right of the sternum, on the lower border of the first right costal cartilage. The **right,** about 2.5 cm. (1 in.) long, descends almost vertically to the above point from the right sternoclavicular joint.

Venæ cavæ.—The **superior** descends from the point above given for the meeting of the innominate veins in the first intercostal space, close to the sternum, and perforates the right atrium on a level with the third costal cartilage. The **inferior vena cava.**—The opening of this vein into the right atrium lies under the middle of the fifth right interspace and the adjacent part of the sternum.

The esophagus.—The relations of this tube (figs. 913, 914) in its cervical a thoracic portions are most important, e.g., to the trachea and left bronchus: t vagi and left recurrent nerve; the pleuræ, left above and right below, aorta, a pericardium. Its lymphatics (fig. 612) go below into the posterior mediasti and superior gastric nodes; above into the lower deep cervical nodes, a p sometimes diagnostic in malignant disease.

The lumen of the esophagus is narrowed at three points:—(1) and best marked at the coid cartilage, (2) where it is crossed by the left bronchus, (3) as it passes through the phragm. The tube, 25 to 27 cm. (10 to 11 in.) long, extends from the sixth cervical to the lo border of the tenth thoracic vertebra. In an adult, the distance from the incisor teeth to cricoid is about 15 cm. (6 in.); an additional 7.5 cm. (3 in.) gives the level of the crossin the left bronchus, while from the teeth to the opening in the diaphragm would be from 41 to cm. (16 to 17 in.). The upper part of the esophagus just below the cricoid cartilage poster has a weak spot. The mucous membrane may herniate at this point giving rise to esopha diverticula. To expose the tube in the neck an incision is made on the left side, much as for higher ligature of the common carotid, but carried lower down. The depressors of the h being drawn medially or divided, the pretracheal fascia is opened, which allows of the over ping thyroid and trachea being displaced medially, while the carotid sheath is retracted la ally. The tracheal rings are the best guide to the esophagus. The recurrent nerve mus avoided.

THE ABDOMEN

The regions and subdivisions will first be considered, the abdominal w next, and finally the abdominal cavity, including the peritoneum and the vari organs.

Subdivision of the abdominal cavity.—Certain arbitrary horizontal vertical planes, represented by lines drawn on the ventral surface, are used subdivide the abdomen for topographical purposes (fig. 916). **A. Horizo planes:** (1) *Infracostal* through the lower margins of the tenth costal cartila (the lowest part of the costal margin). This plane crosses the body of the th lumbar vertebra. (2) *Intertubercular*, passing through the tubercles, promin points of the iliac crests, which are situated about 5 cm. (2 in.) behind the ante superior spines. This plane crosses the body of the fifth lumbar vertebra. **Vertical planes:** (1) *Median vertical*, drawn upward in the middle line from symphysis pubis. (2) *Lateral vertical*, drawn upward on each side parallel to former, from a point midway between the anterior superior iliac spine and symphysis pubis.

These lateral lines if prolonged upward into the thorax pass rather more than 2.5 cm. (1 to the medial side of the male nipple and meet the clavicle a little medial to its midpoint.

According to the BNA system, the lateral vertical lines are slightly curved, extending ward from the pubic tubercle on each side along the lateral margin of the rectus muscle (co sponding to the linea semilunaris); and the lower horizontal is drawn between the ante superior iliac spines.

The infracostal and intertubercular planes, with the two lateral verti planes that intersect them divide the abdomen into nine regions;—three medi viz., the epigastric, umbilical, and hypogastric and on each side three lateral, v hypochondriac, lumbar, and iliac (fig. 916).

Another transverse plane of practical importance, though we do not use it as a bound of the abdominal subdivisions, is represented by Addison's transpyloric line (fig. 1095), dr horizontally through a point midway between the umbilicus and the sternoxiphoid junction midway between the symphysis pubis and suprasternal notch). It crosses the spine at the l the first lumbar vertebra. It must be noted that the pylrous only lies in this plane du life when the subject is in the horizontal position. On assuming the upright position the pyl falls at least one vertebra lower. The sternoxiphoid plane, drawn horizontally through junction of the body of the sternum with the xiphoid, cuts the spine at the disk between ninth and tenth thoracic vertebræ, and the umbilical plane, passing through the umbili crosses the disk between the third and fourth lumbar vertebræ (though in corpulent subjects i somewhat lower).

The abdominal wall. Bony and muscular landmarks.—The linea a (see p. 460) forms a perceptible groove in the middle line from the xiphoid c tilage to the umbilicus. It is a band of interlacing fibers, mostly crossing ea other at right angles, that forms the main insertion of the transversus and obliq muscles, and stretches between the two recti muscles from xiphoid cartilage symphysis. It is on the average 1.2 cm. ($1\frac{1}{2}$ in.) wide above the umbilic Below the umbilicus it narrows rapidly and becomes merely a thin fibrous septu between the two recti, which in this position lie close together.

In its broad supraumbilical portion, small hernial protrusions of subperitoneal fat sometimes force their way through interstices in the linea alba, and true peritoneal sacs may be drawn through after them. Subperitoneal fat usually forms the greater part of such a protrusion. The linea alba is not very vascular, and hence was at one time the favorite site of incisions in opening the abdominal cavity. Since the resulting scar is weak and yielding, however, it is now more customary to make vertical incisions through the rectus sheath, to one side of the middle line, where the abdominal wall can be sutured in layers, and an incisional hernia prevented.

The umbilicus lies in the linea alba rather below its center. It is somewhat prone to hernia formation (p. 1402) and is occasionally the site of congenital fistulæ, which may originate in a Meckel's diverticulum (p. 1376) or a patent urachus.

When the recti are thrown into contraction the **linea semilunaris** on each side is made evident as a groove, extending with a slight lateral convexity from the tip of the ninth costal cartilage, where the lateral vertical line meets the thoracic margin, to the pubic tubercle.

The linea semilunaris shares the disadvantages of the linea alba as a site for incisions, and there is the further danger of injury to the nerve supply of the rectus, which may involve a diffuse bulge of the atrophied muscle.

The contraction of the recti muscles also shows up the three *lineæ transversæ*, fibrous intersections adherent to the anterior layer of the sheath of the rectus, which cross the substance of the muscle (1) at the umbilicus, (2) at the tip of the xiphoid, and (3) midway between the former two. A tonic contraction of one or both recti localised to one of these segments occasionally gives rise to the 'phantom' tumors which occur in some hysterical cases.

In tapping the bladder above the pubes, the trocar should be introduced immediately above the pubes and driven backward and a little downward. In this operation, and in suprapubic cystotomy, the retropubic (prevesical) space or **cavum Retzii** is opened (cf. figs. 1025, 1046). This is bounded anteroinferiorly by the pubes and superior fascia of the urogenital diaphragm, posterosuperiorly by the anterior surface of the bladder. Below are the true ligaments of this viscus. The space contains fatty tissue and veins, increasing in size with the advance of life. If about ten ounces of fluid are injected nto the bladder, the peritoneum will be raised sufficiently to allow of a three-inch incision being made between the recti and pyramidales immediately above the pubes. The transversalis fascia is thicker below, and is often separated from the linea alba by fat, which must not be mistaken for the extraperitoneal layer. The peritoneal reflection is loosely connected to the bladder and can always be peeled upward.

A transverse line drawn from one anterior superior iliac spine to the other crosses at about the level of the top of the promontory of the sacrum. Such a line will always show whether the pelvis is horizontal or not. (Holden.)

The **inguinal (Poupart's) ligament** (fig. 1109) corresponds to a line drawn with a slight curve downward between the anterior superior iliac spine and the pubic tubercle. The first of these bony prominences corresponds to the starting-point of the above ligament, the attachment of the fascia lata to the ilium, the meeting of the fleshy and aponeurotic parts of the external oblique (denoted by a line drawn upward from this spine to the ninth costal cartilage, or often a little anteriorly to these points), the point of emergence of the lateral cutaneous nerve of the thigh, and part of the origins of the internal oblique, transversus, and tensor fasciæ latæ.

The pubic tubercle marks the lateral pillar (inferior crus) of the **subcutaneous inguinal (external abdominal) ring**, the mouth of which corresponds to the crest of the pubes lying between the tubercle and the symphysis. The neck of an inguinal hernia is above the tubercle and Poupart's ligament; that of a femoral hernia below and lateral to the tubercle, and below the same ligament. The ring, and especially its lateral pillar, can easily be felt by invaginating the scrotal skin with a finger, and pushing upward and laterally. In a female patient, if the thigh be abducted, the tense tendon of the adductor longus will lead up to the site of the ring. The **abdominal inguinal (internal abdominal) ring** is situated about 1.2 cm. (½ in.) above the center of Poupart's ligament; oval in shape, and nearly vertical in direction, it has the arching fibers of the transversus above it, and to its medial side the inferior epigastric artery, lying behind the spermatic cord. The pulsations of this vessel here guide the finger in the insertion of the uppermost deep sutures in radical cure of hernia. The **canal** runs obliquely downward and forward between the two rings. In the adult it is about 3.7 cm. (1½ in.) long, but in early life, and in adults with a large hernia dragging upon the parts, the two rings are much nearer, and may be one behind the other. For the anatomy of this region and of inguinal hernia, see pp. 463 and 1394.

Vessels in the abdominal wall (fig. 535).—The three superficial branches of the common femoral, the external pudic, epigastric, and circumflex iliac, supply the lowest part of the anterior abdominal wall and the adjacent groin and genitals.

The others that have to be remembered are the inferior epigastrics and epigastric branch of the internal mammary, the deep circumflex iliacs, the two intercostals, and the abdominal branches of the lumbar arteries.

Of these, the inferior epigastric is the most important; its course will be marked out line drawn from a point just medial to the center of the inguinal ligament, upward and med to the medial side of the abdominal ring, and thence to a point about midway between the p and umbilicus, forming the lateral boundary of Hesselbach's triangle (fig. 1108). Here vessel, which at first lies between the peritoneum and fascia transversalis, perforates the l and, passing over the semicircular line (fold of Douglas) enters the sheath of the rectus. It runs upward, closely applied to the back of that muscle, and, a little above the level o umbilicus, divides into branches which anastomose with the epigastric branch of the int mammary.

One superficial vein in the abdominal wall needs especial mention, the thoracoepig (fig. 563) joining the veins of the chest, e. g., the long thoracic above with, the superficia gastric below. Its valves directing the blood downward below and upward above (Stiles) be rendered incompetent when this vessel is enlarged, as in interference with the portal with which it communicates by a vein in the round ligament, or in blocking of the inferior cava.

Lymphatics.—It is sufficiently correct to say that those above the umbilical level go t axillary, and those below that line to the inguinal nodes.

Nerves (figs. 794, 807).—The lower seven intercostals and the iliohypoga and ilioinguinal supply the abdominal wall. The sixth and seventh interco supply the skin over the upper epigastrium; the eighth, the area of the mi linea transversa; the tenth, that of the umbilicus; the last thoracic, ilioingu and iliohypogastric, the region above Poupart's ligament, and that of the pu The iliohypogastric supplies the skin over the subcutaneous inguinal (exte abdominal) ring; the ilioinguinal that over the cord and scrotum. The thoracic and iliohypogastric cross the iliac crest to supply the skin of the butt

The diaphragm.—The upper limit of the diaphragm (see. p. 469) rises t following levels in full expiration; Its central tendon to about the lower end o body of the sternum, or the seventh chondrosternal joint; the right half t fifth rib, or about 1 cm. (½ in.) below the nipple; the left half not rising quit high, i.e., to the fifth space, or 2.5 cm. (1 in.) below the nipple.

Topographical relations of abdominal viscera (fig. 1095).—These will inc the peritoneum, liver and bile passages, stomach, spleen, pancreas, intesti kidneys and ureters, and large abdominal vessels.

The peritoneal spaces.—The peritoneum presents certain potential spa determined by its various reflections from the parietes and abdominal visc In these spaces collections of fluid such as abscesses or extravasations from hol viscera or blood vessels may collect and become shut off by adhesions or over in various directions into neighboring spaces. The transverse mesocolon great omentum together form a shelf transversely placed, which divides greater sac into two main divisions—supraomental and infraomental (figs. 9 923, 924).

The supraomental region, in which the various forms of subphrenic abscess are found. tains the following fossæ (Barnard, Brit. Med. Jour., Feb. 15, 1908). (1) Right subphr between the right lobe of the liver and right cupola of the diaphragm, bounded toward median line by the falciform ligament, and behind by the coronary ligament. It communic below with (2) the subhepatic fossa or right renal pouch (Morison), which is bounded abov the visceral surface of the liver, and below by the mesocolic shelf and right kidney. It ext from the right lateral abdominal wall, its most capacious part, across the median line under left lobe of the liver, and on its posterior aspect lie the upper pole of the right kidney, epi foramen, and anterior surface of small omentum. (3) The left subphrenic, also known as anterior perigastric fossa, lies between the left dome of the diaphragm above, and the left of the liver, stomach, spleen and omentum below. It is bounded on the right by the falci ligament which lies somewhat to the right of the median line. (4) The omental bursa ma regarded as a diverticulum from the subhepatic fossa with which it communicates by the ploic foramen. Abscesses in this sac are rare, but occasionally laceration of the panc or acute hemorrhagic pancreatitis gives rise to a collection of pancreatic juice and blood in lesser sac, known as a pancreatic pseudo-cyst (Jordan Lloyd).

The infraomental region is subdivided in its abdominal part into (1) right and (2) compartments by the attachment of the root of the mesentery to the spine, descending from duodenojejunal flexure downward into the right iliac fossa. These fossæ communicate with supraomental regions in the neighborhood of the hepatic and splenic flexures of the c respectively, and below with (3) the pelvis. The deepest level of the peritoneum lining pelvis constitutes in the male the rectovesical, and in the female the rectovaginal fossa (pouc Douglas). The mesentery extends obliquely from above to the left, downward and to the r from the 2nd to the 4th lumbar vertebra. Because of this oblique attachment, an abs

developing from a ruptured appendix which lies in the pelvis may be directed upward and to the left.

It should be noted that with a patient in the supine position, owing to the contour of the psoas muscles and the anterior convexity of the lumbar spine, any fluid above the pelvic brim will tend to gravitate into the subphrenic spaces across the flexures of the colon which lie far back in the loins. This is undesirable in view of the great absorbing power of the subphrenic lymphatics, and may be obviated by propping the patient in a half-sitting position.

Viscera behind the linea alba.—From above downward there are the following;—(1) *Above the umbilicus*—the left lobe of the liver, the stomach, the transverse colon, part of the great omentum, the pancreas; and celiac (solar) plexus. (2) *Below the umbilicus*—the rest of the great omentum, covering in the small intestines and their mesentery. In the child, the bladder occupies a partly abdominal position; and in the adult, the same viscus, if distended, will rise out of the pelvis and displace the above structures, raising the peritoneum until, if distended half way to the umbilicus, there is an area of nearly 5 cm. (2 in.) safe for operations above the symphysis. The gravid uterus also rises behind the linea alba.

The liver (figs. 917, 1095, 1113).—In the erect position, the anterior thin margin of the liver projects about 1 cm. (½ in.) below the right costal margin, but can only be made out with difficulty in this position. It may also be displaced downward by pleuritic effusion or tight lacing. The liver also is proportionately much larger in small children.

Of the three more accessible surfaces, *the right lateral* is opposite the seventh to the eleventh intercostal arches, separated from them by the pleura, the thin base of the lung, and the diaphragm. The *superior* surface is accurately fitted with its right and left portions into the hollows of the diaphragm, a slightly depressed area intervening which corresponds to the central tendon. Its level corresponds to that of the diaphragm given above. On the left side, in the adult, the limit of the left lobe will be in the fifth interspace, about 7.5 cm. (3 in.) from the midline. The *anterior* surface is in contact with the diaphragm, costal arches, and, between them, the xiphoid cartilage, and, below, with the abdominal wall. Both the superior and anterior surfaces are subdivided by the falciform ligament, an important point in subphrenic suppuration. In the right hypochondrium the anterior margin corresponds to the lower margin of the thorax; but in the epigastric region, running obliquely across from the ninth right to the eighth left costal cartilage, it crosses the midline about a hand's breadth below the sternoxiphoid articulation (Godlee), or half-way between the sternoxiphoid junction and umbilicus, i.e., in the transpyloric line (fig. 1095). Behind, the anterior margin, following the right lateral surface within the costal arches, crosses the last rib toward the level of the eleventh thoracic spine. In the anterior border, a little to the right of the midline, is the umbilical notch, where the falciform and round ligaments reach the liver. Still further to the right near the junction of the semilunar line and the infracostal margin, is the fundus of the gall-bladder.

Gall-bladder and bile-passages.—The fundus of the gall-bladder, situated in a fossa on the under surface of the right lobe of the liver, and having the quadrate lobe to its left, lies opposite to the right ninth costal cartilage, close to the lateral edge of the rectus. This point corresponds to the site of intersection of the lateral vertical and transpyloric lines (fig. 1095). It is near the hepatic flexure of the colon and the first part of the duodenum, into either of which, but particularly the latter, large gall-stones impacted in the neck of the gall-bladder occasionally ulcerate. A distended gall-bladder as it enlarges tends to extend downward or obliquely toward the umbilicus from the above point where it emerges from under the costal margin.

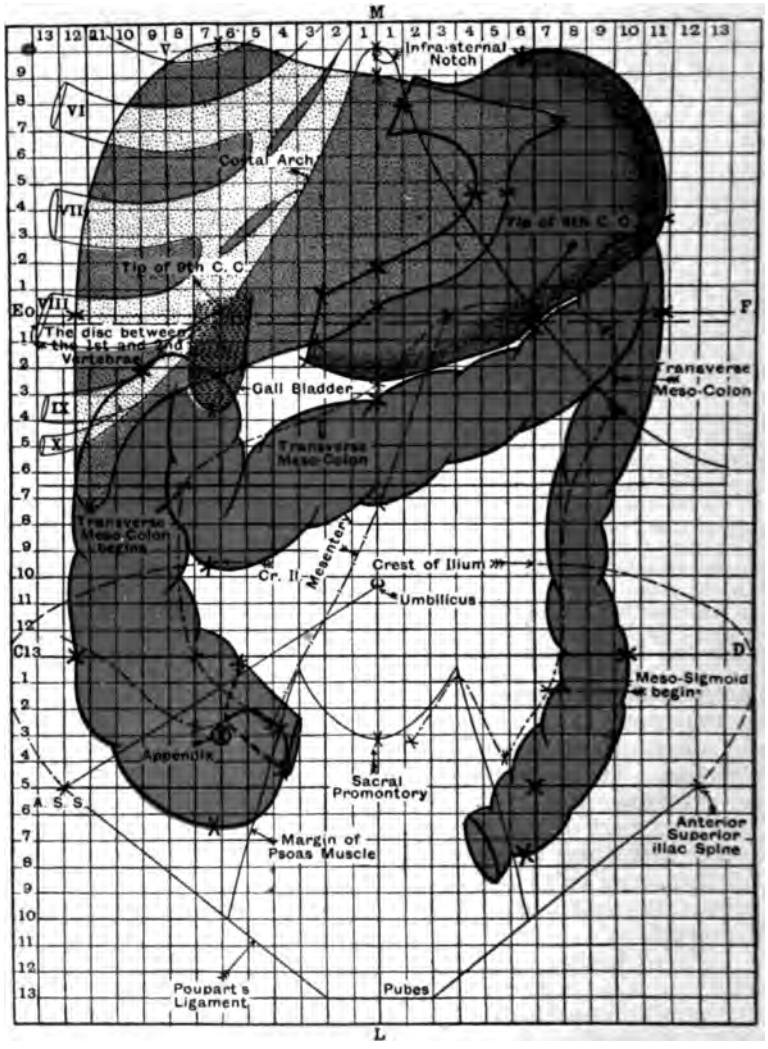
The long axis of the gall-bladder is directed from the fundus backward and upward. The cystic duct runs from the neck downward and forward in the lesser omentum, and so forms an acute angle with the gall-bladder. A spiral fold of mucous membrane at the junction of the two, which fulfils the function of keeping the lumen open for the flow of bile, adds to the difficulty of passing a bougie from the gall-bladder down into the common duct.

The hepatic and cystic ducts join in the right free margin of the lesser omentum to form the **common bile-duct**, 7.5 cm. (3 in.) in length, which as it runs down to open into the duodenum presents four distinct stages (figs. 933, 955, 962). (1) It first lies in the free edge of lesser omentum in front of the epiploic foramen, with the hepatic artery to the medial side, and the portal vein behind them both. (2) Behind the first part of the duodenum with the gastroduodenal artery accompanying it. (3) In a deep groove in the head of the pancreas, between that gland and the posterior aspect of the second part of the duodenum. The pancreatic tissue surrounds it completely in 75 per cent. of cases (Bunger), hence the jaundice that occurs in chronic interstitial pancreatitis. (4) Piercing the muscular wall of the duodenum obliquely it ends by joining the main duct of the pancreas at the ampulla of Vater and opening into the second part of the duodenum by a common orifice. This orifice, situated on the posteromedial aspect of the gut, rather below the center of the second portion, is raised on a small papilla and is narrower than the lumen of the common duct. It should be remembered that the cystic and right hepatic duct run parallel and rather close together for a short distance. Injury or

ligation of the hepatic duct occurs much too frequently in removal of the gall-bladder. d failure to realize the proximity of these two ducts.

The stomach.—The study of this organ by rendering its contents opaque bismuth salts and projecting its shadow by X-rays on a fluorescent screen greatly modified the conception of its shape and position formed from mortem and operative observations. Examined post-mortem, or at opera under general anesthesia it forms a flaccid sac with its long axis directed fro fundus obliquely downward, forward, and to the right (fig. 1095). Seen u

FIG. 1095.—OUTLINE SHOWING THE AVERAGE POSITION OF THE ABDOMINAL VISCE (Addison.)



X-rays, with the patient standing upright, the cardiac portion (the fundus body together) is vertical, and the smaller pyloric portion is directed back and to the right and slightly upward (figs. 926, 927, 1113). The most point is the cardiac orifice.

The **cardiac orifice** lies under the seventh left costal cartilage 2 cm. (¾ in.) from the s xiphoid junction at a depth of about 10 cm. (4 in.) from the surface. Behind, this point sponds to the tenth thoracic vertebra.

The **pyloric orifice** lies in the transpyloric plane when the patient is recumbent, but wh patient is standing it falls to the level of the second or third lumbar vetebra, or lowe when any transient faintness or nausea causes loss of muscular tone (Barclay). The pyl slightly to the right of the midline in the empty stomach. As the stomach fills it de farther and moves a little farther to the right. The *lesser curvature* presents a definite no the junction of the cardiac and pyloric portions of the stomach—the *incisura angularis*.

greater curvature reaches the umbilical plane in the erect posture, even when the stomach is empty. When the viscus is full this curvature lies distinctly below this plane, being lower in women than in men (Hertz). The *pyloric portion* of the full stomach is directed backward and a little upward, as the distended pyloric vestibule moves further to the right than the pyloric orifice and lies on an anterior plane. In the recumbent posture the greater curvature lies above the umbilical plane, even when moderately distended, and the stomach is more obliquely placed. The *fundus* invariably contains gas, even when the stomach contains no food, in which case the organ forms a contracted J-shaped tube. In extreme distention the left dome of the diaphragm is so pushed up by the fundus that it lies at a level as high as or even higher than the right dome (Hertz). The pressure thus exerted on the heart accounts for the dyspnea and cardiac pain so often associated with flatulence. The position of the pyloric sphincter is shown on the outer surface by a very constant venous ring running toward both lesser and greater curvatures in the subserous layer at right angles to the long axis of the pyloric canal (Moynihan).

In connection with the extravasation of contents that results from perforating ulcers of the stomach, a knowledge of the subphrenic peritoneal fossæ is important (p. 1372). Perforation is rare on the posterior surface since it is less mobile than the anterior, and protective adhesions form readily. When it does occur, extravasaton into the omental bursa results, and such a perforation is exposed by turning up transverse colon and stomach and incising the transverse mesocolon. Perforation on the anterior surface usually gives rise to general peritonitis, but in the less serious cases an abscess may form localized to (1) the right subphrenic space, (2) the subhepatic fossa, or (3) the left subphrenic space, according to the situation of the ulcer on the stomach.

The spleen (fig. 1115; also figs. 632–636).—This lies very obliquely in the left hypochondrium, its long axis corresponds closely with the line of the tenth rib. It is placed opposite the ninth, tenth, and eleventh ribs externally, being separated from these by the diaphragm. Medially it extends behind the fundus of the stomach. Below, it overlaps slightly the lateral border of the left kidney. Its highest point is on a level with the spine of the ninth thoracic, and its lowest with that of the eleventh thoracic vertebra. Its upper pole is distant about 3.7 cm. (1½ in.) from the median plane of the body, and its lower pole about reaches the midaxillary line. (Godlee.) In the natural condition it cannot be felt; but if enlarged, its notched anterior margin extends downward toward the umbilicus, and is readily felt below the costal margin.

The pancreas (figs. 964, 965).—The head of the pancreas lies in the hollow formed by the three parts of the duodenum, on the bodies of the second and third lumbar vertebræ. The inferior vena cava lies behind it. The neck, body, and tail of the pancreas pass obliquely to the left and slightly upward, crossing respectively the commencement of the portal vein, the aorta, and the left kidney. The root of the transverse mesocolon is attached to the anterior margin of the gland, so that its anterior surface is related to the omental bursa, and its inferior surface to the greater sac. The importance of this relation in the formation of pancreatic pseudocysts has been referred to above.

Pancreatic ducts (fig. 964).—The main duct, the duct of Wirsung, opens into the common ampulla of Vater with the bile duct. This ampulla usually opens into the gut by a narrow orifice raised on a small papilla. A gall-stone impacted in the ampulla may cause a flow of bile backward along the duct of Wirsung, and so give rise to acute pancreatitis (Opie). The small accessory duct of Santorini opens into the duodenum independently about 2 cm. higher up. It often anastomoses with the larger duct in the substance of the gland.

A cyst originating in the pancreas may 'point' toward the anterior abdominal wall by three routes (which may also be used to reach the pancreas and to establish drainage): —(1 Above the stomach through the lesser omentum; (2) between stomach and transverse colon through the great omentum; (3) below the transverse colon through the transverse mesocolon. The posterior aspect of the head of the gland, with the third part of the common bile duct may be exposed by incising the peritoneum on the lateral margin of the second part of the duodenum, and turning the gut medially toward the middle line.

Small intestine.—The average length of the small intestine is about 6.85 m. (22½ ft.), though the length as measured *postmortem* varies considerably with the degree of contraction of the longitudinal muscular coat. The duodenum is about 25 cm. (10 in.) in length. Of the remaining portion the upper two-fifths constitute the jejunum and the lower three-fifths the ileum, though this division is quite arbitrary. Cases are recorded in which patients have survived the removal of over 5 m. (16 ft.) of small intestine.

The *first part* of the **duodenum** (fig. 965) extends from the pylorus on the first or second lumbar vertebra, backward and to the right. It ends near the upper pole of the right kidney and on the medial side of the neck of the gall-bladder, by turning down to form the less mobile *second part*, which descends in front of the hilum of the right kidney to the level of the third lumbar vertebra. The *third part* of the duodenum crosses the body of the third lumbar vertebra horizontally in the infracostal plane, and then turns up obliquely to the left side of the

spine and ends at the level of the upper border of the second lumbar vertebra in the duodenojejunal flexure. The first part is the most mobile, since it is covered back and front by peritoneum in the first half of its course. The second part has a peritoneal covering in front only and is devoid of it where it is crossed by the commencing transverse colon. The third part is covered by peritoneum in front except where the superior mesenteric vessels pass across it to join the commencement of the mesentery. It is probably the constricting effect of these vessels on the duodenum that gives rise to the acute dilatation of the stomach which occasionally follows abdominal operations.

The **duodenojejunal flexure**, which lies on the left side of the body of the second lumbar vertebra, immediately below the body of the pancreas, is held up to the right crus of the diaphragm by a band of fibromuscular tissue known as the *suspensory ligament of Treitz*. Some of the fibers of this structure are continued onward into the root of the mesentery. It is not found in pronograde animals. The duodenojejunal flexure is the commonest site of traumatic rupture of the small intestine, since it is the point of union of a fixed and a freely movable portion of the gut. The beginning of the jejunum turns downward and to the left (75 per cent) of cases) or to the right (25 per cent.). In the latter case, a mesocolic band and a single peritoneal fossa are found at the convexity of the angle. In the former case, there is no mesocolic band but two fossæ. The duodenal fossæ (see p. 1190) may give rise to retroperitoneal hernia and strangulation of the intestine.

In the operation of posterior gastroenterostomy, the duodenojejunal flexure is readily found by passing the hand along the under surface of the transverse mesocolon to the left side of the spine, the omentum and colon being turned upward. The first coil of the jejunum is anastomosed to the posterior wall of the stomach, which is exposed by making an opening in the transverse mesocolon.

Jejunum and ileum.—The **mesentery** contains between its two peritoneal layers the superior mesenteric vessels and their intestinal branches, the superior mesenteric plexus, lacteals and many lymph nodes on their course. These nodes are frequently enlarged in abdominal tuberculosis in children (*tabes mesenterica*). The attached border of the mesentery may be marked out on the surface by a line drawn from just below the transpyloric plane and a little to the left of the middle line (the duodenojejunal flexure), which curves downward and to the right to end in the iliac fossa at the junction of the intertubercular and right lateral vertical lines (the ileocecal valve).

Meckel's diverticulum which is present in about 2 per cent. of subjects (Treves) is found in the free border of the ileum 30 cm. to 1 m. (1 to 3 ft.) above the ileocecal valve. It is a remains of the vitellointestinal duct. It is usually a blind conical pouch some 6 to 9 cm. long with a free extremity, but may be attached to the umbilicus by a fibrous cord. This cord may cause acute intestinal obstruction by strangulating a coil of gut, or the diverticulum may be invaginated and form the starting-point of an intussusception.

The presence of **aggregated lymph nodules** (Peyer's patches) in the lower part of the ileum accounts for the fact that tuberculous ulcers and perforating typhoid ulcers are almost confined to this part of the gut.

Intestinal localization.—It often happens that the surgeon wishes to ascertain roughly to what part of the small intestine a given coil presenting in a wound belongs. The variations in length of the small intestine and the considerable range of movement of the coils during peristalsis render the problem difficult, but it may be stated as a general rule that the upper third of the intestine lies in the left hypochondrium and is not usually encountered in a wound; the middle third occupies the middle part of the abdomen, and the lower third lies in the pelvis and right iliac fossa (Monks) (see also p. 1194). The jejunum is thicker walled and more vascular than the ileum. The lumen steadily diminishes as we pass downward, hence foreign bodies such as gall-stones that pass through the jejunum are apt to become impacted in the lower ileum.

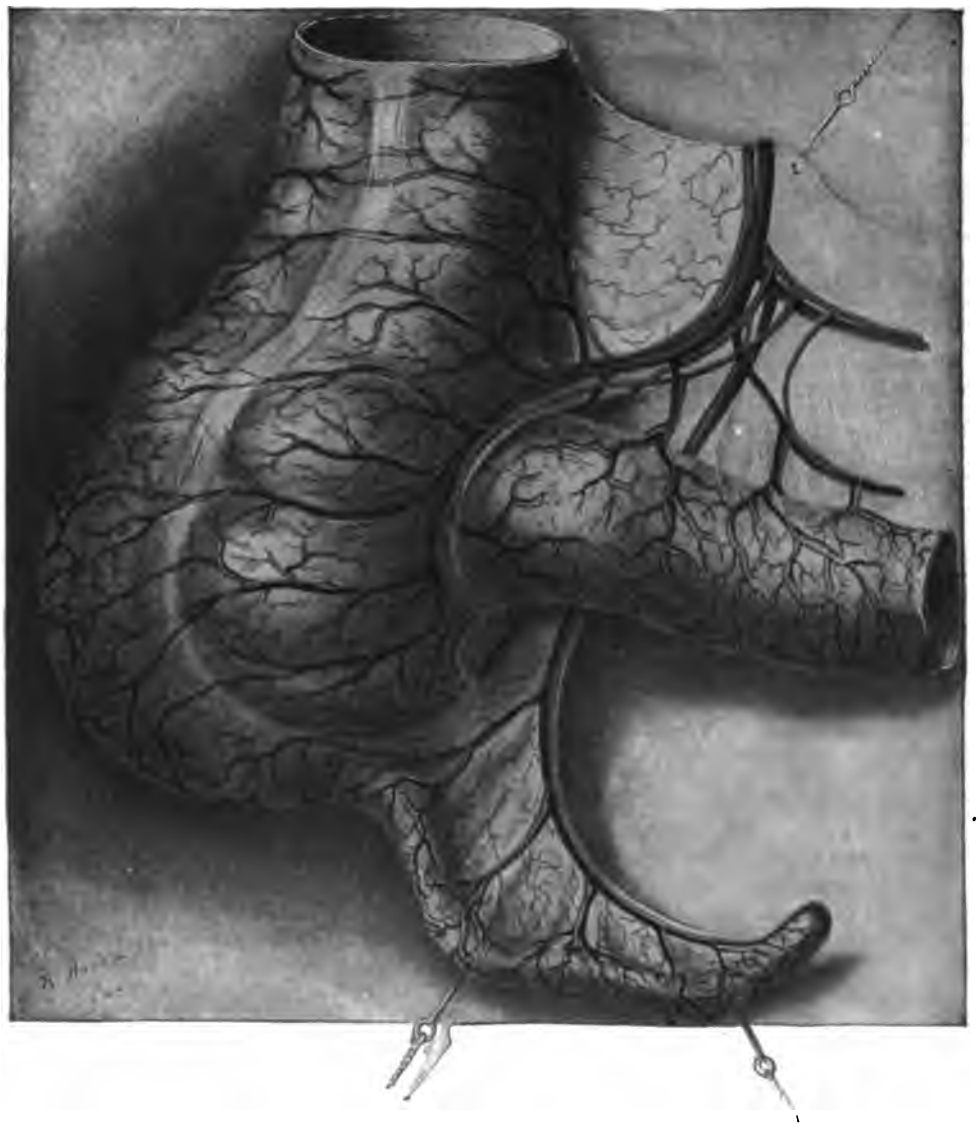
The most reliable indications of the level of a given coil are found, however, on inspection of the mesentery and its blood-vessels (see fig. 522) in Section VI). Opposite the upper part of the bowel the mesenteric arteries are arranged in a series of large primary anastomosing loops. From these the vasa recta run to the gut 3 to 5 cm. long, straight and unbranched. Passing downward toward the lower end, the single large primary loops give place to smaller and more numerous secondary loops arranged in layers coming nearer and nearer to the bowel. Hence the vasa recta become shorter. They become also less regular and more branched, and in the lower third of the small intestine are less than 1 cm. in length. The mesenteric fat in the upper third never reaches quite to the free edge of the mesentery, so that clear transparent spaces are left near the bowel. In the lower third the fat usually occupies the whole of the mesentery right up to the intestine, and makes it thicker and more opaque. (Monks: Trans. Amer. Surg. Assoc., 1913).

The average width of the mesentery, from its root at the posterior parietes to the bowel is 20 cm. (8 in.) and the longest part lies between 2 and 8 m. from the duodenum (Treves). The ileum is freely movable on a long mesentery down to the ileocecal region. In some cases however a congenital fusion of the left half of the mesentery with the parietal peritoneum near

the pelvic brim binds the bowel down a few inches above the ileocecal valve, and has been said to give rise to symptoms of intestinal stasis. (Flint, Gray, and Anderson.)

Large intestine. Ileocecal region.—The position of the ileocecal valve may be marked on the surface by the junction of the intertubercular and right lateral vertical lines, though it is often found considerably lower. It is situated on the posteromedial aspect of the cecum. The **cecum** (fig. 1096), which is the blind extremity of the colon lying below the horizontal level of the ileocecal valve, is approximately 6.2 cm. (2½ in.) in both vertical and transverse diameters, though

FIG. 1096.—BLOOD-VESSELS OF THE ILEOCECAL REGION. (Kelly). (See explanation of fig. 523.)



its size varies much with the degree of distention. It lies usually in contact with the anterior abdominal wall above the lateral half of the inguinal ligament (fig. 1095). The orifice of the appendix (vermiform process) lies some 2 cm. below the ileocecal valve. The cecum is completely covered by peritoneum as a rule, though exceptionally its posterior surface is bound down in the right iliac fossa.

The axial rotation of the midgut and descent of the cecum that normally take place during intrauterine life (p. 1173) are occasionally not completed, with the result that the cecum and appendix may be found above and to the left of the umbilicus, or less uncommonly just below the right lobe of the liver (3 per cent., Alglave), when an attack of appendicitis may simulate

inflammation of the gall-bladder. On the other hand certain cases occur in which the cec descends unusually far, proceeding downward and medially until it becomes a pelvic or whenever the bladder and rectum are empty. This pelvic position of the cæcum is foun 10 per cent. of infants (G. M. Smith, Anat. Record, vol. 5, 1911, p. 549).

In the commonest form of intussusception, the ileocecal valve and lower ileum are lapsed into the colon and carried down by the force of peristalsis toward the anus. The v in these cases forms the apex of the intussusceptum, however far it travels.

The **vermiform process** (**appendix**) (figs. 1095, 1096) is developed at apex of the cecum, and persistence of the apical appendix of fetal type, is uncommon. The fact that all three teniæ coli converge at the base of the app dix is an anatomical reminder of its primitive position. The anterior tenia i great service in operations on the appendix, since by following it down from colon the base of the appendix can always be found. The adult position of base of the appendix on the posteromedial aspect of the cecum is due to the proportionate growth of the lateral saccule of the cecum which comes to form apparent cecal apex.

The appendix averages 8 to 10 cm. (3.2–4 in.) in length in the adult. The position of its only is at all constant. It lies distinctly below McBurney's point, which is midway betwee umbilicus and the right anterior superior iliac spine. This point is often the seat of gre tenderness in appendicitis. The appendix itself may be found (1) pointing upward and t left toward the spleen, behind the terminal ileum and mesentery; (2) hanging over the p brim, in which position tenderness on rectal examination or pain on micturition results the organ is inflamed; (3) in the retrocolic fossa; and (4) with its tip projecting to the rig the cecum in the right lateral paracolic fossa, where it causes tenderness when inflamed to the anterior superior iliac spine. The course and to some extent the gravity of abs originating in the appendix will depend upon the position the inflamed organ is occupyi the time of perforation.

The **artery of the appendix** (fig. 1096) derived from the posterior branch of the ileo reaches it by running down behind the end of the ileum. It raises a fold of peritoneum e the *mesenteriolum* or *mesoappendix*. Very rarely the artery comes from the anterior bran the ileocolic.

The *teniæ coli* referred to above as converging on the base of the appendix contribut longitudinal *muscular coat*. The inner circular coat is thicker, but along the attachme the mesenteriolum certain gaps for the passage of lymph and blood-vessels occur in the mus coats. Through these gaps infection may easily spread from the mucosa to the perito (Lockwood).

The appendix is essentially a *lymph-gland* and has been called the 'abdominal to The lymph-follicles lie in the submucosa, fig. 953. They are poorly developed at birth reach their full development within the first few weeks of extrauterine life (Berry, Jour. A and Phys. vol. 35, 1900). Obliteration of the lumen is common but is usually inflammato origin, and not, as was once thought, a change normal in advanced age.

Pericecal fossæ.—In addition to the mesentery of the appendix certain other folds of toneum are usually present at the ileo-cecal junction: (1) the **ileocolic or anterior vasc** fold (fig. 1096) containing the anterior branch of the ileocolic artery; (2) the **ileocecal** bloodless fold of Treves, running from the lower border of ileum onto the cecum. The appe may be in a fossa behind either of these folds. It may also be found in the **retrocolic f** lying behind the cecum and commencement of ascending colon.

The **colon** (fig. 1095; cf. also figs. 944–948, 1020) is readily distinguished fr the small intestine by its three longitudinal teniæ and saccules (**haustra**) and the appendices epiploicæ, which are developed before birth.

The **ascending colon** (fig. 1095) runs with a slight lateral convexity upw from its junction with the cecum to the hepatic (right colic) flexure which under the ninth right costal cartilage at the level of the second lumbar verte and in contact with the anterior surface of the right kidney and the lower surf of the right lobe of the liver. It lies lateral to the right lateral vertical pl (linea semilunaris). This description is only true of an ascending colon exami by X-rays in the recumbent position. When the patient stands up, the flex may sink to the infracostal plane (third lumbar vertebra) or even lower. As colon ascends in the angle between the quadratus lumborum and psoas, it a passes backward at an angle of 51° with the horizontal, as may be seen in a sagi section through the right half of the abdo(men Coffey, Surg., Gyn and Ob 1912, 15: 390). The cecum and ascending colon are distended as a rule with fl contents and gas, and form the widest part of the colon.

The variations in the peritoneal attachments of the colon, which are of growing clin importance, are explained by its mode of development (p. 1174). During intrauterine after rotation of the midgut round an axis formed by the superior mesenteric vessels, ther a stage in which the colon has almost assumed its permanent position in the abdomen bu still provided with a free mesocolon for both ascending and descending parts. This represe the normal condition of quadruped mammals. In the normal human individual this stag

transient, and before birth the ascending and descending colons lose their mesenteries by fusion of the posterior layers with the parietal peritoneum. Meanwhile the great omentum, formed by a bulging out of the primitive dorsal mesogastrium, fuses with the transverse colon and its mesocolon. The extent of these processes of fusion varies, particularly as far as the ascending and descending colons are concerned. Thus only 52 per cent. of adults have neither ascending nor descending mesocolons (the normal condition). A mesocolon is found on the left side in 36 per cent. of all cases and on the right side in 26 per cent. (Treves). In only a small proportion (1.8 per cent.), however, does the true primitive type of ascending mesocolon persist, continuous with the mesentery of the small intestine (G. M. Smith). Such an anomaly renders the patient liable to volvulus of the ileocecal region. In the common types of incomplete fusion of its peritoneal attachments the colon is inadequately adapted to the upright position and is predisposed to ptosis. A layer of peritoneum sometimes found passing downward and medially from the parietes in the right flank onto the front of the ascending colon, known as Jackson's pericolic membrane, is probably due to persistence of an early stage in the development of the great omentum, which passes to the right across the ascending colon to join with the parietal peritoneum before the descent of the cæcum is complete, and so is the most primitive agent in fixing the proximal colon back in the right loin. This membrane is usually associated with a congenitally mobile ascending colon (Morley, Lancet, Dec. 1913).

At the **hepatic flexure** the colon bends forward and to the left, leaving the front of the kidney to which it is fixed, and crossing the second part of the duodenum. In the region of the flexure three inconstant peritoneal folds are met with giving it additional attachment to the neighboring parts, viz., (1) the *phrenocolic* and less commonly (2) the *hepatocolic* and (3) *cystocolic* ligaments (Testut). They must not be confused with pathological adhesions acquired after birth.

The **transverse colon** is freely mobile except at its extremities. It crosses the abdomen with a convexity downward and forward, being separated from the anterior abdominal wall in the middle region by the great omentum.

At the midline it usually lies near the umbilical plane in the recumbent posture, considerably lower in the erect, but may be found anywhere from the infracostal plane to the pubes, depending on the tonicity of the stomach. Its main artery, the middle colic branch of the superior mesenteric, must be avoided carefully in the operations of gastroenterostomy and gastrectomy, since ligature of this branch may cause gangrene of the transverse colon.

The left colic or **splenic flexure** lies far back in the left hypochondrium (figs. 1095, 1113) and is considerably higher than the hepatic flexure. It is in contact with the lower end of the spleen, and is almost invariably held firmly in position by its *phrenocolic ligament*, derived from the left extremity of the great omentum.

The **descending colon** is of narrower caliber than the preceding parts and usually is found firmly contracted and empty. It passes downward and forward in the angle between the psoas and quadratus lumborum and obliquely across to the right in the iliac fossa to end in the sigmoid (pelvic) colon. The lower part of the descending colon, from the iliac crest to the pelvic brim, is often termed the *iliac* colon.

In its upper part it lies in front of the convex lateral margin of the left kidney. The variations in its peritoneal attachments have been referred to above (p. 1378). The operation of lumbar colostomy, common in preantiseptic days, was performed through an incision in the back parallel with the last rib. The colon lies 2.5 cm. (1 in.) to the lateral side of the edge of the sacrospinalis, between the twelfth rib and iliac crest. The occurrence of a mesocolon here was a common source of difficulty in gaining access to the bowel without opening the peritoneum.

The **sigmoid colon** (pelvic colon or omega loop), is almost as long as the transverse colon, and forms a loop, the two ends of which, at the pelvic brim and at the front of the second (or third) sacral vertebra respectively, are placed somewhat closely together. The loop is thus anatomically predisposed to axial rotation, and is the commonest seat of volvulus in the whole intestinal tract.

On the left and inferior aspect of the pelvic mesocolon near its base, a small peritoneal fossa (*intersigmoid*) is usually found in the angle formed by the root of the mesocolon and the parietal peritoneum. It occasionally contains an internal hernia which may become strangulated.

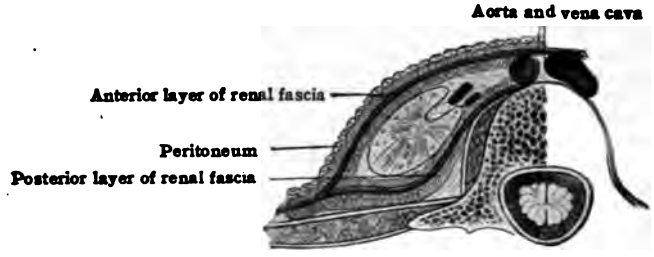
The upper part of the pelvic colon is frequently brought out and opened through an incision in the left iliac region to form an artificial anus in cases of inoperable growth of the rectum.

In advanced life, and in the chronically constipated, certain **diverticula** of mucous membrane are occasionally met with which project through the vascular gaps of the muscular coat into the bases of the appendices epiploicæ in this region, and also between the layers of the pelvic mesocolon (usually at the points where the vessels enter). They often contain fecal concretions and may become inflamed or even perforate, forming an abscess in the left iliac fossa. (McGrath: Surg., Gyn. and Obst., 1912, 15: 429.)

The junction of pelvic colon and rectum opposite the second (or third) sacral vertebra forms a more or less acute angle and constitutes the narrowest part of the colon. It is a frequent site of stricture.

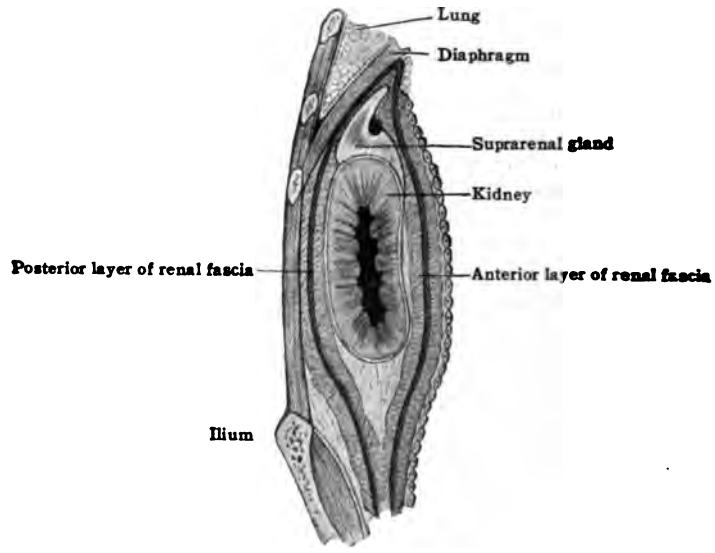
The kidneys.—These lie at the back of the abdominal cavity so deeply in hypochondriac and epigastric region as to be beyond palpation in most individu unless enlarged or unduly mobile (figs. 1020, 1099, 1113, 1115). The lo end of the right, being slightly lower than its fellow, encroaches in health upon lumbar and umbilical regions, and may be palpable on deep inspiration in sp subjects. These organs lie much higher and nearer to the vertebræ tha usually supposed to be the case, the upper two-thirds of the right and all the kidney being behind the ribs. Relatively to the vertebræ, the kidneys lie al the sides of the last thoracic and the first three lumbar.

FIG. 1097.—RENAL FASCIA, AS SEEN IN CROSS-SECTION.



To outline the kidneys from the front the following points should be noted: The u extremity of the right should reach as high up as the seventh costal cartilage, the left up t sixth, on either side close to the costochondral and interchondral junctions. This level correspond to one half way between the sternoxiphoid and transpyloric lines. The lower about 11 cm. (4½ in.) below this point, would be opposite to the subcostal line; that of right kidney is usually lower, and may encroach upon the umbilical line. For practical poses the hilus is opposite a point on the anterior abdominal wall, a finger's breadth media the tip of the ninth costal cartilage (Stiles), or the junction of the transpyloric and lat

FIG. 1098.—RENAL FASCIA, AS SEEN IN SAGITTAL SECTION.



vertical (or semilunar) lines. The importance of the relation of the last rib has been m tioned at p. 1275. The lateral vertical line has one-third of the kidney to its lateral side, a two-thirds to its medial side. The shortest distance between the two kidneys, obliqu placed as so to be closer above, 'at the upper part of their medial borders' (Thane and Godle measures about 6.2 cm. (2½ in.).

On the posterior surface of the body the kidney's boundaries are indicated by the followi —(1) A line parallel with, and 2.5 cm. (1 in.) from, the midline, between the lower edge of the of the spinous process of the eleventh thoracic and the lower edge of the spinous process of third lumbar vertebra; (2) and (3) lines drawn from the top and bottom of this line lateral at right angles to it, for 7 cm. (2¾ in.); (4) a line parallel to the first, and connecting the tremities of (2) and (3). Within this parallelogram the kidney lies (Morris).

The chief relations of the kidneys are:—posteriorly—quadratus lumboru psoas, diaphragm, last thoracic, iliohypogastric, and ilioinguinal nerves. T twelfth rib lies behind both, the right, as a rule, not reaching above the upp

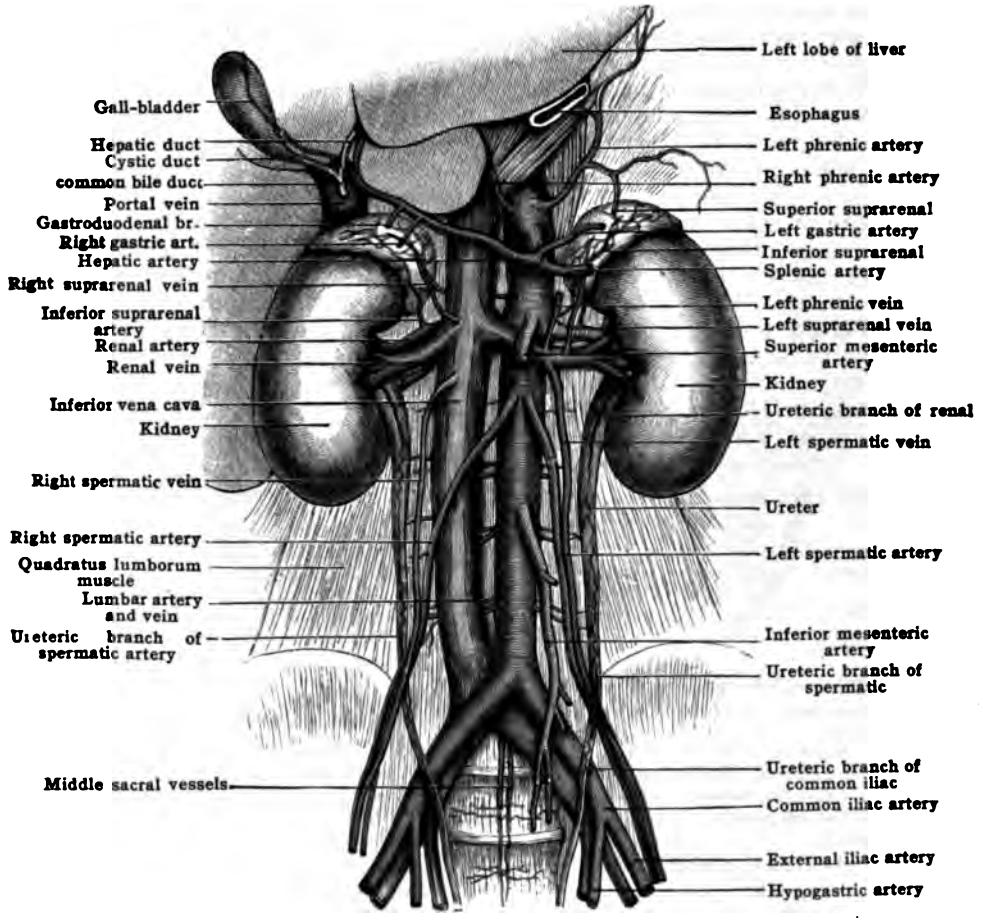
border. The left often reaches the eleventh rib. The pleural reflection usually crosses the twelfth rib obliquely reaching below its neck. **Anteriorly**—The liver, right colic flexure and second part of the duodenum (figs. 965 and 1020), on the right side. The liver, and stomach above, the body of the pancreas and spleen over the center, and the descending colon over the lower part of the left kidney.

The attachments of the specialized fibrous sheets known as the **renal fascia** are shown in figs. 1016, 1097 and 1098.

The anterior and posterior layers are seen to be continuous above and laterally. Medially and below they remain separate and it is in this direction that the abnormally movable kidney travels. The fatty tissue between the kidney and the renal fascia is known as the perinephric fat; that outside the fascia is the paranephric fat.

The kidneys are maintained in position by (1) the vascular pedicle: (2) fatty capsule and fascia: (3) above all by the intra-abdominal pressure.

FIG. 1099.—THE KIDNEYS, ABDOMINAL AORTA AND VENA CAVA INFERIOR.



Failure to ascend during development from its original position near the pelvic brim to its normal level accounts for certain cases of *movable kidney* of congenital origin. In these cases the renal artery may take origin from the common iliac artery. An *accessory renal artery* running into the lower end of the kidney from the aorta may cause kinking of the ureter and is a not uncommon cause of hydronephrosis.

Brödel has shown that incisions into the kidney should be made rather behind its convex border (Brödel's bloodless line). Occasionally fusion of the lower poles occurs during development across the middle line of the body, and a single *horseshoe-kidney* results, with double ureter and vascular supply.

The suprarenal glands (figs. 1064, 1099) are not so firmly attached to the kidneys as to the diaphragm: hence they are not encountered in operations for movable kidney and are not removed in nephrectomy.

The ureter (fig. 1099).—On an average 30 cm. (12 in.) long, this tube descends almost vertically in its abdominal course on the psoas muscle. It is crossed

obliquely by the internal spermatic or ovarian vessels. It crosses the brim of pelvis just in front of the bifurcation of the common iliac, and descends on side wall of the pelvis in front of the hypogastric artery.

The abdominal part of the ureter may be exposed extraperitoneally by an extension ward of the usual lumbar renal incision. It is found lying between peritoneum and p 3.7 cm. (1½ in.) from the middle line and when the peritoneum is stripped from the post abdominal wall the ureter is invariably carried with it. For further details and figures p. 1279.

Aorta and iliac arteries (figs. 570, 577).—The aorta enters the abdomen posite the last thoracic vertebra, a point 12 to 15 cm. (5 to 6 in.) above the bilicus, or rather above the midpoint between the infrasternal depression and umbilicus (Thane and Godlee), and thence, lying to the left of the midline, div into the two common iliacs opposite the disk between the third and fourth lun vertebræ, or opposite the body of the fourth lumbar vertebra. This poin about 2.5 cm. (1 in.) below and to the left of the umbilicus, and on a level wi line drawn across the highest part of the iliac crest. A line drawn from this pc with a slight curve laterally, to just medial to the center of Poupart's ligam will give the line of the iliac arteries; the upper third of this line giving the a age length of the common iliac. The relation of the common iliac veins is sh in fig. 1099. The **right,** much shorter than its fellow, lies at first behind and t somewhat lateral to its artery. The **left** is at first to the medial side of its art and then behind the right. At the upper part of the fifth lumbar vertebra bel and lateral to the right artery, the vena cava begins.

The site of some of the **branches of the aorta** may be thus approxima remembered as follows; The **celiac artery** is given off immediately after the a has perforated the diaphragm; directly below this is the **superior mesent artery.** About 2.5 cm. (1 in.) lower down, or 7.5 cm. (3 in.) above the umbili the **renal arteries** are given off. About 2.5 cm. (1 in.) above the umbilicus wo be the level of the **inferior mesenteric artery.** The relation of the above vessel the transpyloric line (p. 1183) is as follows: (Stiles.) The **celiac artery** is t fingers' breadth, the superior mesenteric one, above the line, the **renal arteries** a finger's breadth below it. The origin of the inferior mesenteric is midway tween the transpyloric and intertubercular lines.

Collateral circulation after ligature of the common iliac.—The chief vessels here ar

ABOVE.		BELOW.
Pubic branch of inferior epigastric	with	Pubic branch of obturator.
Internal mammary and lower intercostals	with	Inferior epigastric.
Lumbar	with	Iliolumbar and circumflex iliac.
Middle sacral	with	Lateral sacral and superior gluteal.
Superior hemorrhoidal	with	Inferior and middle hemorrhoidal.
Ovarian	with	Uterine.

Collateral circulation after ligature of the external iliac:—

Internal mammary, lower intercostals, and lumbar	with	Inferior epigastric.
Iliolumbar, lumbar, and gluteal	with	Deep circumflex iliac.
Internal and external circumflex	with	Superior and inferior gluteal (sciatic).
Perforating branches of profunda	with	Inferior gluteal (comes nervi ischiad
Circumflex and epigastric	with	Obturator.
External pudic	with	Internal pudic.

Collateral circulation after ligature of the internal iliac:—

Branches of profunda	with	Inferior gluteal (sciatic).
Inferior mesenteric	with	Hemorrhoidal arteries.
Vessel of opposite side	with	Pubic branch of obturator.
Branches of opposite side	with	Branches of pudic.
Superior and inferior gluteal (sciatic)	with	Circumflex and perforating of profur
Middle sacral	with	Lateral sacral.
Iliolumbar and superior gluteal	with	Circumflex iliac.

THE PELVIS

The male pelvis will be considered first, then the female pelvis, and finall section on hernia.

The Male Pelvis

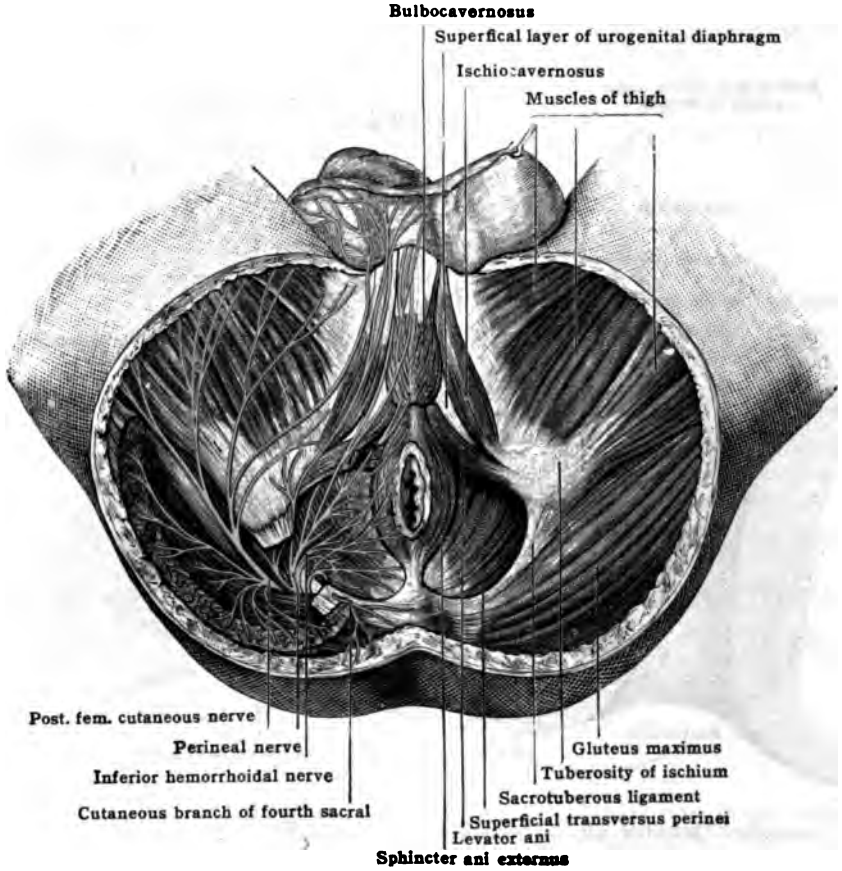
The topics under this heading will be considered in the following ord boundaries and subdivisions, scrotum and testis, ductus deferens and sperm

cord, penis and urethra, prostate, bladder, ischiorectal fossa, rectum and ana canal.

Bony boundaries.—These are the same in either sex (see p. 223). Above and in front is the symphysis pubis, rounded off by the subpubic ligament; diverging downward and laterally from this point on either side are the rami of the pubes and ischia, ending at the tuberosities of the latter. In the middle line behind is the apex of the coccyx, and reaching from this to the tuberosities are the sacrotuberous (great sacrosciatic) ligaments, to be felt by deep pressure, with the lower border of the gluteus maximus overlapping them.

The depth of the perineum varies greatly—from 5 to 7.5 cm. (2 to 3 in.) in the posterior and lateral part to 2.5 cm. (1 in.) or less in front. In the middle line, extending longitudinally through the perineum, is the raphe, the guide to the urethra, and 'the line of safety' (on account of the small size of the vessels here) for operations on it.

FIG. 1100.—THE MALE PERINEUM. (Modified from Hirschfeld and Leveillé.)



Subdivisions.—An imaginary line drawn transversely across the perineum from one tuber ischii to its fellow divides the lozenge-shaped space into **two triangles**—(1) An **anterior** or **urogenital**; and (2) a **posterior** or **anal** (rectal). The pelvic floor includes an upper or pelvic diaphragm (formed by the levator ani and coccygeus on each side) and a lower incomplete urogenital diaphragm.

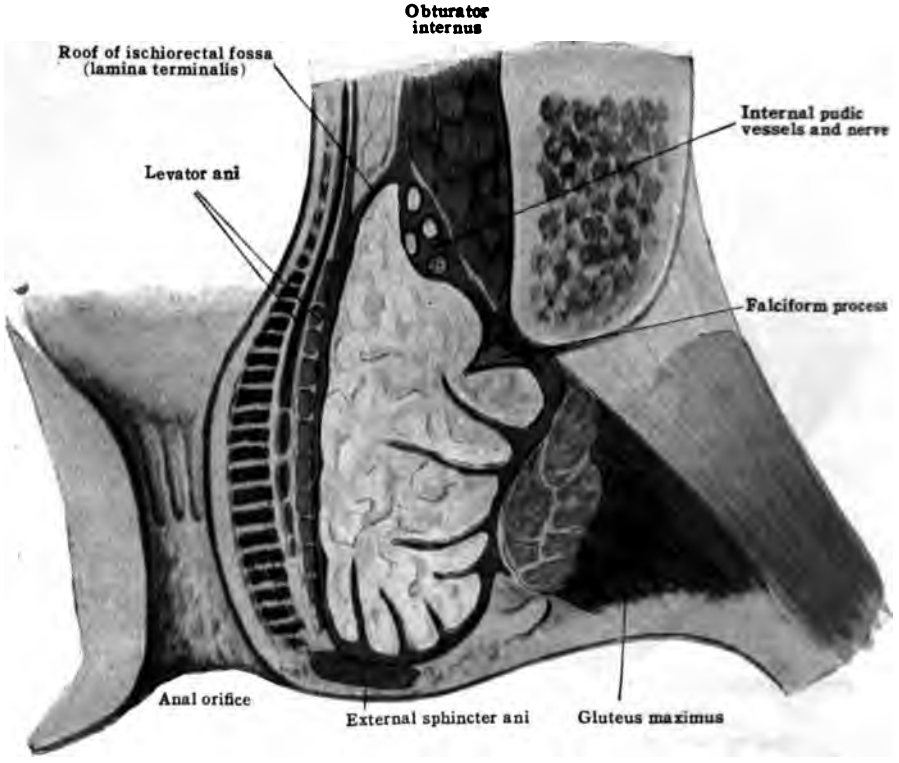
The **pelvic diaphragm** (figs. 1100–1102: see also figs. 428–431) is made up of the levator ani and coccygeus muscles. It is somewhat funnelshaped. When viewed from above or below (fig. 426), its fibers are seen to form horseshoe-like loops, arising on either side anteriorly, and passing posteriorly backward around the urogenital apertures to be inserted chiefly in the midline posteriorly. The pelvic diaphragm serves primarily for the support of the abdominal viscera. For a detailed description of these muscles, as well as those of the urogenital diaphragm and fasciæ, see section on the MUSCULAR SYSTEM.

The **urogenital diaphragm** (or trigone) (figs. 431, 1025, 1036), the lower dia-

phragm of the pelvic floor, is both morphologically and functionally differ from the upper. The urogenital diaphragm is a sphincter muscular layer. rived (with the sphincter ani externus) from the primitive *sphincter cloacæ*. T urogenital diaphragm is composed of superior and inferior fascial layers, enclos the membranous urethra, the sphincter urethræ membranaceæ and the tra versus perinei profundus. Superficial to the urogenital diaphragm is the sup ficial perineal interspace (fig. 431). This is covered by the superficial perin (Colles') fascia, and includes the crura and bulb of the corpora cavernosa, w associated muscles, vessels and nerves.

The space in the pelvic floor on each side below the pelvic diaphragm is ischiorectal fossa (figs. 430, 431, 1101). In the posterior or anal triangle, wh the urogenital diaphragm is absent, the ischiorectal fossæ form large wed shaped spaces. The *lower* wall or base is formed chiefly by the corresponding s and superficial fascia, and partly by the external sphincter ani; the *medial* w

FIG. 1101.—CORONAL SECTION OF THE ISCHIORECTAL FOSSA. (G. Elliot Smith.)



by the muscles (levator ani and coccygeus) and inferior fascia of the pelvic d phragm; the *lateral* wall by the obturator internus muscle, with the correspondi obturator fascia (with Alcock's canal, including the pudic vessels and nerve The *apex* of the fossa is above, where medial and lateral walls meet. The narr fibrous roof joining the medial and lateral walls just above the level of the inter pudic vessels and nerves has been called the *lamina terminalis* (Elliot Smi fig. 1101). Posteriorly the fossa is bounded by the gluteus maximus and l sacrotuberosum. Anteriorly on each side the ischiorectal fossæ extend as narr spaces between the pelvic diaphragm above, the urogenital diaphragm below, a the pelvic wall laterally (figs. 431–433).

Contents.—The ischiorectal fossa is filled with loose adipose tissue continuous with subcutaneous fat of the buttock. It is traversed by the inferior hemorrhoidal branches the internal pudic artery, with the associated veins and nerves, passing to the external a sphincter, the skin and the adjacent mucosa (fig. 1102). The superficial vessels and ner as they run forward to pierce the superficial perineal fascia, lie in this space, as well as inferior clunial (perforating cutaneous) branches and branches of the fourth sacral nerve. T inferior hemorrhoidal veins traverse the fossa obliquely from the lateral wall downward a medially. They are usually somewhat dilated near the anal orifice, and when morbidly

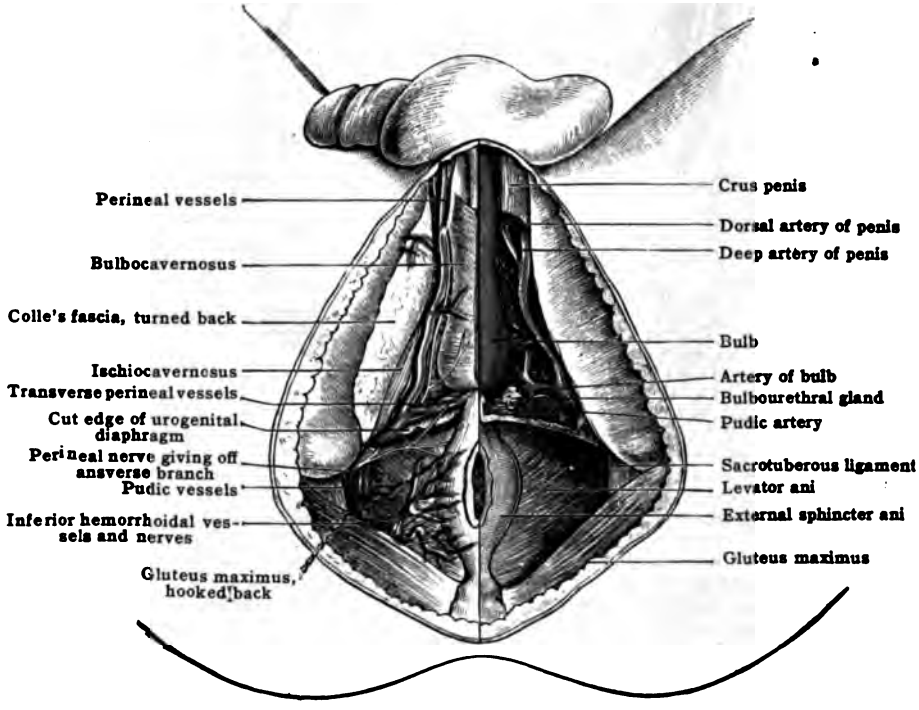
larged constitute the condition known as hemorrhoids ('piles'). The inner opening of an anal fistula caused by the bursting of an ischiorectal abscess into the gut is usually within 2 cm. of the anal margin, between the internal and external sphincters. Or (more frequently) these fistulas are subcutaneous, the opening into the bowel being external to the external sphincter.

The **central point of the perineum** (figs. 1100, 1102, 1103) is in the adult nearly an inch (2.5 cm.) in front of the anus, or midway between the center of the anus and root of the scrotum. Here the following structures meet, viz., the levatores ani, the two transverse perineal muscles, the bulbocavernosus, and the sphincter ani.

The comparative weakness of the attachment of the sphincter ani in front, i. e., not into a bony point, is important in the division of it, as in operation for fistula. The sphincter should never be cut through anteriorly, especially in women, where its attachment here, blending with the sphincter vaginæ, is very weak. This point also corresponds to the center of the lower

FIG. 1102.—THE ARTERIES OF THE PERINEUM.

On the right side of the perineum (left side of fig. 1102) Colles's fascia has been turned back to show the superficial vessels. On the left side the superficial vessels have been cut away with the anterior layer of the urogenital diaphragm to show the deep vessels.



margin or base of the urogenital diaphragm (triangular ligament). Its development varies much in different bodies. A little in front of this point is the bulb, with the corpus spongiosum passing forward from it. This would also be the level of the artery of the bulb, so that in lithotomy the incision should always begin below this point. A knife introduced at the central point, and carried backward and very slightly upward, should enter the membranous urethra just in front of the prostate, e. g., in median lithotomy and Cock's external urethrotomy. If pushed more deeply, it would enter the neck of the bladder.

In median lithotomy, an incision 3.7 cm. (1½ in.) long is made through the central tendinous point and raphe, so as to hit the membranous urethra. The following structures are divided:—Skin and fasciæ; some of the most anterior fibers of the external sphincter ani; raphe and central tendinous point; minute branches of transverse perineal vessels and nerves; base of urogenital diaphragm in center; membranous urethra and constrictor urethræ.

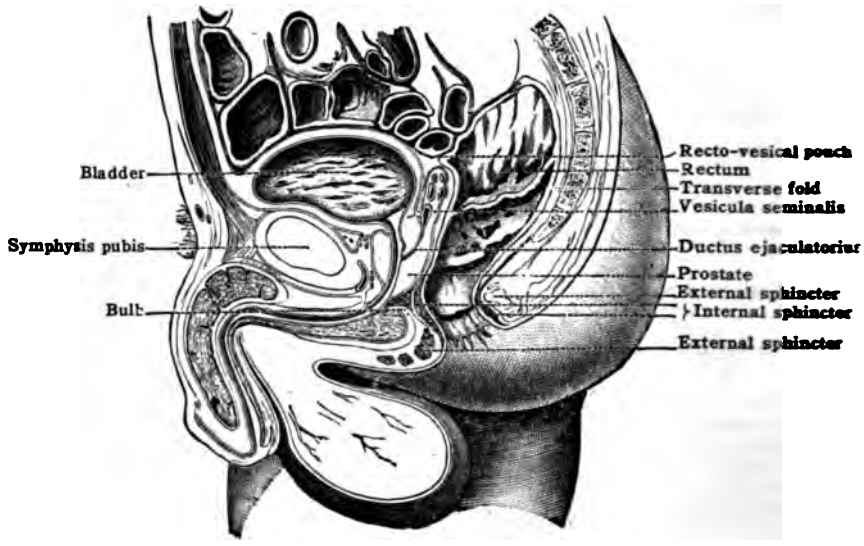
The attachments and arrangements of the **superficial fascia** (fig. 1102) must be traced and remembered. Of the two layers of which it consists, the superficial alone extends over both urogenital and anal triangles alike, and is continuous with the similar structures in adjacent regions, the only difference being that, if traced forward into the scrotum and penis, it loses its fat, and contains dartos fibers. The deeper layer, found only over the urogenital triangle, is called the fascia of Colles. Attached at the sides to the rami of the pubes, behind to the base

of the urogenital diaphragm, and open in front, it forms the superficial wall of a somewhat triangular pouch (*superficial perineal interspace*), containing the superficial vessels, nerves, and muscles, the bulb, adjacent part of the urethra, and crura of the penis. Owing to this space being closed behind and open in front, urine or other fluids extravasated within this space will obviously tend to make their way forward into the scrotum, penis, and lower part of the abdominal wall.

More deeply located, **between the two layers of fascia of the urogenital diaphragm,** are—(1) The membranous urethra; (2) deep transverse perineal muscle and sphincter of the membranous urethra; (3) the bulbourethral (Cowper's) gland; (4) and (5) part of the pudic artery and nerve, and branches.

The scrotum.—The skin of the scrotum is thin and delicate so that when distended, as by a hydrocele in the tunica vaginalis, it is remarkably translucent. Attached to its deep aspect is a layer of involuntary muscle, the dartos. When the dartos is contracted, as under the influence of cold, the scrotal skin becomes rugose.

FIG. 1103.—SAGITTAL SECTION OF MALE PELVIS (× 1/3). (Braune.)



To this tendency to wrinkling, with consequent irritation from retained dirt, and the presence of many sweat glands the frequency of epithelioma in this part is due. The dartos is apt to cause inversion of the skin in wounds of the scrotum, but this difficulty in suturing may be counteracted by the application of a hot sponge, which relaxes the muscle.

The **superficial fascia** of the scrotum is continuous with the fascia of Colles and the superficial fascia of the penis. Hence extravasation of urine under the fascia of Colles's balloons the scrotum and penis. The laxity of the areolar tissue under the dartos accounts for the great swelling that occurs in edema of this part.

The lymphatics of the scrotum, important by reason of the extension of scrotal cancer, drain into the superficial inguinal nodes. Those from the anterior aspect nearest the median raphé run to the superolateral glands of this group, within a few cm. of the anterior superior spine. (Morley: Lancet, 1911 (ii), p. 1545.)

The numerous large sebaceous glands that are found in the skin of the scrotum may give rise to cysts or adenomata. The deeper layers of the scrotum are derived from the abdominal wall, being brought down by the processus vaginalis in the descent of the testis.

Testis and epididymis.—The left testis, the first to descend, lies somewhat lower in the scrotum, and this fact is one reason for the frequency with which a varicose condition of the spermatic veins occurs on the left side. On *palpation* the smooth firm body of the testis, pressure on which causes the characteristic 'testicular sensation' can be felt to lie in front of and rather medially to the epididymis. The three parts of the latter, the *caput* above, the *body*, and the *cauda epididymidis* below, can also be distinguished. Running upward from the back of the epididymis to the subcutaneous inguinal ring the spermatic cord can

be felt. The bulk of the cord is made up of its coverings, of which the cremaster muscle is the most considerable, and of the pampiniform plexus of veins. On rolling the cord between the finger and thumb the **ductus deferens** can be felt like a piece of whipcord in the posterior part.

The *ductus (vas) deferens* is thickened and nodular in tuberculous epididymitis. The nodule which is so characteristic of tuberculous epididymitis develops in by far the greater majority of cases in the tail of the epididymis. In varicocele the dilated and elongated veins of the pampiniform plexus feel on palpation like a bag of worms in the scrotum. It is important that the student, before studying diseased conditions, should make himself familiar with the feel of the normal parts as mentioned above and be able to identify them. Dissection made with the view of removing the epididymis should be made from the lateral side, so that when the spermatic artery is approached the epididymis has been practically freed.

Underneath the visceral layer of the tunica vaginalis, the body of the testis is covered by a dense fibrous layer, the *tunica albuginea*, which accounts for the small extent of swelling in orchitis as compared with epididymitis. The *lymphatics* of the testis run up in the spermatic cord through the inguinal canal, and accompanying the spermatic vessels end in the lumbar lymph nodes, below the level of the renal arteries. These nodes may be reached and removed along with the vessels by making an incision in the loin above the inguinal (Poupart's) ligament, and stripping the peritoneum off the posterior abdominal wall.

The **epididymis** is the convoluted first part of the duct of the testis, about 6 m. (20 feet) in length. Its three portions are in differing connection with the testis. Thus the *cauda* is held in place by connective tissue, the *body* by the same medium; the *caput* by the vasa efferentia. Thus, when tubercular disease begins here, the testis itself is more likely to be early involved.

Ductus deferens.—The two extremities and the course of this involve several practical points. About 45 cm. (18 in.) long, it begins, convoluted at first and with a distinct bend upward, in the cauda epididymidis. It thence passes almost vertically upward at the back of the testis and cord to the tubercle of the pubes. Entering the canal, it lies on the grooved upper aspect of the inguinal (Poupart's) ligament, and then under the arching fibers of the internal oblique and transversus, upon the transversalis fascia. Its position, characteristic feel, and yellowish aspect are well-known guides in operations for varicocele and hernia, while it is always to be isolated and palpated when tubercular disease below is suspected. Leaving the canal by the abdominal inguinal ring, it hooks round the inferior epigastric artery and then descends into the pelvis over the external iliac vessels. Continuing its course downward and backward over the side of the pelvis, it arches backward over the side of the bladder (fig. 950), superficial to the obliterated hypogastric artery, and then deep to the ureter. The two ducts now help to form the lateral boundaries of the external trigone, between the base of the bladder and the rectum. They here become dilated [ampulla ductus deferentis] and then contract to empty into the ejaculatory ducts (see figs. 1025, 1030–1032).

The **vesiculæ seminales** are diverticula growing out from the lower end of the deferential ducts at an acute angle, one on each side. They lie below and lateral to the deferential ducts and are related in front to the base of the bladder and posterior surface of the prostate, behind to the rectum, and above to the rectovesical pouch of peritoneum, which also descends to cover the upper part of their posterior aspect. The normal vesiculæ seminales can scarcely be distinguished from the base of the bladder on rectal palpation, but when diseased, as in tuberculous or gonorrheal vesiculitis, are enlarged and indurated and can be detected readily.

The **ejaculatory ducts,** formed by the union of the vesicular and deferential duct of each side, are 2–2.5 cm. in length. The first few millimeters of their course is extraprostatic, and then entering the posterior surface of the prostate they run side by side downward and forward through the gland, close to the middle line, to open into the urethra on the colliculus seminalis at either side of the opening of the prostatic sinus. It is by these little ducts that infection travels from the urethra to the vesiculæ and epididymis in gonorrhea.

Descent of the testis.—The testis is developed between the tenth and twelfth thoracic segments of the embryo (see p. 53), and subsequently moves downward. By the third month of intrauterine life it descends into the iliac fossa; from the fourth to the seventh month it lies at the abdominal inguinal ring; during the seventh month it passes obliquely through the abdominal wall by the inguinal canal; by the eighth month it lies at the subcutaneous inguinal ring, and it reaches the fundus of the scrotum about the time of birth. The left testis is slightly earlier than the right in all these stages. The descent referred to is due in part to the common descent of organs, associated with the descent of the diaphragm, but mainly to the **gubernaculum.** This is a mass of fibromuscular tissue that forms under the *inguinal fold* (or *plica gubernatrix*) of peritoneum below the testis as it lies in the iliac fossa, and in the mesorchium. It grows down obliquely through the abdominal wall from a point lateral to the inferior epigastric artery, and tunnels out a passage for the testis. As it travels down into the scrotum it carries in front of it three layers of investing fascia derived from the abdominal wall, viz., external spermatic fascia from the external oblique, cremasteric from internal oblique and transversus muscles, and infundibuliform fascia from the transversalis fascia. The gubernaculum is attached above to the peritoneum and the posterior aspect of the testis, and by its subsequent contraction it draws down into the scrotum first a diverticulum of peritoneum, the **processus vaginalis,** and secondly the testis, which projects into the processus from behind just as it did into the celom.

Shortly after birth, obliteration of the processus vaginalis should occur, commencing at the deep abdominal ring and immediately above the testis. The part of the processus between these two points disappears completely. The lowest part, surrounding the testis, persists as the tunica vaginalis. Failure of obliteration, if complete, leaves a *congenital hernial sac;* if only the upper part persists, and does not communicate with the tunica vaginalis, it is called a

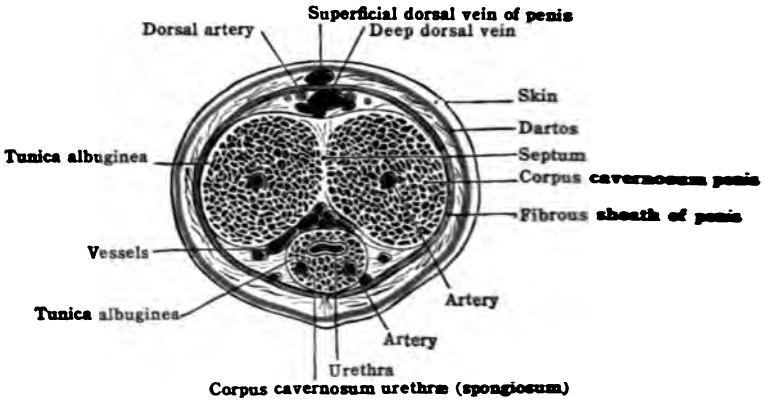
funicular sac. Cysts originating in the processus vaginalis between the upper and lo points of primary occlusion are known as *encysted hydrocele of the cord.*

Undescended testis.—It occasionally happens that descent of the testis fails on one both sides, and in these cases the organ may remain, (1) in the iliac fossa, (2) in the ingu canal, or (3) at the subcutaneous ring. Deprived of the protection normally afforded aga injury by the scrotum and tunica vaginalis, the misplaced testis is subject to trauma, sho tendency to torsion of its pedicle owing to its long mesorchium, and sometimes becomes seat of malignant disease. A funicular hernial sac is generally present. Such testes are a phic and functionally deficient, and it is probably owing to their small size at an early stage the gubernaculum fails to gain a hold on them. It has been shown by Bevan (Jour. A.M 1903, 41 : 718) that in undescended testis the ductus deferens is usually long enough to allow organ to be placed in the bottom of the scrotum by the surgeon without tension provided the spermatic artery and pampiniform plexus of veins are divided. The blood-supply of organ is then entirely derived from the deferential artery, a branch of the superior vesical. rare cases the testis descends in a wrong direction (ectopia testis) and comes to lie in the perine over Scarpa's triangle, or on the pubes.

Penis (figs. 1102–1104).—The subcutaneous tissue of the penis, as of scrotum, is devoid of fat and the delicate skin is very mobile and distensible, he the ballooning of these parts in extravasation of urine or edema. The fa penis is continuous with Colles's fascia.

In radical amputation of the penis for malignant disease the whole organ, including crura, is removed through an incision that splits the scrotum, and the stump of the co spongiosum (corpus cavernosum urethræ) is brought out into the perineum behind the scro

FIG. 1104.—CROSS-SECTION OF PENIS.



The preputial orifice varies greatly in size. Normally large enough to allow easy re tion of the prepuce from off the glans, it is frequently so small that retraction is impos and it may even cause difficulty in micturition. The mobility of the skin over the penis be borne in mind in the operation of circumcision, and care taken lest too much of the pre be removed, leaving insufficient skin to cover the penis. In this operation the vessels which bleeding occurs lie, (1) on the dorsum, (2) in the frenum.

Congenital malformations of penis.—At an early stage of development (see p. 52 the thra opens on the inferior aspect of the penis behind the glans. After the ingrowth of epithel that forms the glandular urethra, this primitive meatus should close. Occasionally, however persists, and the glandular urethra is represented by a groove on the under aspect of the gl In these cases of *hypospadias* the glans is flexed on the penis and the prepuce is deficient be and has a peculiar 'hooded' appearance. In *epispadias* the upper wall of the urethra corresponding part of the corpora cavernosa are absent. This condition is usually pre in cases of ectopia vesicæ.

The **male urethra** (figs. 1025, 1037) is about 20 cm. (8 in.) in length, consist of the **cavernous** portion, 16 cm. ($6\frac{1}{2}$ in.), **membranous** 1 cm. ($\frac{2}{5}$ in.) and pr **tatic** 3 cm. ($1\frac{1}{4}$ in.). The narrowest part is the external orifice, and next to it membranous urethra. The prostatic urethra is the widest and most dilatab The bulbous urethra, just in front of the urogenital diaphragm, is wider than rest of the penile portion, but since it forms the most dependent spot in fixed part of the urethra from bladder to suspensory ligament of penis, it specially prone to gonorrheal stricture. Behind the bulb, the urethra curv suddenly as it passes through the urogenital diaphragm and contractile of sphincters of the membranous urethra may here give additional difficulty in passage of a catheter.

False passages most commonly occur just outside the floor of the bulb on account of the ease in entering the membranous urethra. The point of a small catheter may also be cau

in the following apertures: (1) The lacuna magna in the roof of the fossa navicularis of the glandular urethra; (2) other crypts or lacunæ in the penile part, mostly situated in the upper wall; (3) the prostatic sinus in the floor of the prostatic urethra about its center. With the penis raised the urethra presents a simple curve under the symphysis with the proportions of an ordinary silver catheter.

It is in the region of the urogenital diaphragm that the urethra is most liable to be damaged by a fall or blow, and the urine extravasated as a result will be beneath Colles's fascia. In rupture of the membranous urethra urine may find its way in front of the inferior fascia of the urogenital diaphragm by coexisting injury to this, or through openings in the vessels, etc.; in a few such cases urine will make its way backward behind the fascia into the space of Retzius, ascending thence between the peritoneum and transversalis fascia. The attachment of the deep layer of superficial fascia to the base of the urogenital diaphragm accounts for the fact that urine extravasated from a ruptured urethra or through an opening behind a stricture passes not backward into the anal triangle, but forward onto the scrotum and abdominal wall.

The **prostate** (figs. 1025, 1103) consists of a mass of racemose glandular tubules imbedded in a fibromuscular stroma, that surrounds the first part of the urethra and lies below the neck of the bladder. Its **base** is intimately connected with the bladder by the continuation of vesical and urethral mucous membrane and by the insertion of the outer longitudinal muscular coat of the bladder into the gland.

The inner circular muscle fibers of the bladder become specialized round the internal urethral orifice to form the *internal sphincter*. Adenomatous enlargements of the gland usually grow upward through this sphincter which is thus dilated and pushed aside, so that the glandular growth is covered only by vesical mucous membrane.

The **apex** of the prostate lies at the level of the lower border of the pubic symphysis and 1.5 cm. behind it. It is firmly fixed to the superior fascia of the urogenital diaphragm (deep layer of the triangular ligament) and here the urethra leaves it to become the membranous part. The **anterior surface** directed vertically lies 2 cm. behind the lower part of the pubic symphysis in relation to the prostatic plexus of veins: and from it the dense puboprostatic ligaments run forward on either side to the pubes. The **posterior surface** is in contact with the rectum, through the anterior wall of which it may be palpated 4 cm. (1½ in.) above the anal margin. It is separated from the rectum by the two layers of the rectovesical septum (Elliot Smith, Jour. Anat. and Physiol., vol. 42, 1908). The **lateral surfaces** are supported by the anterior fibers of the levator ani, from which, however, they are separated on each side by a dense mass of fibrous tissue in which the pudendal (prostatic) plexus of veins is imbedded.

The *prostatic urethra* traverses the gland nearer the anterior than the posterior surface, with a slight forward concavity. Its floor is placed posteriorly and presents an eminence, the *colliculus seminalis*, about the center of which is the orifice of the prostatic sinus, on either side of which open the common ejaculatory ducts. The prostate is indefinitely divided into two lateral lobes. The fissure uniting them across the middle line in front of the urethra (the anterior commissure) is fibromuscular and contains no glandular tissue. Behind the urethra the lateral lobes are continuous and the portion of gland lying between bladder, ejaculatory ducts and urethra has been erroneously termed the 'middle lobe.' Though not a separate lobe anatomically, adenomatous hypertrophy of this part is common, when it projects up into the bladder, and prevents the proper emptying of that organ.

Capsule and sheath of the prostate.—In senile enlargement of the prostate removal may be effected by the *suprapubic* or by the *perineal* route. In the former, the bladder is opened above the pubes, the mucous membrane lying over the gland as it projects into the bladder is scratched through and with the finger the whole adenomatous mass is enucleated. This process usually involves tearing out the whole of the prostatic urethra, and the ejaculatory ducts. The parts left behind consist of (1) the **'capsule'** which is simply the outer part of the gland proper stretched over the adenomatous mass, and consists of fibromuscular tissue with a few flattened glandular tubules (C. Wallace). Outside this (2) the fibrous 'sheath' is derived from the visceral layer of pelvic fascia, in which is imbedded, on the anterior and lateral aspects of the gland, the prostatic plexus. Since these veins are not torn there is comparatively little hemorrhage. In the *perineal* operation the posterior surface of the gland is exposed by cutting through the perineum between the bulb and external sphincter ani, and dividing the attachment of the rectourethral muscle to the urogenital diaphragm and its inferior fascia. This exposes the back of the rectovesical septum (aponeurosis of Denonvilliers) which is split at its base, opening up the rectoprostatic space of Proust. By a longitudinal incision into the prostate on each side the adenomatous lateral lobes may be enucleated separately, and it is claimed without injury to the urethra or ejaculatory ducts (Hugh Young, J. H. Hosp. Rep., vol. 14, 1906.

The **urinary bladder** (fig. 1103) lies above the pubic symphysis at birth and so is mainly an abdominal organ. The *anterior surface*, in contact with the abdominal wall, has no peritoneal covering, but posteriorly the peritoneal reflection descends to cover the posterior surface of the prostate, which is relatively lower

than in the adult. The adult bladder when empty forms
organ behind the symphysis, and bounding the retropu
posteriorly.

Into this space urine is extravasated in extraperitoneal rupture
mount up behind the abdominal wall in the subperitoneal tissue. Th
the puboprostatic ligaments and prostatic plexus of veins. In dis
bladder and prostate being relatively fixed and immovable, the free
domen. As it does so it raises the peritoneum off the abdominal v
distention 5 cm. (2 in.) of abdominal wall above the pubes are fre
bladder may be tapped here safely. The *upper surface* is covere
is also related to the upper halves of the vesiculæ seminales. Below t
base of the bladder presents a small *triangular area* in contact with
peritoneal *cul-de-sac* above, the converging deferential ducts on ea
below. Through this triangle which is rather expanded in distention
per rectum was formerly practised. The *inferolateral surfaces* are slun
by a hammock. The *interior* of the bladder can be examined by th
patient. The mucous membrane is loose and rugose in contraction, e
the base, the angles of which are formed by the ureteric orifices and t
mucosa here is firmly adherent to the muscular coat and smooth.
bladder-muscle from obstruction, a fasciculated appearance of the mu
diverticula between the bands of muscle.

Rectum and anal canal (figs. 950, 1103).—The rectum
the end of the sigmoid colon, opposite the second (or third)
upper end of the narrow anal canal, which runs downward
at right angles to the rectum and is 3–4 cm. in length. T
the rectum lies 13–14 cm. (5–5½ in.) above the anus in the
marked internally by an infolding of the mucosa on the ri
and to some extent of the circular muscle fibers, due to the a
pelvic colon turns into the fixed rectum. This shelf of
known as the **upper transverse fold** (first valve of

Under normal conditions the rectum does not form a reservoir
is stored in the lower end of the pelvic colon, above the upper tra
rectum empty except in defecation. The rectum proper is subdivide
by the **inferior transverse fold** on the anterior wall (third or great val
8–9 cm. (3–3½ in.) above the anus at the level of the anterior cul-de-s
resulting from the adaptation of the rectum to the hollow of the sa
be made out on digital examination. The other transverse folds
present on great distention.

The rectum and anal canal may be divided into three re
from the second sacral vertebra to the lower transverse fold
of peritoneum onto bladder or vagina; (2) **infraperiton**
below this and above the levator ani; (3) **anal canal,** b
levator ani, constriction by which marks it off from the
it into an anteroposterior slit.

The **mucous membrane** of the rectum proper is redundant and m
color as seen by the sigmoidoscope. It is dotted over by **rectal pits,**
containing lymphoid follicles, and by the smaller and more numer
In the peritoneal chamber the mucosa is transversely plicated. In the
longitudinal folds in which lie branches of the superior hemorrhoid
tudinal folds, known as the **rectal columns,** converge into the **anal c**
of the **anal valves** half way down the canal, each uniting two adjacent
probably represent the original cloacal membrane, dividing the proct
ectoderm) from the entodermal hindgut, and persistence of this mer
imperforate anus. (Wood Jones, Brit. Med. J., Dec. 14, 1904.) Th
by hard feces may be a cause of anal fissure, etc. (Ball). The muco
canal is more firmly adherent to the underlying muscular coat than th
prolapse the mucosa of the rectal ampulla is the first to be extruded.

Peritoneal relations.—Excepting the upper end, the rectum has n
behind, and the peritoneum, leaves the sides obliquely and finally is
the bladder (or the vaginal fornix in the female), at the level of the
from the anus. Thus the rectal ampulla and anal canal are witho
1025).

Blood-supply.—(1) The **superior hemorrhoidal artery, a continu**
enteric, reaches the rectum behind, via the pelvic mesocolon and bifu
branches run around on either side below the peritoneal reflection; givi
that pierce the muscular coat about the level of the inferior transve
toneal reflection. Joining the submucous layer, these arteries run d
to the anal canal, where they anastomose with (2) the **middle hemor**
of the hypogastric (internal iliac) and (3) the **inferior hemorrhoidal**

pudendal. The veins correspond. Their free anastomosis in the **hemorrhoidal plexus** under the rectal columns, the union afforded here between the portal and systemic veins, the absence of valves in the superior hemorrhoidal veins, and the constriction they are subject to in passing through the muscular coat, are some of the anatomical causes of the frequency of hemorrhoids.

The branches of the superior hemorrhoidal artery to the rectum anastomose but little with one another, as compared with the sigmoid arteries to the pelvic colon. The main trunk of the superior hemorrhoidal usually receives a large anastomotic branch from the lowest sigmoid artery 1–2 cm. below the sacral promontory, upon which the upper part of the rectum is dependent for its blood-supply after ligature of the superior hemorrhoidal. Hence in high excision of the rectum it is important to place the ligature on the superior hemorrhoidal above the sacral promontory if sloughing of the gut is to be avoided. (Hartmann, Ann Surg., Dec., 1909.)

For lymphatics of the rectum see p. 769).

Supports of the rectum.—The anal canal is fixed by its attachment to the levator ani and perineal body. After division of the perineal body and rectourethral muscle in front, the rectum is readily separable from the back of the prostate and rectovesical septum. When the levator ani has been divided on each side and the peritoneum opened, as in the perineal operation for excision of the rectum, the gut cannot be pulled down freely. The hand passed up behind it in the hollow of the sacrum meets on each side with a dense fibrous layer running from the sacrum opposite the third foramen onto the side of the rectum. This is the *rectal stalk* (Elliot Smith) and consists of dense fibrous tissue round the nervi erigentes from second, third and fourth sacral foramina and the middle hemorrhoidal vessels. It lies about 2.5 cm. above the levator ani, and after division of it the bowel is easily freed, so that the whole of the rectum and part of the pelvic colon may be drawn out at the perineum without tension.

Rectal examination.—The following points can be made out by the finger introduced into the male rectum (cf. fig. 1025):—(1) The thickened, roll-like feel of a contracted external sphincter; (2) the thinner, more expanded, internal sphincter extending upward for 2.5 cm. (1 in.) from this; (3) the rectal insertion of the levatores ani, which here narrows somewhat the lumen of the gut; (4) above the anal canal, with its contrasting capaciousness, is the more or less dilated ampulla of the rectum proper; (5) the condition of the ischiorectal fossæ on either side; (6) the membranous urethra in front, especially if a staff has been introduced; the instrument now occupies the middle line, and has the normal amount of tissue between it and the finger, thus differing from one in a false passage (in a child an instrument is especially distinct); (7) just beyond the sphincters, or 3.7 cm. (1½ in.) within the anus, lies the prostate; (8) converging toward the base of the prostate, and forming the sides of the triangular space, are the vesiculæ seminales and ejaculatory ducts. These can rarely be felt unless diseased and enlarged; any enlargement of the sacculated ends of the deferential ducts is much more perceptible; (9) it is within this triangular space that the elasticity of a distended bladder can be felt. (10) Usually the lowest of the transverse folds (folds of Houston), semilunar in form and about 1.2 cm. (½ in.) in width, can be made out (fig. 1103). (11) Behind, the coccyx and its degree of pliability and the lower part of the sacrum. It may also be possible to feel enlarged sacral nodes and a growth from the other pelvic bones.

The following relations are found by **rectal examination in the female** (cf. figs. 1046, 1048): Anteriorly, the soft perineal body and rectovaginal septum will be met with, and, through the latter, the cervix and external orifice (os uteri), and, higher up, the lower part of the cervix uteri. More laterally the ovaries may be felt, but the uterine or Fallopian tubes, unless enlarged and thickened, are not to be made out. The student should be familiar with the feel of a healthy rectouterine or rectovesical pouch, according to the sex, and the coils of intestine which it may contain, so as to be able to contrast this with any collection of inflammatory or other fluid or mischief descending from the upper pelvis, e. g., from the vermiform appendix. Posteriorly, certain structures are met with in either sex. After a very short interval (sphincter and anococcygeal body) the finger reaches the tip of the coccyx and explores the hollow of the sacrum. On each side are the ischial tuberosity and wall of the true pelvis. The finger hooked lateralward and upward, comes on the border of the falciform process of the sacrotuberous (great sacrosciatic) ligament, passing between the above-mentioned bones.

FEMALE GENITAL ORGANS

The external organs will be considered first, followed by the internal. Under the external organs are included, for convenience, the labia majora and minora at the sides; and, in the middle line, from above downward—(1) The glans clitoridis with its prepuce; (2) the vestibule; (3) the urethral orifice; (4) the vaginal orifice with the hymen or its remains; (5) the fossa navicularis; (6) the fourchette; (7) the skin over the base of the perineal body.

These parts have been described elsewhere, and only those points which are of importance in a clinical examination will be alluded to here.

The **labia majora** (fig. 1049) are two thick folds of skin, covered with hair on their outer surface, especially above, where they unite (*anterior commissure*) in the mons Veneris. They contain fat, vessels, and dartos, but become rapidly thinner below, where they are continuous at the front of the perineum (their *posterior commissure*). When the above folds are drawn aside, the **labia minora,** or **nymphæ,** appear, not projecting, in a healthy adult, beyond the labia majora. They are small folds of skin, which meet anteriorly in the prepuce of the clitoris,

and posteriorly blend with the labia majora about their center. Sometime especially in nulliparæ, they unite posteriorly to form a slight fold, the fourchett The **glans clitoridis,** covered by its prepuce, occupies the midline anteriorl

Behind it comes the **vestibule,** a triangular smooth surface of mucous mem brane, bounded laterally by the labia minora. In the midline of the vestibu about 12 mm. (½ in.) behind the glans clitoridis and 25 mm. (1 in.) in front of tl fourchette, is the meatus or opening of the urethra (figs. 1046, 1049).

The **vaginal orifice** lies in the midline of the vestibule. Its orifice is partial closed in the virgin by a fold of mucous membrane, the **hymen** (fig. 1049). Th is usually crescentic in shape, attached below to the posterior margin of the vagin orifice, and with a free edge extending anterosuperiorly. In some cases it diaphragmatic, i.e., attached all around, but perforated in the center. Tl remains of the hymen probably constitute the **caruncuIæ hymenales.** On eith side of the vaginal orifice, at its lower part, lie the racemose, muciparous, **vestibul glands** (glands of Bartholin), situated beneath the superficial perineal fasc and sphincter vaginæ. Their ducts run slightly upward and open, extern to the attachment of the hymen, within the labia minora. In relation to tl upper two-thirds of the vaginal orifice, placed between the urogenital diaphrag behind and the sphincter vaginæ in front, are the vascular **bulbs** of the vestibul rupture of which produces pudendal hematocele.

Fourchette and fossa navicularis.—The fourchette, as stated above, is tl posterior commissure of the labia minora. Normally the inner aspect of this in contact with the lower surface of the hymen. When the fourchette is pull down by the finger, a shallow depression is seen, the **fossa navicularis,** with tl fourchette for its posterior, and the hymen for its anterior, boundary.

Internal organs.—The examinations through the vaginal relations will l considered first, followed by uterus and appendages, ovary and ureter.

Examination per vaginam (Cf. figs. 1046, 1048).—The finger, introduced past the glute cleft, perineum, and fourchette, comes upon the elliptical orifice of the vagina, and notes hc far it is patulous or narrow; the presence or absence of any spasm from the adjacent muscle then, passing into the canal itself, the presence or absence of rugæ, a naturally moist or a d condition are observed. In the *anterior wall* the cord-like urethra can be rolled between tl finger and the symphysis; and further up than this, if a sound be passed, the posterior wall of tl bladder. The anterior wall of the vagina is about 6.7 cm. (2½ in.) long. The *posterior wa* 7.5 cm. (3 in.) long, forms the rectovaginal septum, and through it any feces present in tl bowel are easily felt. The cervix uteri is next felt for in the *roof* of the vagina, projecting dow ward and backward in a line from the umbilicus to the coccyx. Besides its direction, its siz shape, mobility, and consistence should be noted. The external orifice (os uteri) should form dimple or fissure in the center of the cervix. Of its two lips, the posterior is the thicker and mo fleshy feeling of the two. The vaginal fornix (anterior and posterior) is next explored. Th should be soft and elastic, giving an impression to the finger similar to that when it is intr duced into the angles of the mouth. Any resistance felt here may be due to scars, swellin connected with the uterus (displacements or myomata), effusions of blood or inflammato material, and, laterally, a displaced or enlarged ovary, or dilations of the Fallopian tube The posterior cul-de-sac is much deeper than the anterior, and, owing to the peritoneu descending upon the posterior wall of the vagina, when the finger is placed here it is onl separated from the peritoneal sac by the vaginal wall and pelvic fascia. In examination of th pelvic organs the bimanual method, by which one hand on the hypogastric region, pushes the down and steadies them as well, is always to be employed to complete an examination.

The uterus and appendages.—The normal non-gravid uterus is usuall anteflexed and anteverted so as to lie with its long axis approximately at righ angles to that of the vagina (fig. 1046). Its position varies considerably with th degree of distention of the bladder in front and of the rectum behind. Th distance from external orifice (os) to fundus, as estimated by the passage of sound is in the adult virgin uterus 5.5 cm. of which 3 cm. belong to the cervix an 2.5 cm. to the body. In the empty multiparous uterus the total length of th cavity is 6 cm., 2.5 cm. comprising the neck and 3.5 cm. the body.

Peritoneal relations (fig. 1046).—In front the peritoneum is reflected from the uterus t form the uterovesical pouch at the level of the isthmus. Behind it covers not only the uteru but the posterior fornix of the vagina, before turning off onto the front of the rectum. Laterall the peritoneum leaves the uterus and passes on to the lateral pelvic wall as a large twofol partition (fig. 1105), the broad ligament.

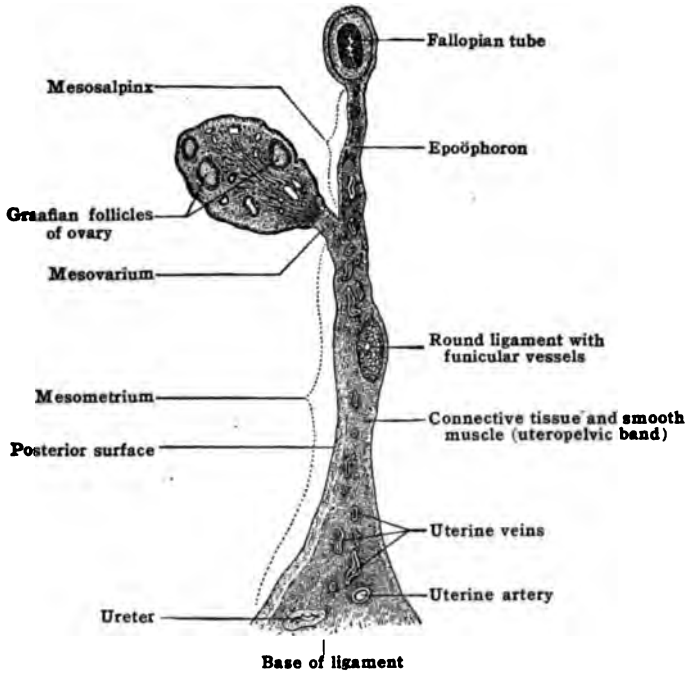
The **broad ligament,** bearing in its upper border the uterine tube, in front the round ligamen and behind the ovary, consists of (1) an upper thin part, the mesosalpinx lying above th attachment of the mesovarium, and containing the ovarian vessels and the epoöphoron, an below this (2) the thicker mesometrium, between the layers of which is a dense mass of fibrou tissue surrounding the uterine artery.

The anterior aspect of the cervix below the uterovesical pouch of peritoneum, is readily separable from the bladder with which it lies in contact, and the peritoneum may be raised off the uterus with ease in the lower part of its attachment both front and back. Over the upper part of the body and fundus, however, the peritoneal covering is firmly adherent, and cannot be dissected off.

Supports of the uterus.—The great mobility of the body of the uterus has been referred to above. The organ derives its support almost entirely from the attachments of the cervix and vaginal fornices. These rest on the pelvic floor, formed by the levator ani and perineal body which support them the more efficiently since the long axis of the vagina is at right angles to that of the uterus. Above the pelvic diaphragm the cervix is held up to the pelvic walls by strong specialized bands of fibromuscular tissue running in both anteroposterior and transverse directions. The chief of these, lying in the base of the broad ligaments is a fibrous sheath surrounding the uterine artery as it descends medially from the hypogastric. In the anteroposterior direction the uterovesical ligaments hold up the cervix to the pubes in front and the sacrouterine ligaments bind it to the anterior aspect of the sacrum behind. While firmly supporting the uterus these bands are elastic, and so do not fix it rigidly, but allow of the cervix being drawn downward by traction with vulsellum forceps.

For **lymphatics of uterus and vagina** see p. 777. For **blood-vessels**, see figs. 531, 571.

FIG. 1105.—SAGITTAL SECTION OF THE BROAD LIGAMENT.



The **ovary,** attached by its hilus to the mesovarium (figs. 1105, 1041, 1042), lies in a fossa at the back of the lateral wall of the pelvis just between the diverging external iliac and hypogastric vessels. To feel it the finger should be pushed well up in the side of the vagina toward the lateral wall of the pelvis. On the abdominal surface its position corresponds to the middle of a line drawn from the anterior superior iliac spine of that side to the opposite pubic tubercle (Rawlings).

The **lymphatics** of the ovary follow the ovarian veins (see p. 777). For **blood-vessels**, see figs. 525, 526, 571. Metastatic growths secondary to carcinoma or mixed tumors of the ovary will be found in the epigastrium, for the ovarian lymphatics drain into retroperitoneal lumbar lymph-nodes situated medial to the kidney.

The ureter.—The pelvic portion of this duct is of special importance in operations on the uterus and upper vagina.

It crosses the brim of the pelvis on either side at the bifurcation of the common iliac artery, or just in front of it, and descends on the side wall in front of the hypogastric artery, crossing the obliterated umbilical and obturator arteries. Curving forward and medially it passes under the base of the broad ligament (figs. 531, 1105), where the uterine artery crosses above it, and so gains the lateral angle of the bladder by passing across in relation to the lateral fornix of the vagina. In the base of the broad ligament the ureter lies about 2 cm. (⅘ in.) from the side of the cervix, and this relation must be borne in mind in excision of the uterus.

Pelvic floor.—The pelvic floor of the female corresponds in general to that of the male (see p. 1383). There are, however, important differences, due to the sexual organs. The *uro-*

(p. 1387) of the tunica vaginalis below, in this fashion: During the first few weeks after b
the process becomes obliterated at two spots—one near the abdominal ring, and one
above the testis. The obliterative process, commencing first above and descending, and t
ascending from below, the shrivelling continues until nothing is left save the tunica vagi
below. The following are possible hernial results of an imperfect obliteration of the proce

(1) If the process does not close at all, a descending **hernia** is called **congenital**. This
make its way into the scrotum. The testis is now enveloped and concealed by the herni

(2) If the process is closed only above, i. e., near the abdominal ring, two varieties ma
met with, *the infantile* and the *infantile encysted*. In the *infantile* owing to pressure above
weak septum gradually yields and forms a sac behind the unobliterated lower part of the
cessus funiculovaginalis. Thus three layers of peritoneum may now be met with in an o
tion, the two of the incompletely obliterated tunica vaginalis, and the proper sac of the he
In the **encysted infantile** variety the hernial pressure causes the septum to yield and form
projecting into, not behind, the incompletely obliterated tunica vaginalis. Here, theoreti
two layers of peritoneum will be met with. Another variety of such an encysted hernia
be produced by rupture, not stretching, of the above-mentioned septum. The discussi
these forms which have been handed down by the older anatomists is of theoretical int
Surgically the classification is of little importance for the sac is removed usually witho
attempt at determining the number of layers of peritoneum in front of its contents.

(3) If the process is vaginalis be [illegible] a hernia will [illegible] peritoneum which lined down as far as the testis. And hernia [illegible]
a hernia into the funicular process. [illegible]

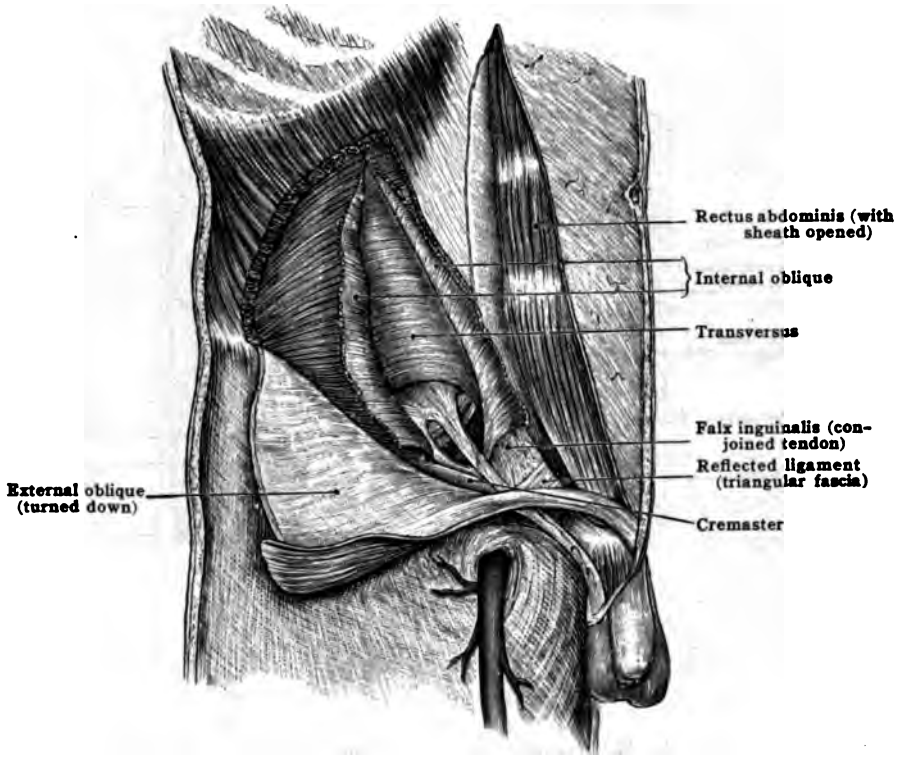
Inguinal hernia in the female. [illegible]

lata. On this inferior, stronger crus rests the cord (and so the weight of the testicle) or round ligament. **Shape**: triangular or elliptical, with the base downward and medially toward the pubic crest.

Intercrural fibers (intercolumnar fascia) (external spermatic fascia).—This, derived from the lower part of the aponeurosis of the external oblique, ties the two crura together, and, being continued over the cord, prevents there being any ring here, unless made with a scalpel. This is the rule in the body: when any structure passes through an opening in a fibrous or muscular layer, it carries with it a coating of tissue from that layer; e. g., the inferior cava passing through its foramen in the diaphragm, and the membranous urethra through the urogenital diaphragm.

Effect of position of the thigh on the ring.—As the lower crus is blended with Poupart's ligament, and as the fascia lata is connected with this, movements of the thigh will affect the ring much, making it tighter or looser. Thus extension and abduction of the thigh stretch the crura and close the ring. In flexion and adduction of the thigh the crura are relaxed; and this is the position in which reduction of a hernia is attempted. In flexion and abduction of the thigh, the ring is open; and this is the position in which a patient should sit, with thighs widely apart, to try on a truss, and cough or strain downward, as in rowing. If the hernia is now kept up, the truss is satisfactory.

FIG. 1107.—DISSECTION OF INGUINAL CANAL. (Wood.)



Helping to protect this most important spot, and preventing its being more than a potential ring, are not only the two crura and the intercrural fibers, but also a structure which has been called a third or posterior 'pillar,' namely, the **reflected inguinal ligament** (figs. 1106, 1107). This has its base above at the lower part of the linea alba, where it joins its fellow and the aponeurosis of the external oblique, and its apex downward and laterally, where, having passed behind the medial crus it blends with the lacunar (Gimbernat's) ligament. Again, the **falx inguinalis** (the conjoined tendon of the internal oblique and transversalis), curving medially and downward to be attached to the iliopectineal line and spine, is a most powerful protection, behind, to what is otherwise a weak spot and a potential ring.

Inguinal canal (fig. 1107).—This is not a canal in the usual sense, but a chink or flatsided passage in the thickness of the abdominal wall. The descriptions of the canal usually given apply rather to the diseased than to the healthy state. It was a canal once, and for a time only, i.e., in the later months of fetal life (p. 1387). It remains weak for a long time after, but only a vestige of it remains in the well-made adult.

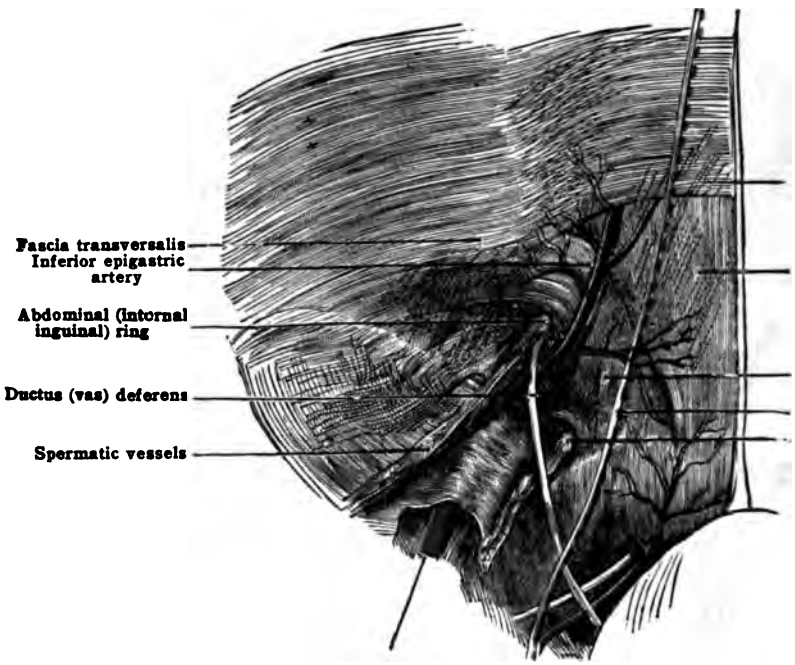
Length.—In early life there is no canal; one ring lies directly behind the other, so as to facilitate the easy passage of the testis. In the adult it measures about 37 mm. (1½ in.) in length,

this lengthening being brought about by the growth and separation of the ala of the pel
This increased obliquity gives additional safety. On the other hand, a large hernia has not o
opened widely the canal and rings, but it has pulled them close together, and one behind
other thus not only rendering repair much more difficult, but also the path to the peritoneal
shorter and more direct. **Direction.**—From the abdominal to the subcutaneous ring, do
ward, forward, and medially.

Boundaries.—For convenience sake, certain limits (largely artificial) have been named
(1) *Floor.*—This is best marked near the outlet, where the cord rests on the grooved up
margin of the inguinal (Poupart's) and the lacunar (Gimbernat's) ligament. The meet
of the transversalis fascia with this ligament forms the floor. (2) *Roof.*—The apposition of
muscles and the arched border of the internal oblique and transversus. (3) *Anterior wall*
Skin, superficial fascia, external oblique for all the way. Internal oblique, i.e., that part aris
from Poupart's ligament, for the lateral third or so. To a slight extent, the transversus a
the cremaster. (4) *Posterior wall.*—For the whole extent, transversalis fascia, extraperiton
tissue, and peritoneum. For the medial two-thirds, conjoined tendon of internal oblique a
transversus, and the lateral edge of the reflected inguinal ligament, when developed.

The **transversalis fascia** is thicker and better marked at its attachments below; these ar
(*a*) laterally, to medial lip of iliac crest; (*b*) to the inguinal ligament between the anteri
superior spine and the femoral vessels, where it joins the fascia iliaca; (*c*) opposite the femo

FIG. 1108.—DISSECTION OF THE LOWER PART OF THE ABDOMINAL WALL FROM WITHIN, T
PERITONEUM HAVING BEEN REMOVED. (Wood.)


Fascia transversalis
Inferior epigastric artery
Abdominal (internal inguinal) ring
Ductus (vas) deferens
Spermatic vessels
Border of the pos rior part of th sheath of the re tus (fold of Dou las)
Posterior surface rectus
Falx inguinalis in the triangle of Hesselbach
Obliterated hypo- gastric artery
Lymphatics in femoral ring
External iliac artery

vessel it also joins the fascia iliaca, and forms with it a funnel-shaped sheath; (*d*) medial to t
femoral vessels the fascia transversalis is attached to the terminal (iliopectineal) line, behi
the conjoined tendon, with which it blends.

The **falx inguinalis** (*conjoined tendon*) needs special reference figs. 1106–1108). It is formed
the lower fibers of the internal oblique and transversus (arciform fibers) arching downward ov
the cord to be inserted into the crest and spine and the terminal (iliopectineal) line. The fib
of the internal oblique become increasingly tendinous as they descend, and this, with the f
that below they give off the cremaster, may cause some difficulty in their identification wh
it is desired to unite them to the upper surface of Poupart's ligament in the operation of radi
cure.

The abdominal inguinal (internal abdominal) ring (figs. 1107, 1108).—
has already been said that the term 'ring' is here misapplied except in an artifici
sense, as when an opening is made by a scalpel; or in abnormal conditions when
hernial sac is present. The abdominal ring is not a ring in the least, but merely
funnel-shaped expansion of the transversalis fascia, which the cord carries on wi
it as it escapes from the abdomen.

Site.—Midway between the anterior superior iliac spine and pubic tubercle. Shap
oval, with the long diameter vertical. Boundaries: center of inguinal (Poupart's) ligame
about 12 mm. ($\frac{1}{2}$ in.) below. Medially, the inferior epigastric artery (fig. 1121); the positi

of this vessel, by its pulsation, is an important guide to the insertion of the highest sutures between the arciform fibers and the inguinal ligament. Owing to the artery lying to the medial side, the incision, in cutting to relieve the deep constriction of an inguinal hernia, should always be made directly upward, so as to avoid the above vessel. A large oblique hernia may so have altered the relations of the parts, including the artery, that it is difficult to decide whether the hernia is oblique or direct. The above incision will be safe, because, in either case, parallel to the vessel.

Forms of inguinal hernia.—There are two chief forms of inguinal hernia:—

A. **Lateral, or oblique.—Lateral,** because it appears (at the abdominal ring) lateral to the inferior epigastric artery. **Oblique,** because it traverses the whole of the inguinal canal, entering it at its inlet and leaving it at its outlet. This is the common form of inguinal hernia. In the oblique inguinal hernia, the hernial sac passes downward on the lateral and upper side of the spermatic cord, to which it is closely attached. If the fibers of the cremaster muscle are incised longitudinally the sac is exposed and can be easily isolated.

B. **Medial, or direct.—Medial,** because it appears medial to the inferior epigastric artery. **Direct,** because, instead of making its way down the whole oblique canal, it comes by a short cut, as it were, only into the lower part of the canal, and then emerges by the same opening as the other. This is the rarer form of inguinal hernia.

The sac in medial or direct hernia lies on the medial side of the spermatic cord to which it is not closely related. In the direct form considerable fat is always found in front of the peritoneum. The bladder is often closely related to the sac in the direct form and care should be taken not to injure it in freeing the sac. It may be necessary to divide the remains of the oblilerated hypogastric artery in order to free the sac.

A. **Oblique inguinal hernia.**—This form (which may be either congenital or acquired) possesses **coverings** as follows:—

(1) **At the abdominal ring,** or **inlet,** it obtains three:—(*a*) Peritoneum; (*b*) extraperitoneal fat; (*c*) infundibuliform fascia, or the vaginal process of transversalis fascia prolonged at this spot along the cord. (2) **In the canal** it obtains one. As it emerges beneath the lower border of the internal oblique it gets some fibers from the cremaster. (3) **At the subcutaneous ring,** or **outlet,** the hernia obtains three, viz.: (*a*) Intercrural fibers (intercolumnar fascia); (*b*) superficial fascia; and (*c*) skin.

B. **Direct inguinal hernia.**—This does not come through the abdominal ring, but, making its way through the posterior wall of the lower third of the canal, either through the medial or intermediate inguinal fossa. Its coverings, therefore, vary slightly with its mode of exit (*vide infra*).

Hitherto the two forms of inguinal hernia have been considered from the **superficial aspect,** that in which they are met with in practice. The inguinal region should also be studied as to the **posterior aspect** of its so-called rings and canal, as these have to bear the early stress of a commencing hernia. It is against this aspect that a piece of omentum or intestine is constantly and insiduously pressing and endeavoring to make its way out. On the posterior wall are certain peritoneal folds (cf. fig. 923) and depressions, marking off regions. Thus, there are three more or less prominent peritoneal *folds* (one median unpaired and two lateral paired) and three paired *fossæ*. The three folds are: (1) **median umbilical,** due to the *urachus*, a fibrous cord derived from the embryonic allantois, extending from the apex of the bladder to the umbilicus; (2) the **lateral umbilical fold,** enclosing the *obliterated hypogastric* artery, extending up to the umbilicus; and (3) the **epigastric fold,** enclosing the inferior epigastric vessels (figs. 923, 1108).

In relation to these folds are the following pouches or **fossæ**:—(*a*) A medial or **supravesical fossa,** between the median and lateral umbilical folds. Direct inguinal hernia may occur in the lateral part of this fossa, lateral to the margin of the rectus (fig. 1108). (*b*) Between the lateral umbilical and the epigastric fold is the **medial inguinal fossa,** an intermediate fossa, through which direct inguinal hernia may pass. (*c*) Most laterally is the **lateral inguinal fossa,** corresponding to the abdominal ring, through which oblique inguinal hernia passes.

The **coverings** of a direct hernia may now be considered, together with **the two-fold manner of exit** of this hernia. It only traverses the lower part of the canal, making its way through either the medial or the intermediate pouch. (i) The commonest form, coming through the medial (supravesical) pouch, either pushes its way through or stretches before it the falx inguinalis. Its *coverings* are:—(1) Peritoneum; (2) extraperitoneal fat; (3) transversalis fascia; (4) falx inguinalis (unless this is suddenly burst through); (5) (6) (7). At the subcutaneous ring the three coverings are the same as in the oblique variety. (ii) This rarer form of direct hernia comes through the intermediate pouch. As a rule, the falx inguinalis does not reach over this fossa. The coverings will be the same as in the last, with two exceptions—there is no falx inguinalis, and the cremasteric fascia, if well developed, will be present.

Varieties of inguinal hernia according to the condition of the vaginal process of peritoneum.—Inguinal herniæ have above been classified according to their relation to the deep epigastric artery. It remains to allude to the arrangement of these same herniæ according to the varying condition of the **processus vaginalis.** This pouch of peritoneum, which paves the way for the passage of the testis before this organ makes its start, eventually becomes the parietal layer

(p. 1387) of the tunica vaginalis below, in this fashion: During the first few weeks after bi the process becomes obliterated at two spots—one near the abdominal ring, and one j above the testis. The obliterative process, commencing first above and descending, and th ascending from below, the shrivelling continues until nothing is left save the tunica vagin below. The following are possible hernial results of an imperfect obliteration of the proces

(1) If the process does not close at all, a descending hernia is called congenital. This m make its way into the scrotum. The testis is now enveloped and concealed by the hernia

(2) If the process is closed only above, i. e., near the abdominal ring, two varieties may met with, *the infantile* and the *infantile encysted*. In the *infantile* owing to pressure above, weak septum g·adually yields and forms a sac behind the unobliterated lower part of the p cessus funiculovaginalis. Thus three layers of peritoneum may now be met with in an ope tion, the two of the incompletely obliterated tunica vaginalis, and the proper sac of the her In the encysted infantile variety the hernial pressure causes the septum to yield and form a projecting into, not behind, the incompletely obliterated tunica vaginalis. Here, theoretica two layers of peritoneum will be met with. Another variety of such an encysted hernia n be produced by rupture, not stretching, of the above-mentioned septum. The discussion these forms wh ch have been handed down by the older anatomists is of theoretical inter Surgically the classification is of little importance for the sac is removed usually without attempt at determining the number of layers of peritoneum in front of the contents.

(3) If the processus vaginalis be closed below and not above, a patent tubular proces peritoneum will lead down as far as the top of the testis. Any hernia into this process is ca a hernia into the funicular process. All these varieties save the congenital and hernia into funicular process are rare in practice. Other practical points are that all herniæ in children young adults are probably of congenital origin, and therefore, the weakness is often bilate though it may not be so palpably This applies to both sexes. Again in hernia of sud origin into the funicular process with narrow surroundings, strangulation may be very ac

Inguinal hernia in the female.—The inguinal canal in women is smaller and narrower t in men. Inguinal hernia is, therefore, less common in the female sex, and occurs in patients happen to be the subjects of an unobliterated processus vaginalis, which extends for a vary distance along the round ligament, and is called the *canal of Nuck*. Inguinal hernia in female is, therefore, always congenital. It is practically always of the oblique variety, travels along the round ligament toward the labium majus. Its coverings will be the same those of the oblique variety in the male, save that the cremaster, as a distinct muscle, is abs and any fibers of the internal oblique which may be present are but little developed.

In repairing a hernia, removal of the sac is one of the essentials. The sac should be remo high enough to obliterate any funnel-shaped process. In closing the canal, the Bassini operat in which the falx inguinalis (conjoined tendon) and the transveralis and internal oblique mus are sutured to the shelf of Pouparts ligament is still extensively employed. For operative tails, the surgical text-books should be consulted.

FEMORAL HERNIA

Parts concerned in femoral hernia.—These include (1) superficial fascia, inguinal (Poupart's) ligament, (3) lacunar (Gimbernat's) ligament, (4) fas lata, (5) fossa ovalis, (6) femoral sheath, (7) femoral canal, (8) femoral ring. (F 1110).

(1) **Skin and superficial fascia of groin.**—The latter consists of two laye (*a*) **Superficial layer of superficial fascia** (Camper's fascia).—Fatty, met with o the whole groin, and continuous with the superficial fascia of the rest of the bod (*b*) **Deep layer of superficial fascia** (Scarpa's fascia).—Thin and membrano only met with over the lower third of the abdominal wall and to the med side of the groin.

The latter is continuous through the scrotum with the deep layer of the superficial fas of the perineum (Colles' fascia). Just below the inguinal ligament it is joined to the fas lata. From these two facts it results that in rupture or giving way of the urethra the extra sated urine may come forward by way of the genitals (p. 1386) and from the continuity of fascia make its way on to the abdomen, but not down onto the thigh

Between the two layers of superficial fascia lie the superficial lymph nodes of the groin. superficial branches of the common femoral artery, cutaneous nerves, and some veins desce ing to the fossa ovalis to join the gerat saphenous vein.

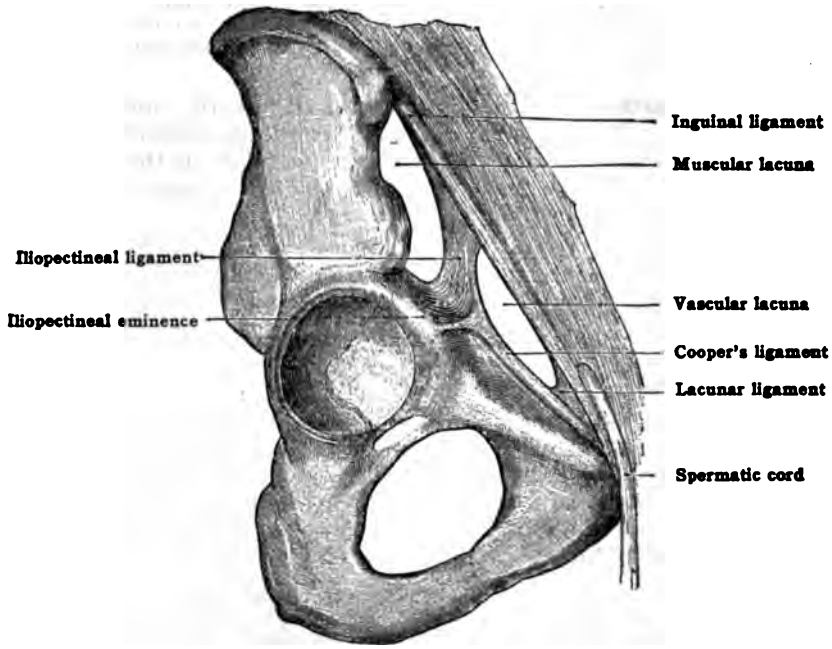
(2) **Inguinal (Poupart's) ligament** (fig. 1109).—This is also known as t crural arch, a misnomer, as 'crus' means leg. A description of its shape a attachments is given on p. 1371. Owing to the connection of the fascia lata its lower border, the fossa ovalis (saphenous opening), which is situated in t fascia lata, and has its upper cornu blending with the inguinal ligament, will affected by movements of the thigh, much as is the subcutaneous inguinal (ternal abdominal) ring, being tightened and stretched when the limb is extend and abducted, relaxed when it is adducted and flexed.

The parts beneath the ligament which block up the gap between it and t innominate bone are of the utmost importance in preventing the escape of

femoral hernia. The different structures are arranged in three compartments, (fig. 1109), named lateromedially:—(A) **lateral iliac** or **muscular**; (B) **central** or **vascular**; and (C) **medial** or **pectineal.** Of these, the first is the largest; the second or intermediate one lies slightly nearer to the inguinal ligament than the other two; while the medial compartment differs from the other two by not communicating with the pelvis, being closed above (*vide infra*).

(A) The **lateral** or **iliac compartment** is bounded in front by the inguinal ligament and the iliac fascia, which is here blending with it, behind by the ilium, laterally by this bone and the sartorius, and medially by the iliopectineal septum, which, descending from the blending of the iliac fascia and the inguinal ligament above, passes down to the iliopectineal eminence, and thence to the medial aspect of the front of the capsule of the hip-joint. This compartment transmits the iliopsoas muscle and femoral (anterior crural) and lateral cutaneous nerves. (B) The **vascular compartment** is bounded in front by the inguinal ligament and the transversalis fascia, which here blends with it, forming the so-called *deep crural arch*, and at the same time

FIG. 1109.—THE LACUNÆ BENEATH THE INGUINAL LIGAMENT. (Lockwood.)



descends on to the front of the femoral sheath. The posterior boundary, *Cooper's ligament*,[1] is formed by the meeting of the iliopectineal septum laterally and the pectineal fascia or sheath. Medially is the lacunar (Gimbernat's) ligament, and laterally the iliopectineal septum. This intermediate compartment transmits the external iliac vessels and the lumboinguinal nerve. This lies to the lateral side of the artery, the vein medially Between the vein and the base of the lacunar ligament is the femoral ring (*vide infra*). (C) The **medial or pectineal compartment** is bounded by the pectineal fascia, continuous with the pubic part of the fascia lata, and behind by the pubic ramus. It lodges the upper end of the pectineus muscle, so that the handle of a scalpel passed upward along the muscle would be prevented from passing into the pelvis by the lacunar ligament and the blending of the pectineal fascia with the upper border of the pubic ramus. The pectineal fascia is employed in some operations for the cure of femoral hernia.

(3) **Lacunar (Gimbernat's) ligament.**—This is merely the triangular medial attachment of Poupart's ligament. Its apex is attached to the pubic tubercle; of its three borders, the base is free toward the vein and the femoral canal. Its upper border is continuous with Poupart's ligament; its lower is attached to the terminal (iliopectineal) line (fig. 1109).

(4) **Fascia lata.**—Two portions are described over the upper part of the thigh:—(*a*) An **iliac,** lateral and stronger, attached to the inguinal ligament in its whole extent and lying over the sartorius, iliopsoas, and rectus. (*b*) A **pubic,** medial, weaker, and much less well defined, is attached above to the terminal line and the tubercle of the pubis. The upper cornu of the fossa ovalis is at the lacunar ligament, and at the lower cornu the two portions of the fascia blend.

Relation of fascia lata to the femoral vessels.—The iliac portion, being attached along Poupart's ligament, passes over these. The pubic portion, fastened down over the pectineus, which

slopes down on to a deeper plane than the adjacent muscles, passes behind the femoral ve to end on the capsule of the hip-joint.

(5) **Fossa ovalis (saphenous opening).**—This is not an opening, but an depression, situated at the spot where the two parts of the fascia lata diverg different levels. Though the fascia lata is wanting here, there is no real open as the deficiency is made up by the deep layer of superficial fascia, or cribrif fascia, which fills up the opening (fig. 420).

Though a weak spot, the fossa ovalis serves to transmit the saphenous to the femoral and the superficial to the deep lymphatics. The depression is present in order to allow saphenous vein to be protected from pressure in flexion of the thigh. It is located at the m and upper part of the thigh, with its center 3.7 cm. (1½ in.) below and lateral to the tub of the pubis. It is 2.5 cm. (1 in.) in height by 1.2 or 1.8 (½ or ¾ in.) in width. *Shape:* with its long axis downward and laterally. *Two extremities* or *cornua:* upper blending with lacunar ligament; lower, where the two parts of the fascia lata meet. *Two borders:* later falciform, also known as the *ligament of Hey*, or femoral ligament. Semilunar in shape, ar downward and laterally from the lacunar ligament to the inferior cornu. This lies ove femoral vessels, and is adherent to them; to it is fixed superficially the cribriform fascia *infra*). The medial border is much less prominent, owing to the recession of the pubic of the fascia lata which forms it.

(6) **Femoral sheath.**—This is a funnel-shaped sheath, carried out by femoral vessels under Poupart's ligament, and continuous above (in front) the transversalis fascia as it descends to the ligament, lining the inner surfac the abdominal wall, and (behind) with the iliac fascia, and below contin with the proper sheath of the femoral vessels.

It is not only funnel-shaped, but large and loose, for two reasons:—(*a*) That there be pl of room for the femoral vein and the slowly moving venous current in it to ascend without pression; (*b*) to allow all the movements of the thigh taking place—flexion and extensi without undue stretching of the vessels. By two connective-tissue septa the sheath is div into three compartments—the lateral for the artery, the intermediate for the vein, and medial one for the femoral canal (*vide infra*). Thus one septum lies between the artery vein, and another between the vein and the femoral canal.

(7) **Femoral canal.**—This occupies the medial division of the femoral she The fascia transversalis and fascia iliaca meet directly on the lateral side of femoral artery, but not so closely on the medial side of the femoral vein. He a space exists here, perhaps to prevent the thin-walled vein, with its slug current, from being pressed upon; but it is merely a slight gap, not a canal, un so made by a knife or by the dilating influence of a hernia.

Length: about 1.9 cm. (¾in.). *Limits:* below, fossa ovalis; above, femoral ring. *Bo aries.*—Laterally, a septum between it and the vein; medially, base of the lacunar ligam (above) and meeting of fasciæ iliaca and transversalis; behind, fascia iliaca; in front, fascia tr versalis. *Contents.*—Cellular tissue and fat, continuous with extra-peritoneal fatty layer a lymphatic node, which is inconstant. Lymphatic vessels pass from inguinal nodes to t in the pelvis through the femoral canal, which is therefore sometimes called the 'lymph canal' (fig. 1108).

(8) **Femoral ring.**—This is mainly an artificial product. It is the upper abdominal opening of the femoral canal (figs. 535, 1108, 1110). *Shape:* o with its long axis transverse. It is larger in women. *Boundaries:* media the lacunar ligament; laterally, the femoral vein; in front, the inguinal ligam and the thickening of the transversalis fascia attached to it (called 'the d crural arch'); behind, the pectineus and Cooper's ligament, a thickened fas bundle attached to the linea terminalis (fig. 1109). It is closed by the *sept crurale*, which is a mass of fatty connective tissue, continuous with the ex peritoneal fatty layer, perforated by lymphatics passing upward to the pe nodes (figs. 1108, 1110).

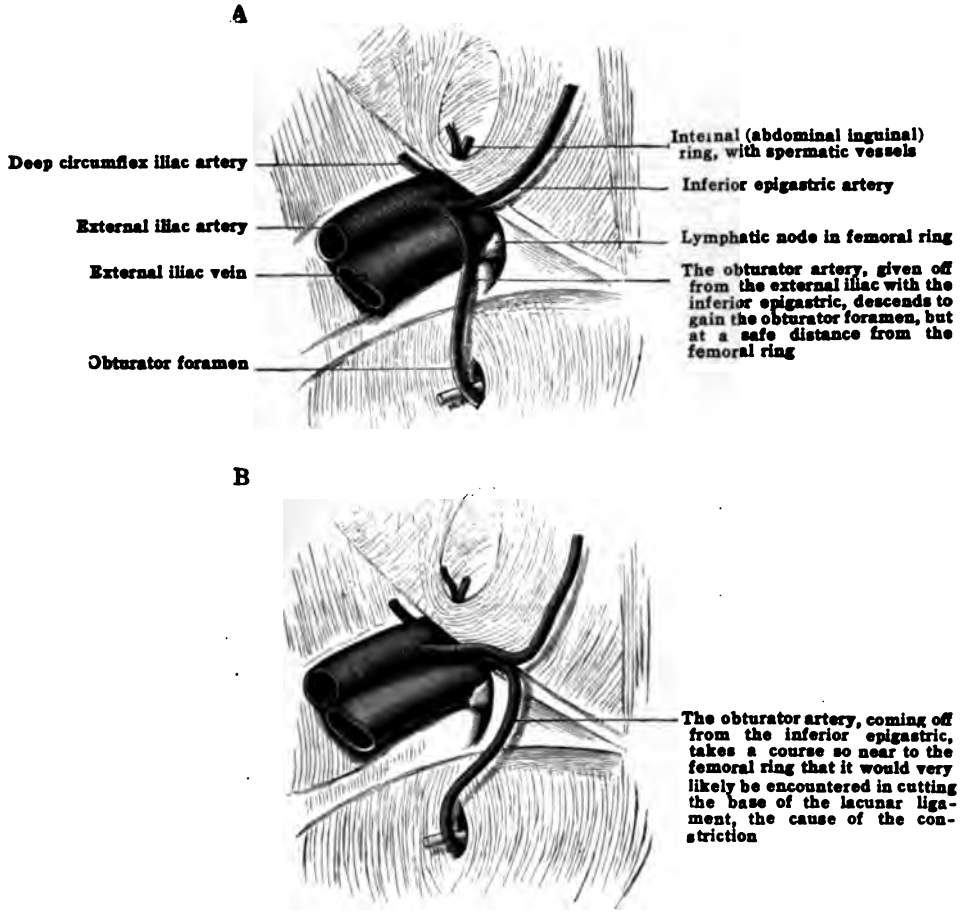
Position of vessels around the ring.—Laterally the femoral vein; above, epigastric vessels as they ascend from the external iliac vessels, pass close to upper and lateral aspect of the ring; immediately in front are the cord and s matic vessels always to be remembered in this hernia in the male; toward medial side there may be an unimportant anastomosis between the epigas artery above and the obturator below (fig. 1108).

If from dilation of the above anastomosis the obturator artery comes off abnormally f the inferior epigastric, it will descend, and usually does so, close to the junction of the exte iliac and common femoral vein, and thus to the lateral, and so the safe, side of the ring 1110, A). In a very few cases it curves more medially, close to the lacunar ligament,

thus to the medial side of the ring, and is then in great danger (fig. 1110, B) if the constricting femoral ring is incised. In two out of every five cases the obturator arises from the inferior epigastric. In about thirty-seven per cent. of the cases with such an origin the artery either crosses or courses along the side of the ring. (Cunningham.)

Course of femoral hernia.—At first this is downward in the femoral canal. A pouch of peritoneum having been gradually, after repeated straining, coughing, etc., pushed through the weak spot, the femoral ring, further weakened perhaps, together with all the parts in the femoral arch, by child-bearing, some extra effort will force intestine or omentum into this pouch and thus form a hernia. It has been recently claimed that some femoral herniæ are congenital; the peritoneal pouch which forms the sac being carried out with the limb-bud as it develops. When formed, femoral hernia passes at first downward in the femoral canal as far as the fossa ovalis, but, as a rule, does not go farther downward on the thigh, but mounts forward and upward, and somewhat laterally, even reaching the level of the inguinal ligament. The reasons for this change of position are:—(1) The narrowing of the femoral sheath, funnel-like, i. e.,

FIG. 1110.—FEMORAL RING AND IRREGULARITIES OF THE OBTURATOR ARTERY. (After Gray.)


A
Deep circumflex iliac artery
External iliac artery
External iliac vein
Obturator foramen
Internal (abdominal inguinal) ring, with spermatic vessels
Inferior epigastric artery
Lymphatic node in femoral ring
The obturator artery, given off from the external iliac with the inferior epigastric, descends to gain the obturator foramen, but at a safe distance from the femoral ring
B
The obturator artery, coming off from the inferior epigastric, takes a course so near to the femoral ring that it would very likely be encountered in cutting the base of the lacunar ligament, the cause of the constriction

wide above, but narrowed below; (2) the unyielding nature of the lower margin of the fossa ovalis; (3) the fact that this margin and the lateral border are united to the femoral sheath; (4) the constant flexion of the thigh; (5) the fact that vessels (chiefly veins) and lymphatics descend to the fossa ovalis, the veins to join the saphenous vein and the lymphatics to join the deeper group; these descending vessels serve to loop upward or suspend a femoral hernia, and thus prevent its further course downward. (For relations of femoral hernia, see fig. 1111.)

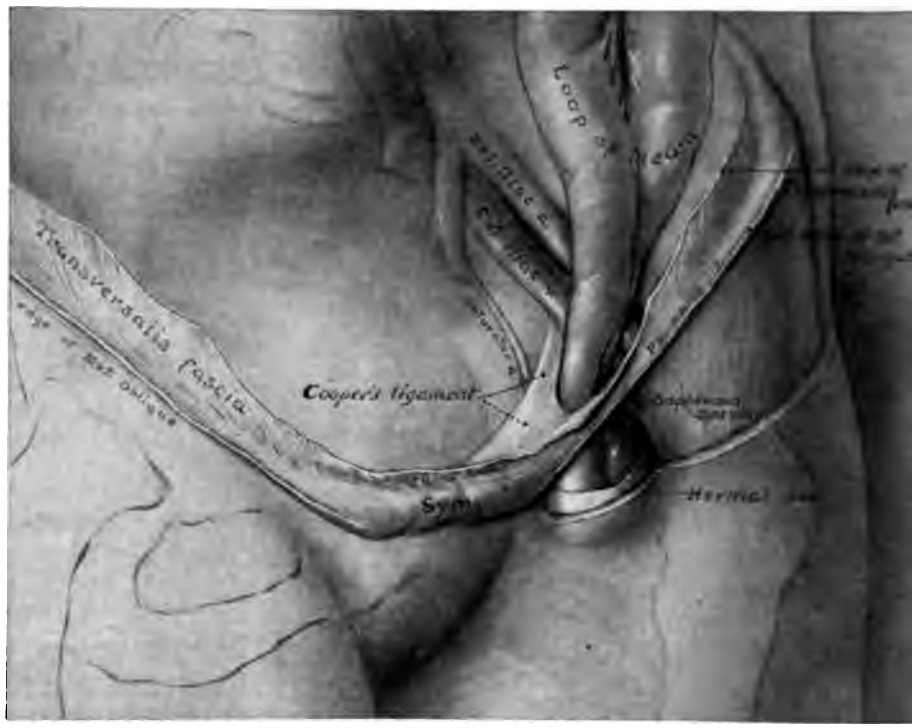
Coverings of a femoral hernia.—(A) **At the upper** or **femoral ring** it includes peritoneum, extraperitoneal fat, and septum femorale (crurale). (B) **In the canal,** a coating of the femoral sheath. (C) **At the external opening,** further coverings of cribriform fascia, skin, and superficial fascia are added.

Some of these coverings may be deficient by the hernia bursting through them, or they may be matted together. Sir A. Cooper thought this matting likely to occur with the layer of femoral sheath and septum crurale, to which he gave the name of *fascia propria.* The sac of a femoral hernia is usually covered by a relatively large amount of fat. At times there may be so much fat that the sac is found with difficulty.

The relations of an inguinal and a femoral hernia respectively to the pubic tubercle a importance in distinguishing between them clinically. If a finger is placed on the pubic tub a hernia that lies above and medial to it will be inguinal, one below and lateral to it wi femoral.

Radical cure of femoral hernia.—The close proximity of the femoral vein always i duces difficulty in the introduction of the deep sutures for closure of the crural ring. Any sure below this point is certain to be inefficient. The safest and simplest method is to for the pulsation of the femoral artery, and make allowance for the vein on its medial side. latter vessel is then protected by the finger-tip passed up the femoral canal, so that its do rests against the vein and its tip upon the linea terminalis. The sutures are then passe as to pick up the iliopectineal fascia and its thickened part, Cooper's ligament, below, and deep crural arch and Poupart's ligament above (fig. 1109). Thus, when tightened, they the anterior and posterior boundaries of the ring together. (Lockwood, Bassini.) There growing tendency to operate upon femoral hernia from above, that is through the ing canal. The hernial sac can thereby be completely removed, and the opening compl closed.

FIG. 1111.—RELATIONS OF FEMORAL HERNIA. (From Seelig and Tuholski; in Binnie's Regi Surgery.)



PARTS CONCERNED IN UMBILICAL HERNIA

A hernial protrusion at the umbilicus, or exomphalos, may occur at th distinct periods of life, according to the anatomy of the part. Any account umbilical hernia would be incomplete without an attempt to explain how t region, originally a most distinct opening, is gradually closed and changed i a knotty mass of scar, the strongest point in the abdominal wall.

During the first weeks of fetal life, in addition to the urachus, umbili arteries, and vein, some of the mesentery and a loop of the intestine pass thro the opening to occupy a portion of the body cavity (the umbilical celom) si ated in the umbilical cord, later on returning to the abdominal cavity (cf. p. 11 Occasionally this condition persists, owing to failure of development, and child is born with a large hernial swelling outside the abdomen, imperfec covered with skin and peritoneum. To this condition the term congen umbilical hernia should be applied.

Later on in fetal life it is the umbilical vessels alone which pass through t opening. At birth there is a distinct ring, which can be felt for some time a in the flaccid walls of the infant's belly. If this condition persists, a piec

intestine may find its way through, forming the condition which should be known as **infantile umbilical hernia.**

This condition is not uncommon. Why it is not more frequently met with is explained by the way in which this ring of infancy is closed and gradually converted into the dense mass of scar tissue so familiar in adult life. This is brought about—(1) by changes in the ring itself; (2) by changes in the vessels which pass through it.

(1) **Changes in the ring itself.**—The umbilical ring is surrounded by a sphincter-like arrangement of elastic fibers, best seen during the first few days of extrauterine life, on the posterior aspect of the belly wall. In older infants these fibers lose their elasticity, become more tendinous, and then shrink more and more. As they contract they divide, as by a ligature, the vessels passing through the ring, thus accounting for the fact that the cord, wherever divided, drops off at the same spot and without bleeding.

(2) **Changes in the vessels themselves.**—When blood ceases to traverse these, their lumen contains clots, their muscular tissue wastes, while the connective tissue of their outer coat hypertrophies and thickens. Thus, the umbilical vessels and the umbilical ring are, alike, converted into scar tissue, which blends together. This remains weak for some time, and may be distended by a hernia (infantile).

Finally, we have to consider the state of the umbilicus in adult life. The very dense, unyielding, fibrous knot shows two sets of fibers:—(1) Those decussating in the middle line; and (2) two sets of circular fibrous bundles which interlace at the lateral boundaries of the ring. The lower part of the ring is stronger than the upper. In other words, **umbilical hernia of adult life,** when it comes through the ring itself and not at the side, always comes through the upper part. In the lower three-fourths of the umbilicus the umbilical arteries and urachus are firmly closed by matting in a firm knot of scar tissue; in the upper there is only the umbilical vein and weaker scar. To the lower part run up the umbilical arteries and the urachus. Owing to the rapid growth of the abdominal wall and pelvis before puberty, and the fact that the urachus and the umbilical arteries, being of scar tissue, elongate with difficulty, the latter parts depress the umbilicus by reason of their intimate connection with its lower half.

Owing to the usual exit of an umbilical hernia of adult life being through the upper part of the ring, the constricting edge in strangulation should be sought below and divided downward. As pointed out by Mr. Wood, it is here that the dragging weight of the hernial contents and the weight of the dress tend to produce the chief results of strangulation. An incision here also gives better drainage if required.

Coverings of an umbilical hernia.—These, more or less matted together, are:—(1) Skin; (2) superficial fascia, which loses its fat over the hernia; (3) prolongation of scar tissue of the umbilicus gradually stretched out; (4) transversalis fascia; (5) extraperitoneal fatty tissue; (6) peritoneum. If the hernia come through above the umbilicus, or just to one side, the coverings will be much the same; but, instead of the layer from the umbilical scar, there will be one from the linea alba.

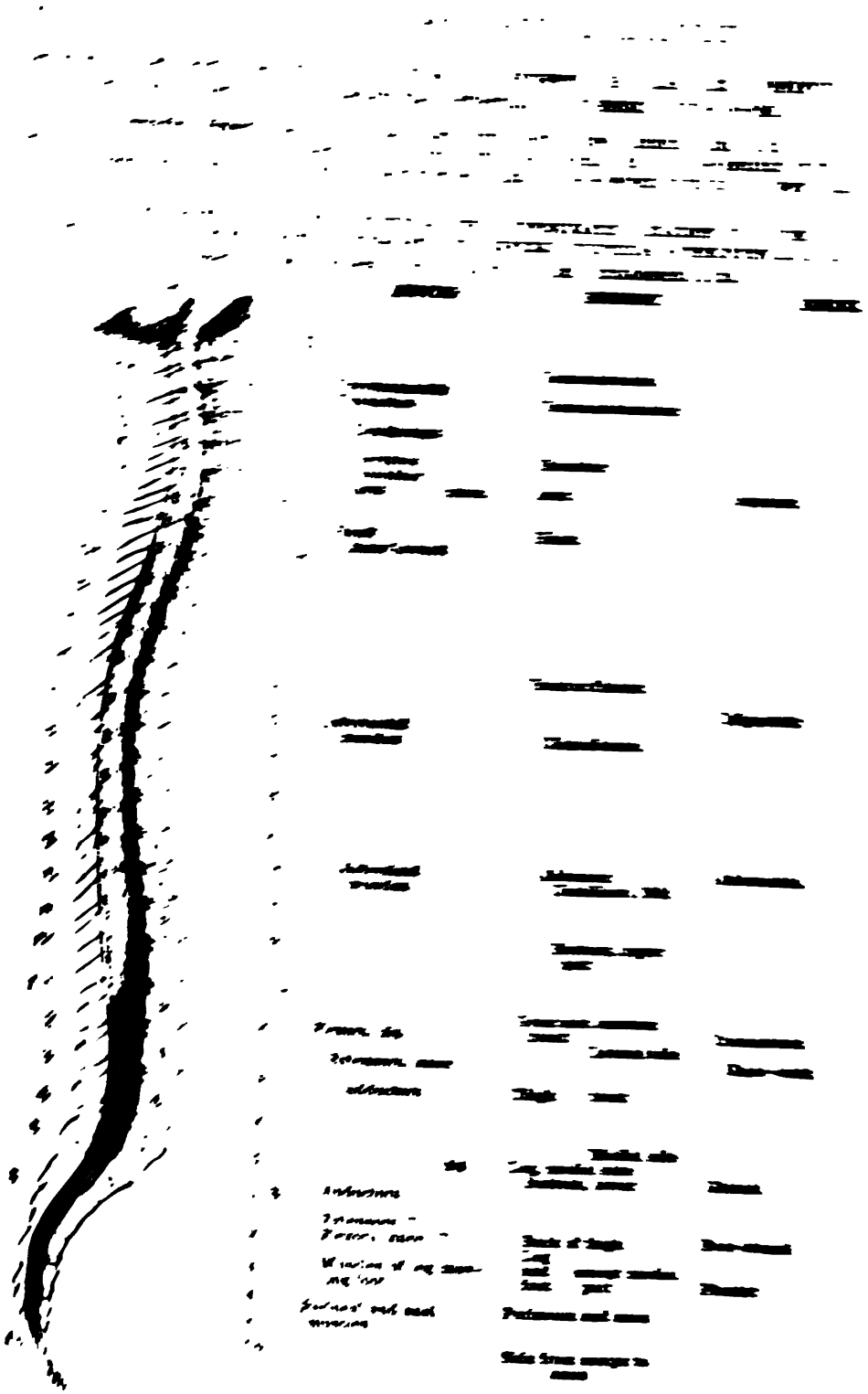
Strangulated umbilical hernia of adult life.—In this, the most fatal of the strangulated hernia ordinarily met with, the following are practical points in the surgical anatomy:—1. The coverings, including the sac, are always thin, at times so markedly so that the intraperitoneal contents are practically subcutaneous. 2. The sac is multilocular, and one or more of its chambers may lie very deep. 3. The contents are numerous, viz., omentum, often voluminous and adherent, transverse colon, and later in the history, small intestine. 4. The contents are often adherent to the sac and each other, thus explaining the irreducibility. 5. The long duration of the presence of the transverse colon with its stouter walls accounts for the period, often prolonged, in which warning evidence of incarceration precedes that of strangulation. 6. The communication with the peritoneal sac is direct, short, and during a prolonged operation, free. Infection is thus readily brought about.

THE BACK

The surface form and landmarks of the back will be considered first, followed by the relations of skeleton, muscles, viscera and nervous system.

Median furrow.—This is more or less marked according to the muscular development, lying between the trapezii and semispinales capitis, in the cervical region, and the sacrospinales lower down. The lower end of the furrow corresponds to the interval between the spines of the last lumbar and the first sacral vertebra. (Holden.)

Vertebral spines.—The tips of the spinous processes of the upper cervical region are scarcely to be made out even by deep pressure. That of the axis may be detected in a thin subject. Over the spines of the middle three cervical vertebra is normally a hollow, owing to these spines receding from the surface to allow of free extension of the neck. The seventh cervical is prominent, as its name



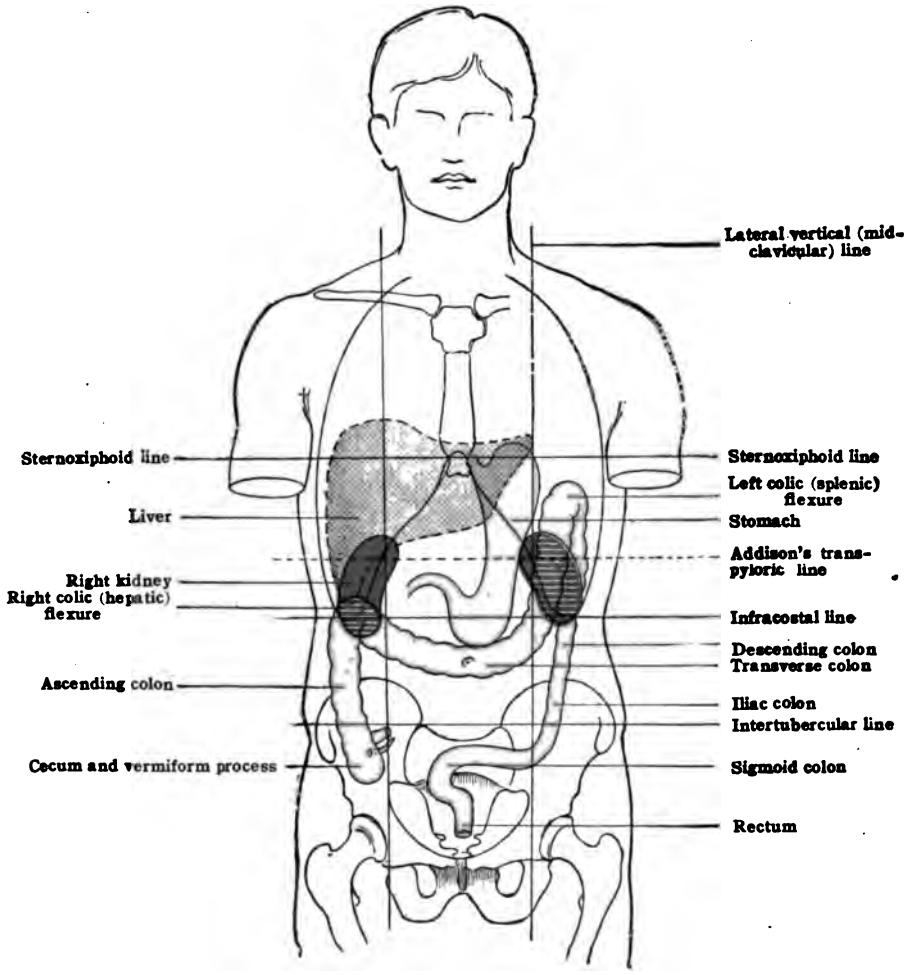
corresponds with the head of the te
and so on till we come to the eleven
their corresponding ribs. Holden.

In the lumbar spines, the most important are the second, which corresponds to the terma-
tion of the ribs and the fourth, which marks the highest part of the iliac crests and the
direction of the abdominal aorta. The lumbar spines project horizontally, and correspond

with the vertebral bodies. The third is a little above the umbilicus. The relations in Quincke's lumbar puncture are mentioned later.

The lower **ribs** may be felt lateral to the sacrospinalis but in counting them from below it must be remembered, as pointed out by Holl, that in quite a considerable percentage the last rib is so abnormally short that it does not reach as far as the lateral border of the sacrospinalis; or is so rudimentary as to resemble a transverse process (consequently the only safe method of counting ribs is from above). In these cases the lower end of the pleura may pass from the lower part of the twelfth thoracic vertebra, almost horizontally to the lower edge of the eleventh rib.

FIG. 1113.—RELATIONS OF THE ABDOMINAL VISCERA TO THE ANTERIOR BODY WALL. (Kidneys somewhat too widely separated.)



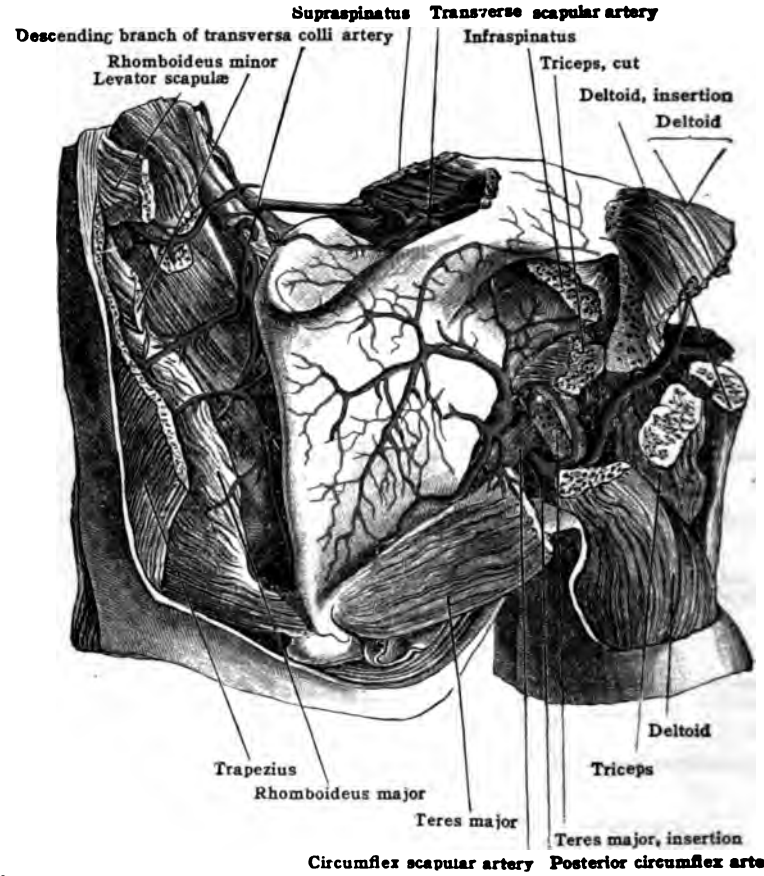
Muscles.—The student will remember the greater number and complexity and the numerous tendons of the muscles which run up on either side of the spinal column; the firmness and inextensibility of their sheaths; the large amount of cellular tissue between them; and the fact that toward the nape of the neck these muscles lie exposed instead of being protected in gutters, as is the case below: all these anatomical points explain the extreme painfulness and obstinacy of sprains here.

Trapezius.—To map out this muscle, the arm should be raised to a right angle with the trunk. The external occipital protuberance should be dotted in, and the superior nuchal line passing out from this; below, the twelfth thoracic spine should be marked; and laterally, the lateral third of the clavicle and the commencement of the scapular spine. Then a line should be drawn from the protuberance vertically downward to the twelfth thoracic spine; a second from about the middle of the superior nuchal line to the posterior and lateral third of the clavicle; and a third from the last thoracic spine upward and laterally to the root of the spine of the scapula.

Latissimus dorsi.—The arm being raised above a right angle, the spines of the sixth tho and the third sacral vertebra should be marked; then the outer lip of the crest of the ilium lower two or three ribs, the lower angle of the scapula, and the posterior fold of the axilla, finally the intertubercular (bicipital) groove should all be marked.

A vertical line from the sixth thoracic to the third sacral spine will give the spinal orig the muscle. Another from the third sacral spine to a point on the iliac crest, 2.5 cm. (1 in more lateral to the edge of the sacrospinalis, will give the origin of the muscle from the sh of the sacrospinalis and the ilium. A line from the sixth thoracic spine, almost transve at first, with increasing slight obliquity over the inferior angle of the scapula to the axilla intertubercular groove, will mark the upper border of the muscle. Another very oblique from the point of the iliac crest upward and laterally to the axilla will give the lower bo and the tapering triangular apex of the insertion. The muscle may be attached to the s of the scapula, or separated from it by a bursa.

FIG. 1114.—CHIEF ARTERIAL ANASTOMOSES ON THE SCAPULA.
(From a dissection in the Hunterian Museum.)



Triangle of Petit.—This small space lies above the crest of the ilium, at about its cen bounded posteriorly by the anterior edge of the latissimus and anteriorly by the posterior bor of the external oblique (fig. 418). Through this gap, when the muscles are weak, a lum abscess occasionally, and very rarely, a lumbar hernia, may appear.

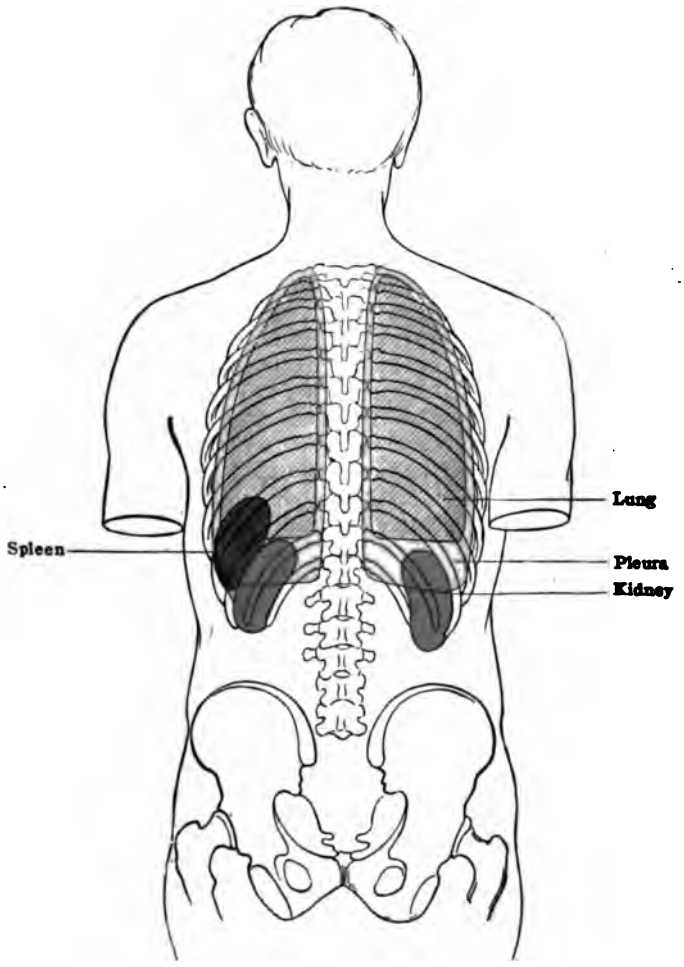
Origin of spinal nerves.—It is very important to remember the relations these to the vertebral spines, in determining the results of disease or injury of t cord and the parts thereby affected. The above relations may be given brie as follows:—

The origins of the eight cervical nerves correspond to the cord between the occiput and sixth cervical spine. The upper six thoracic come off between the above spine and that of fifth thoracic vertebra. The origins of the lower six thoracic nerves correspond to the inter between the fourth and the tenth thoracic spines. The five lumbar arise opposite the eleve and twelfth thoracic spines; and the origins of the five sacral correspond to the first lum spine. The diagram and table (fig. 1112), arranged by Dr. Gowers from anatomical a pathological data, show the relations of the origins of the *nerves* to their exits from the vertel canal, and the regions supplied by each. For further details on neural topography, see Sect on NERVOUS SYSTEM.

Scapula; its muscles and arterial anastomoses.—Amongst the landmarks in the back, the student should be careful to trace the angles and borders of the scapula as far as these are accessible. The upper border is the one most thickly covered. With the hands hanging down, the upper (medial) angle corresponds to the upper border of the second rib; the lower angle to the seventh intercostal space; and the root of the spine of the scapula to the interval between the third and fourth thoracic spines.

The axillary border of the scapula, covered by the latissimus dorsi and teres major, may best be palpated with the arm hanging to the side. The vertebral border is brought into prominence by placing the hand on the opposite shoulder. This border is held in apposition

FIG. 1115.—RELATIONS OF THE ABDOMINAL VISCERA TO THE POSTERIOR BODY WALL. (Kidneys somewhat too widely separated.)



with the thorax by the serratus anterior; consequently in paralysis of that muscle, supplied by the long thoracic nerve (5, 6, and 7 C.), it becomes unduly prominent, giving rise to 'winged scapula.' Figs. 505, 1089, 1114 show the chief arteries around the scapula. The anastomoses on the acromial process between the transverse scapular (suprascapular), thoracoacromial, and circumflex humeral arteries are not shown. The numerous **points of ossification**, primary and secondary, by which this bone is developed explain, in part, the frequency of cartilaginous and other growths here.

The anatomy of the loin behind, the **iliocostal region**, is of prime importance, owing to the numerous operations here. **The lateral border of the sacrospinalis and quadratus lumborum** may be indicated on the surface thus. (Stiles.) That of the sacrospinalis by drawing a line from a point on the iliac crest 8.2 cm. (3½ in.) (four fingers'-breadth) from the middle line upward and slightly laterally to the angles of the ribs. That of the quadratus passing upward and slightly medially lies a little lateral to that of the sacrospinalis at the crest, and a little medial to it at the twelfth rib. The ascending and the descending colon lie in the slightly depressed angle between the two muscles. The iliocostal region varies greatly in space according to the length of the lower ribs, shape of the chest, and development of the iliac crest. An

incision here—that for exploration of the kidney may be taken as the type—would be an obl one, about 10 cm. (4 in.) long, starting in the angle between the twelfth rib and the sacrospi muscle and passing forward and downward toward the anterior extremity of the iliac c In its upper part the incision should lie 1.2 cm. (½ in.) below the twelfth rib. The ant fibers of the latissimus dorsi are divided behind, the posterior ones of the external obliqu front. The yellowish-white lumbar fascia now comes into view, and is the first important l mark. It and the fibers of the internal oblique and transversus which arise from it are carefully divided. The last thoracic nerve and lowest intercostal artery may also req division. If the latter is cut close to the rib, the hemorrhage is troublesome. The transver fascia remains to be divided. To avoid the peritoneum, the deeper part of the incisions sh always be made from behind forward. If more room is required, as in large growths c exploration of the ureter, the incision must be prolonged beyond the iliac crest, the lumbo inguinal incision of Morris.

Viscera.—Several of these, which can be mapped in behind—viz., the kidn spleen, etc.—have been already mentioned (pp. 1375, 1380).

The commencement of the **trachea** and **esophagus** has been given in fron corresponding to the sixth cervical vertebra. If examined from behind, the of the corresponding spine would be a little lower down. The **trachea,** ab 12.5 cm. (5 in.) long, descending in the middle line, bifurcates opposite to interval between the third and fourth thoracic spines (or fourth and fifth bodi The **bronchi** enter the lungs at about the level of the fifth thoracic spine, the ri being the shorter, wider, and more horizontal. The **root of the lung** is oppo to the fourth, fifth, and sixth dorsal spines, midway between these and vertebral border of the scapula. The structures in it are the bronchus, pulmon artery, two pulmonary veins, bronchial vessels, lymphatics, and nerves. phrenic nerve is in front, the posterior pulmonary plexus behind. On the r side the superior vena cava is in front, the vena azygos (major) arching over root at the level of the fourth thoracic vertebra. On the *left* side the aorta arc over the root, and the thoracic aorta descends behind it. The **esophagus** 913), about 25 cm. (10 in.) in length, starting in the midline, curves twice to left, at first gradually at the root of the neck; from this point it tends to reg the middle line up to the fifth thoracic vertebra; thence finally turns again, a more markedly to the left, and passes through the diaphragm opposite to tenth, entering the stomach here or at the eleventh thoracic vertebra (ninth tenth thoracic spine). In the thorax this tube traverses first the superior, t the posterior, mediastinum. At three points, i.e., its commencement, where i crossed by the left bronchus, and at the cardiac orifice, it presents narrowi The relations of this tube to the pleura, pericardium, aorta, vagi, and thor duct are important in the ulceration of malignant disease and infected bod and in the passage of instruments.

The **aorta** reaches the left side of the vertebral column, with its arch just ab the fourth thoracic spine, and thence descends on the front of the column, wit slight tendency to the left, to bifurcate opposite the fourth lumbar spine.

The spinal cord.—This, about 45 cm. (18 in.) long, extends from the foran magnum to the junction between the first and second lumbar vertebræ. Up the third month of fetal life it reaches to the sacral end of the vertebral car later, owing to the more rapid growth of the bony wall, its lower limit is at bi opposite the third lumbar vertebra (cf. figs. 43–48). The dura mater is continu as a sheath over the subdural space, as low as the second sacral vertebra (f 748, 749). It is anchored above to the upper cervical vertebra and the foran magnum, and below, as the filum terminale, to the periosteum of the cocc The deficiency of the spinous processes and lamina of the fourth and fifth pie of the sacrum (hiatus sacralis) allows of infection, e.g., of a bed-sore reach the membranes, and so the cord. Solutions for local anesthesia may be injec through the hiatus into the spaces around the roots of the sacral nerves.

The parts of the spinal column most exposed to injury are the thoracolumbar and cervicothora partly because here more mobile parts are joined to those which are more fixed, and also fi the amount of leverage exerted on the thoracolumbar region; and, in the case of the up region, because this is affected by violence exerted on the head. *The chief provisions for p tection of the cord* are the number of bones and joints which allow of movement without ser weakening, the three curves and columns, cervical, thoracic, and lumbar, ensuring bend before breaking; the large amount of cancellous tissue and the number and structure of intervertebral disks all tending to damp vibrations; the large size of the dural sheath and way in which the cord, anchored and slung by the thirty-one pairs of nerves and the ligame denticulata, about twenty in number, occupies neutral ground in the center of the canal regards injury directly and indirectly applied (figs. 758, 759).

In **lumbar puncture** (Quincke) as a means of diagnosis or of relieving pressure advantage is taken of the fact mentioned above that the dural sheath extends below the cord. The relations are also important in injections for local (spinal) anesthesia.

A line drawn joining the highest points of the iliac crests crosses the fourth lumbar spine. The needle is inserted in the median line between the third and fourth or the fourth and fifth spines, and directed forward and slightly upward. The back must be flexed as fully as possible in order to widen the interspinous spaces. The needle is passed to a depth of about 5 cm. (2 in.) in an adult, or 1.8 cm. (¾ in.) in an infant. In the supine position the lowest part of the subarachnoid space is in the midthoracic region, and an anesthetic fluid, non-diffusible and of a higher specific gravity than the cerebrospinal fluid, will tend to gravitate there (Barker). The level of the anesthesia can be varied by raising the pelvis or the shoulders to different levels.

The following table, from Holden and Windle, with additions, will be found very useful in determining the relation of numerous viscera and other structures to the bodies of the vertebræ.

STRUCTURES AT LEVELS OF THE VERTEBRAL BODIES

Cervical

First. Level of hard palate.

Second. Level of free edge of upper teeth.

Second and third. Superior cervical ganglion of sympathetic.

Fourth. Hyoid bone. Upper aperture of larynx.

Fifth. Thyroid cartilage and rima glottidis. Between this and the last would be the bifurcation of the common carotid.

Sixth. Cricoid cartilage. Ending of pharynx and larynx. Consisting of the fused fifth and sixth ganglia, the middle cervical ganglion is usually opposite this vertebra. Here the omohyoid crosses the common carotid, and at this spot, the seat of election, the center of the incision for tying this vessel is placed. At this level the inferior thyroid passes behind the carotid trunk.

Seventh. Inferior cervical ganglion. Apex of lung. Arch of thoracic duct over apex of lung, outward and downward to termination.

Thoracic

First. Summit of arch of subclavian. (Godlee.) The height of this varies. Usually it is from 1.2 to 2.5 cm. (½ to 1 in.) above the clavicle. It is always in close relation with the cervical pleura.

Second. Level of episternal notch. This is usually opposite the disk between the second and third. Bifurcation of innominate. (Godlee.)

Third. Beginning of superior cava, at junction of first right costal cartilage with sternum. Highest part of aortic arch, about 2.5 cm. (1 in.) below notch.

Fourth. Bifurcation of trachea. Second piece of aortic arch, extending from upper border of second right costal cartilage, reaches spine. Arch of vena azygos. The superior mediastinum is bounded behind by the upper four thoracic vertebræ. Louis' angle, junction of manubrium and body of sternum. Thoracic aorta begins.

Fifth to ninth. Base of heart.

Sixth. Pulmonary and aortic valves, opposite third left costal cartilage at its sternal junction, in front. Commencement of aorta and pulmonary artery. End of superior cava, third right chondrosternal junction in front.

Seventh. Mitral orifice.

Eighth. Tricuspid orifice.

Ninth. Lower level of body of sternum and sternoxiphoid line (at lower border) Opening in diaphragm for inferior vena cava (lower border).

Tenth. Level of tip of xiphoid cartilage. Lower limit of lung posteriorly. Upper limit of liver comes to the surface posteriorly. Esophagus passes through diaphragm. Cardiac orifice of stomach (sometimes). Upper limit of spleen.

Eleventh. Lower border of spleen. Suprarenal gland. Cardia (sometimes).

Twelfth. Lowest part of pleura. Aorta passes through diaphragm (lower border). Celiac artery (lower border). Upper end of kidney.

Lumbar

First. Superior mesenteric arteries. Pancreas. Pelvis of kidney. Renal arteries. Transpyloric line (Addison.)

Second. Spinal cord ends at junction of first and second. Duodenojejunal flexure. Cisterna (receptaculum) chyli. Lower end of left kidney.

Third. Umbilicus, opposite disk between third and fourth. Lower end of right kidney.

Fourth. Bifurcation of aortic arch. Highest part of iliac crest.

Fifth. Commencement of superior vena cava.

Sacral

Second. End of sigmoid colon and beginning of first piece of rectum proper. Lower limit of dural sheath and subdural space.

Fifth. Reflection of rectovesical pouch of peritoneum 2.5 cm. (1 in.) above base of prostate.

Coccyx (tip). 2.5 cm. (1 in.) below this commencement of anal canal. Termination of filum terminale.

THE UPPER EXTREMITY

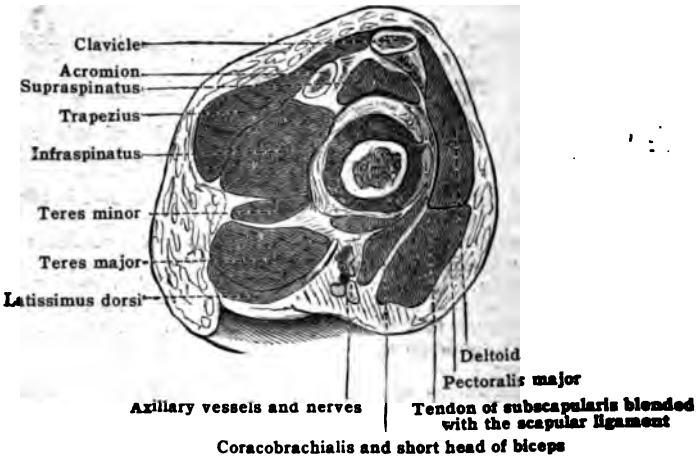
The surface form and landmarks of the upper extremity will first be consider followed by the various regions of the shoulder, arm, forearm and hand.

THE SHOULDER AND ARM

General surface form. Landmarks.—The following surface marks, of greatest importance in determining the nature of shoulder injuries, can be ma out here:—The **clavicle** in its whole extent, the **acromion process,** the gr **tuberosity,** and **upper part of the shaft of the humerus.** Much less distinct the position of the **coracoid process** in the infraclavicular fossa and the **head the humerus** through the axilla can be made out. The **anterior margin** of t **clavicle,** convex medially and concave laterally, can be **made out** in its wh extent, the bone, if traced laterally, being found not to be **horizontal,** but risi somewhat to its junction with the acromion. The **sterno- and acromioclavic lar joints** have been referred to on p. 1363.

The *frequency of fracture of the clavicle* is explained chiefly by its exposure to shocks of var kinds from the upper extremity, inseparable from the out-rigger-like action of the bone and early ossification. On the other hand, *the main safeguards* are the elasticity and curves of bone, the way in which it is embedded in muscles which will damp vibrations, and the buff

FIG. 1116.—TRANSVERSE SECTION THROUGH THE RIGHT SHOULDER-JOINT, SHOWING THE STRUCTURES IN CONTACT WITH IT. (Braune.)



bond articular disks at either extremity. The looseness and toughness of the overlying s explain the rarity of compound fracture here. The junction of the two curves is the weak spot and the usual site of fracture. The weight of the limb acting through the coracoclavicu ligaments and overcoming the trapezius is the chief factor in the downward displacement: t pectoralis minor and serratus anterior acting on the scapula draw the acromial fragment f ward. The tip of the *acromion*, when the arm hangs by the side with hand supinated, is the same line as the lateral condyle and the styloid process of the radius. On the medial s the head and medial condyle of the humerus and the styloid process of the ulna are in the sa line. Thus the *great tuberosity* looks laterally, the *head* medially, and the *lesser tuberosity* son what forward. Between the two tuberosities runs the intertubercular (bicipital) groove, whi with the arm in the above position, looks directly forward. In thin subjects its lower p can be defined. Its position can be marked with sufficient accuracy by a line running dow ward from the acromion in the long axis of the humerus. Besides the tendon and its synov sheath, the insertion of the latissimus dorsi, the humeral branch of the thoracoacromial arte and the anterior circumflex artery run in the groove. When the fingers are placed on the ac mion and the thumb in the axilla, the lower edge of the glenoid cavity can be felt; and if t humerus be rotated (the elbow-joint being flexed), the head of the humerus can be felt also.

The characteristic roundness of the shoulder is due to the great tuberosi lying under the deltoid (figs. 1117, 1118). In dislocation the loss of this roun ness is due to the absence of the head and tuberosity and consequent projecti of the acromion.

This normal projection of the deltoid renders it impossible to place a flat straight body contact with both the acromion and the lateral epicondyle at the same time (Hamilton's d

location test). Below the junction of the lateral and middle thirds of the clavicle, between the contiguous origins of the pectoralis major and deltoid, is the *infraclavicular fossa*, in which lie the cephalic vein, the deltoid branch of the thoracoacromial artery, and a lymphatic node which may be involved in obstinate tuberculosis of the cervical groups. On pressing deeply here, the coracoid process can be made out if the muscles are relaxed, and the axillary artery compressed against the second rib.

On raising the arm and abducting it, the different parts of the **deltoid** can often be made out —viz., fibers from the lower border of the spine of the scapula, the lateral edge of the acromion, and the lateral third or more of the front of the clavicle; the characteristic knitting of the surface

FIG. 1117.—ADULT SHOULDER-JOINT, AS SHOWN BY THE RÖNTGEN-RAYS. (Cf. fig. 216.)

owingl to the presence of fibrous septa continuous, alike, with the skin and the sheath of the muscle and the tendinous septa which separate the muscular bundles, will also be seen. The musce will be marked out by a base-line reaching along the above bony points, and two sides converging from its extremities to the apex, a point on the lateral surface of the humerus, about its center. In paralysis of the deltoid, the humerus being no longer braced up against the scapula, the finger-tips can be placed between it and the acromion.

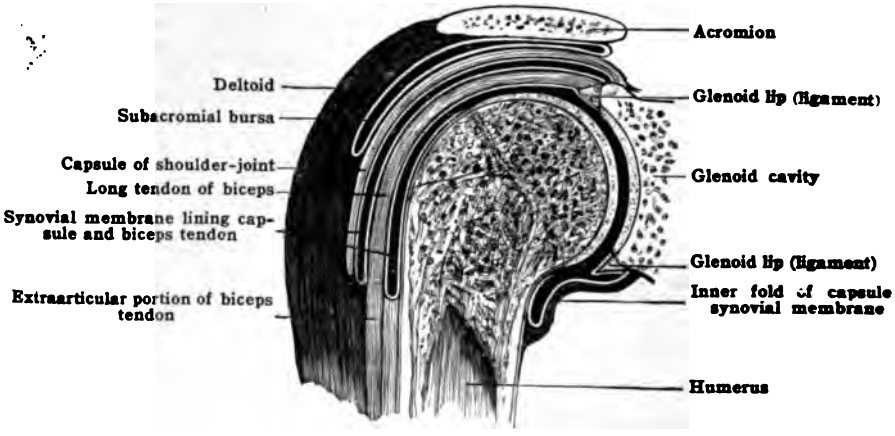
To map out the **pectoralis major,** a line should be drawn down the lateral aspect of the sternum as far as the sixth costal cartilage, and then two others marking the borders of the muscle—the upper corresponding to the medial border of the deltoid, the lower starting from the sixth cartilage, and the two converging to the folded tendon, which is inserted as a double layer into the lateral tubercular (bicipital) ridge. The **pectoralis minor** will be marked out by two lines, from the upper border of the third and the lower border of the fifth rib, just lateral to their cartilages, and meeting at the coracoid process. The lower line gives the level of the long thoracic artery; the upper, where it meets the line of the axillary artery, that of the thoracoacromial.

When the arm is abducted and the humerus rotated a little laterally, the prominence o well-developed **coracobrachialis** comes into view; a line drawn from the center of the clavi along the medial border of this muscle to its insertion into the humerus gives the line of t axillary artery.

Axillary fossa.—The boundaries of this space anterior, posterior, medial, thoracic, lateral or humeral, apex and base, with the structures forming them a the vessels and nerves in relation to them, must be remembered (see p. 405 a fig. 1116). The chief vessels are the axillary on the lateral wall, brought in prominence when the arm is abducted, as in removal of the mamma, and t subscapular on the posterior wall. The apex is felt, when the finger is push upward in an operation here, to be bounded by the clavicle in front, the first r behind, and the coracoid somewhat laterally. The base is concave, owing the coracoclavicular (costocoracoid) membrane as it descends to blend with t sheath of the pectoralis minor, giving also a process to the axillary fascia whi unites the anterior and posterior boundaries. This process also sends septa the skin.

An **axillary abscess,** always to be opened early to avoid subsequent interference with t movements of the shoulder, is reached by an incision on the medial wall, midway between t anterior and posterior boundaries, so as to avoid the long thoracic and subscapular vesse respectively, the back of the knife being directed toward the lateral wall. The only vessel this wall is the superior thoracic, which lies high up. Additional safety is given by the use Hilton's method. For **exploration** of the axilla the best incision is an angular one, the t

FIG. 1118.—DIAGRAMMATIC SECTION OF SHOULDER THROUGH THE INTERTUBERCULAR (BICI TAL) GROOVE. (Anderson.)



limbs being placed in a line with the anterior margin of the great pectoral, and in the line the axillary vessels. This runs from a point on the center of the clavicle (the limb being at right angle to the trunk) to the medial margin of the coracobrachialis. If this be obliterat by swelling, the above line should be prolonged to the middle of the bend of the elbow, whi will give the guide to the brachial also. **Collateral circulation.** If the first part of the arte be tied, the channels are the same as in ligature of the third part of the subclavian (*q.v.*). ligature of the third part of the axillary, if the ligature be *above* the circumflex arteries, the chi vessels concerned are the transverse scapular (suprascapular) and thoracoacromial above a the posterior circumflex below. If the ligature be *below* the circumflex, the anastomoses will those concerned in ligature of the brachial above the profunda (p. 1415). The lymphat nodes in the axilla have been mentioned at p. 753 (fig. 605).

The depression of the **axillary fossa** is best marked when the arm is raised from the s to an angle of about 45°, and when the muscles bounding it in front and behind are contracte In proportion as the arm is raised, the hollow becomes less, the head of the humerus now pr jecting into it. When the folds are relaxed by bringing the arm to the side, the fingers can pushed into the space so as to examine it.

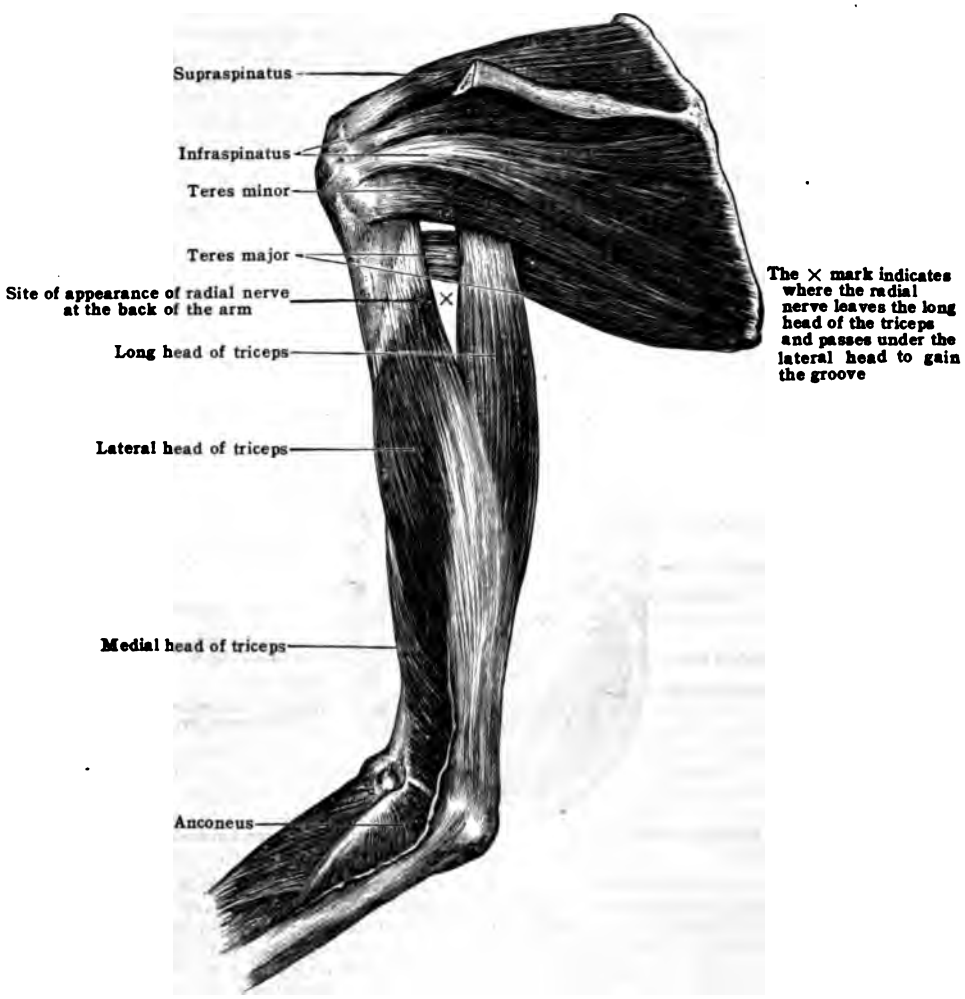
The axillary (circumflex) nerve and posterior circumflex vessels wind around the humer under the deltoid; a line drawn at a right angle to the humerus and a little above the cent of this muscle marks their position on the surface.

To trace the **synovial membrane of the shoulder-joint is a comparative** simple matter (fig. 1118). Covering both aspects of the free edge of the glenoi ligament, it lines the inner aspect of the capsule, whereby it reaches the articul margin of the head of the humerus; there is a distinct reflection, below, from t capsule on to the humeral neck before the rim of the cartilage is reached.

An extensive protrusion of synovial membrane takes place in the form of a synovial bursa, at the medial and anterior part of the capsule, near the root of the coracoid process under the tendon of the subscapularis. Another protrusion takes place between the two tuberosities along the intertubercular groove, as low as the insertion of the pectoralis major. A third synovial protrusion may be seen, but not frequently, at the lateral or posterior aspect, in the form of a bursa, under the infraspinatus tendon. Thus the continuity of the capsule is interrupted by **two** and **sometimes three synovial protrusions.**

A large bursa is found beneath the deltoid which is continuous above with the subacromial bursa (fig. 1118). The subdeltoid bursa does not communicate with the shoulder-joint. It frequently becomes inflamed. When inflamed it may seriously interfere with movement of the shoulder joint. It may even become calcified, giving an *X*-ray shadow lateral to the head of the humerus.

FIG. 1119.—POSTERIOR VIEW OF THE SCAPULAR MUSCLES AND TRICEPS.

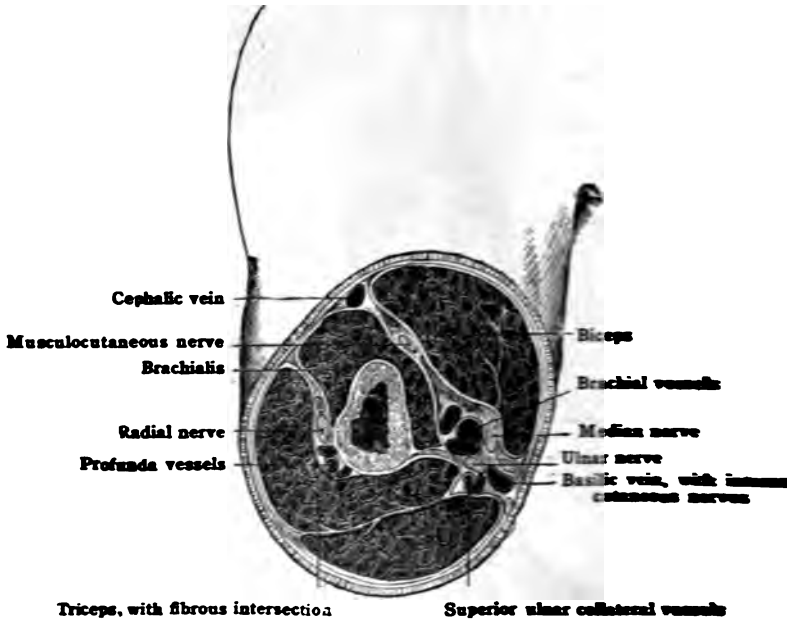

Supraspinatus
Infraspinatus
Teres minor
Teres major
Site of appearance of radial nerve at the back of the arm
Long head of triceps
Lateral head of triceps
Medial head of triceps
Anconeus
The × mark indicates where the radial nerve leaves the long head of the triceps and passes under the lateral head to gain the groove

Shoulder-joint.—The frequency of **dislocations** here calls attention to the points contributing to make the joint alike insecure and safe. **Strength** is given by (1) the intimate blending of the short scapular muscles, especially the subscapularis with the capsule; (2) the coracoacromial vault; (3) atmospheric pressure; (4) the long tendon of the biceps; (5) the elasticity of the clavicle; (6) the mobility of the scapula. The **weakness of the joint** is readily explained by its free mobility, the want of correspondence between the articular surfaces, its exposure to injury, and the length of the humeral lever.

The rent in the capsule is usually anterior and below, and to this spot the head of the humerus must be made to return. While dislocations are usually primarily subglenoid, owing to the above part of the capsule being the thinnest and least protected, they take usually a secondarily forward direction, as the triceps prevents the head passing backward. The coracohumeral ligament usually remains intact and is used in manipulations to reduce the disloca-

triceps and brachialis (anterior), and the lateral one giving origin to the [illegible] nator longus) and extensor carpi radialis longus as well. The medial extends up to of the coracobrachialis, the lateral to that of the deltoid. The lateral septum s the anterior part of the profunda vessels and the radial (musculospiral nerve. The superior and posterior branch of the inferior ulnar collateral (anastomotica magna the ulnar nerve.

FIG. 1120.—CROSS-SECTION THROUGH THE MIDDLE OF THE RIGHT ARM



The **biceps** has a twofold attachment above and below. The former is of much in steadying the various movements, especially the upward one, and in harmonizing taneous flexion and extension of the shoulder- and elbow-joints. (Cleland. T fibrosus curving downward and medially with its semilunar edge upward, across th

A line drawn along the medial edge of the biceps from the insertion of the teres major to the middle of the bend of the elbow corresponds to the **brachial artery.** In the upper two-thirds, this artery can be compressed against the bone by pressure laterally; in its lower third the humerus is behind it, and pressure should be made backward. The presence of the median nerve will interfere with any prolonged digital pressure applied in the middle of the arm.

In **ligature of the artery** here the line extends from the midaxillary region above, prolonged to the center of the front of the elbow. The only structures seen should be the medial edge of the biceps, the basilic vein, and the median nerve. The profunda comes off 2.5 cm. (1 in.) below the teres major, having the same relation to the heads of the triceps; thus, it first lies on the long head, behind the axillary and brachial arteries, then between the long and medial heads, and next, in the groove, between the medial and lateral heads, and courses with the radial (musculospiral) nerve (fig. 1120); the nutrient artery arises opposite the middle of the humerus; in many cases it arises, on the back of the arm, from the profunda; the superior ulnar collateral (inferior profunda) below the middle, and courses with the ulnar nerve through the intermuscular septum to the back of the medial condyle. The inferior ulnar collateral (anastomotica magna) is given off from 2.5 to 5 cm. (1 to 2 in.) above the bend of the elbow. Fig. 1126 will show the **collateral circulation** after ligature of the brachial, according as the vessel is tied above or below the superior profunda, or below the superior ulnar collateral.

The **center of the arm** is a landmark for many anatomical structures. On the lateral side is the insertion of the deltoid; on the medial, that of the coracobrachialis. The basilic vein and the medial brachial cutaneous nerve (nerve of Wrisberg) here perforate the deep fascia, going in reverse directions. The superior ulnar collateral is here given off from the brachial and joins the ulnar nerve; the median nerve also crosses the artery, and the ulnar nerve leaves the medial side of the vessel to pass to the medial aspect of the limb.

FIG. 1121.—CROSS-SECTION THROUGH THE ELBOW. (× 1/2). (After Braune.)

The **brachialis** can be mapped out by two pointed processes which surround the insertion of the deltoid, pass downward into lines corresponding to the two intermuscular septa, and then converge over the front of the elbow to their insertion into the coronoid process.

The **median nerve** (lateral head, 5th, 6th, 7th C.; medial head, 8th C. and 1st T.) can be traced by a line drawn from the lateral side of the third part of the axillary and first part of the brachial artery, across this latter vessel about its center, and then along its medial border to the forearm, where it passes between the two heads of the pronator teres.

The **ulnar nerve** (8th C. and 1st T.) lies to the medial side of the above arteries as far as the middle of the arm, where it leaves the brachial to course more medially and perforate the medial intermuscular septum together with the superior and posterior branch of the inferior ulnar collateral and so get to the back of the medial condyle. A line drawn from the medial border of the coracobrachialis, where, in the upper part of its course, the nerve is in close relation with the medial side of the axillary and brachial arteries, to the back of the medial condyle, will indicate its course. Low down, the nerve is in the medial head of the triceps, and may be injured in operations here.

The **radial (musculospiral) nerve** (5th, 6th, 7th, and 8th C.) can be traced by a line beginning behind the third part of the axillary artery, then carried vertically down behind the uppermost part of the brachial, and then, just below the posterior border of the axilla, curving backward behind the humerus and slightly downward just below the insertion of the deltoid. Thus, passing from laterally and from before backward in its groove, accompanied by the profunda vessels, first the trunk, and then the smaller anterior division, it again comes to the front by perforating the lateral intermuscular septum at a point about opposite to the junction of the middle and lower thirds of the arm, and passes down in front of the lateral supracondyloid ridge, lying here between the brachioradialis and brachialis anterior, to the level of the lateral condyle, in front of which it divides into the superficial (radial) and deep (posterior interosseous) radials. The former of these accompanies the radial artery to the front of the forearm, the latter travels backward to the back of the forearm. A line from the lateral condyle to the insertion of the deltoid indicates the lateral intermuscular septum.

In addition to injuries caused by fracture, the nerve may be injured in crutch pressure, the sleep of intoxication, use of an Esmarch's bandage, or the careless reduction of a dislocated shoulder with the foot in the axilla. To expose the nerve the incision begins below, over the

lateral intermuscular septum, where it lies between the brachioradialis and brachialis anterior. Hence the incision is prolonged freely upward and backward toward the posterior border of the deltoid.

On the back of the arm is the **triceps muscle** (figs. 1119, 1120), with its three heads and tendon of insertion, all brought into relief in a muscular subject when the forearm is strongly extended. Of the three heads, the medial is the least distinct, arising below the groove (musculospiral) for the radial (musculospiral) nerve, reaching to each intermuscular septum, and tapering away above as high

FIG. 1122.—THE ELBOW-JOINT, AS SHOWN BY THE RÖNTGEN-RAYS. (Epiphyses visible

as the teres major. Most of the fibers of this head lie deeply. The lateral head, arising above the groove as high as the great tuberosity, appears in strong relief just below the deltoid; while the middle or long head, arising from the scapula just below the glenoid cavity, appears between the teres muscles. The tendon of insertion, passing into the upper and back part of the olecranon over a deep bursa, is shown by a somewhat depressed area. On the lateral side, an important expansion to the fascia over the anconeus is given off.

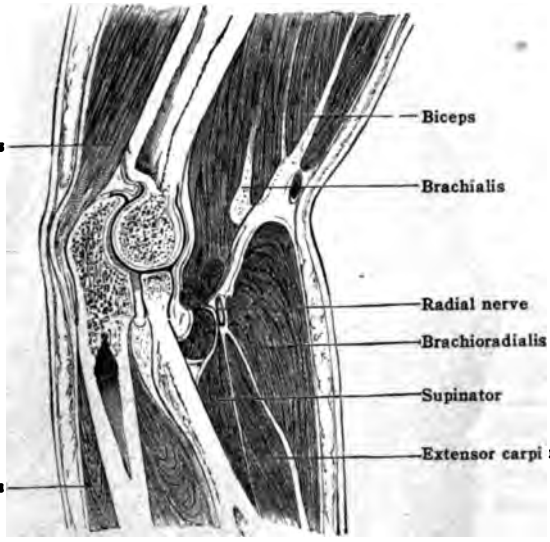
In the ossification of the humerus the epiphyses are of first importance. The upper, consisting of those for the head and two tuberosities, which form one about the seventh year, blends with the shaft between the twentieth and twenty-fifth years. Separation usually takes place at an earlier date, this being explained by the fact that the cone-like arrangement by which the diaphysis fits into the cap of the epiphysis becomes more marked toward the date of union and thus tends to prevent displacement. Thomson. The lower epiphysis (figs. 223, 1122). The condition of this varies with the degree of coalescence of its four centers. The first and chief, that for the capitulum, second or third year, unites with those for the trochlea and lateral epicondyle soon after puberty, and forms an epiphysis which joins with the shaft at about sixteen. The epiphysis for the medial epicondyle appears at the fifth year and unites with the

shaft at the eighteenth. Injury to this epiphysis may damage the ulnar nerve and open the elbow-joint. Thus, at and after puberty, there are two chief epiphyses to remember here:—(*a*) the larger, consisting of capitular, trochlear, and lateral epicondyle centers. This is almost entirely intra-articular; (*b*) the smaller, that for the medial epicondyle; the extent to which this is intra-articular varies. The structures that would be divided in **an amputation at the center of the arm** are shown in fig. 1120. The chief points needing attention are:—(1) To leave as much of the lever of the humerus as possible; (2) clean section of the large nerves, the radial (musculospiral) in its groove being especially liable to be frayed by the saw; (3) the difference between the amount of retraction of the free biceps in front, and the triceps behind, fixed to the bone and septa.

THE ELBOW

The **bony points,** epicondyles, olecranon, and head of radius, and their relation to one another, should be carefully studied. The *medial epicondyle* is the more prominent of the two, is directed backward as well as medially, and lies a

FIG. 1123.—LONGITUDINAL SECTION OF THE ELBOW-JOINT. (× ½). (Braune.)

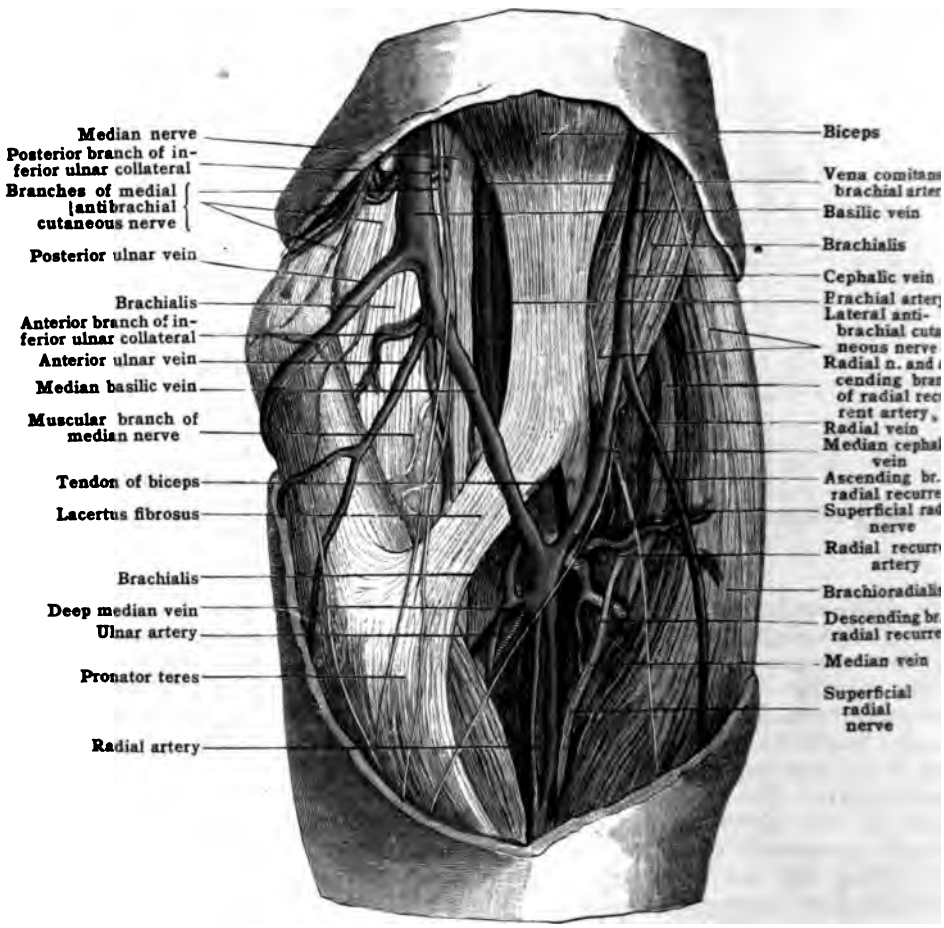


little above its fellow. Above it can be traced upward the supracondyloid ridge and corresponding intermuscular septum. The *lateral epicondyle* is more rounded, and thus less prominent; below, and a little behind it, the *head of the radius* can be felt moving under the capitulum when the forearm is supinated and flexed. A depression marks this spot and corresponds to the interval between the anconeus and brachioradialis and extensor carpi radialis longus; at the back, the upper part of the *olecranon* is covered by the triceps. The lower part is subcutaneous, and separated from the skin by a bursa. If the thumb and second finger be placed on the epicondyles and the index on the tip of the olecranon, and the forearm completely extended, the tip of the olecranon rises so as to be on the line joining the two epicondyles. In flexion at a right angle, the olecranon is below the line of the epicondyles, and in complete flexion quite in front of them. Between the medial epicondyle and olecranon is a pit, in which lie the ulnar nerve and the anastomosis between the inferior ulnar collateral and the posterior ulnar recurrent arteries. The coronoid process is so well covered by muscles, vessels, and nerves that its position cannot be distinctly made out.

The synovial membrane of the elbow-joint communicates with that of the superior radio-ulnar. Hence the facility with which tuberculous disease may be set up after neglected falls on the hand, in early life. At this time the weakness of the annular (orbicular) ligament leads to its being easily injured. Swelling, due to effusion into the joint, appears on either side of the triceps tendon, and soon obliterates the depression below the lateral epicondyle. The simplest incision of an infected elbow-joint is a vertical one, on the lateral side of the olecranon. A superficial swelling over the tip of the olecranon is due to effusion into the subcutaneous bursa (miner's elbow). A deeper, less easily defined swelling in the same region is due to inflammation of the bursa between the olecranon and the triceps. A swelling on the medial side of the elbow-joint, if painful and accompanied by inflammation of the skin, may be due to mischief in the **epitrochlear lymphatic node** situated just above the medial epicondyle, and receiving lymphatics from the medial border of the forearm and the two medial fingers.

The hollow in front of the elbow (figs. 1124, 1125, 1127).—The delicacy of the skin here n always be borne in mind in the application of splints. Owing to the insidious rapidity v which pressure may set up ischemic paralysis, anterior angular splints are always to be u with caution. The **M-like arrangement of the superficial veins as usually described** is by means constant (figs. 567, 1124). The median basilic is the vein usually chosen for venesect and for intravenous injections, owing to its larger size and its being firmly supported by subjacent bicipital fascia (lacertus fibrosus) which separates it from the brachial artery; but median cephalic is the safer. The median basilic is crossed by branches of the medial a brachial (internal) cutaneous nerve, while those of the musculocutaneous lie under the me cephalic. In the semiflexed position, the fold of the elbow is seen, a little above the l of the joint. This forms the base of the *triangular cubital fossa* below the elbow, the lat side corresponding to the brachioradialis, the medial to the pronator teres, and the apex to meeting of these muscles. The tendon of the biceps can be easily made out in the center of fossa, giving off the lacertus fibrosus above from its medial side to fasten down the flexors of

FIG. 1124.—THE BEND OF THE ELBOW WITH THE SUPERFICIAL VEINS.
(From a dissection by Dr. ALDER SMITH in the Museum of St. Bartholomew's Hospital.



forearm. Under the tendon on its medial side lie the **brachial artery and the median nerv** little medial to it, for a short distance. The radial nerve (**musculospiral**) **lies outside the fos** between the brachioradialis and the brachialis (anterior), and **gives off its two terminal branc** in front of the lateral epicondyle. The brachial usually bifurcates **opposite to the neck of** radius.

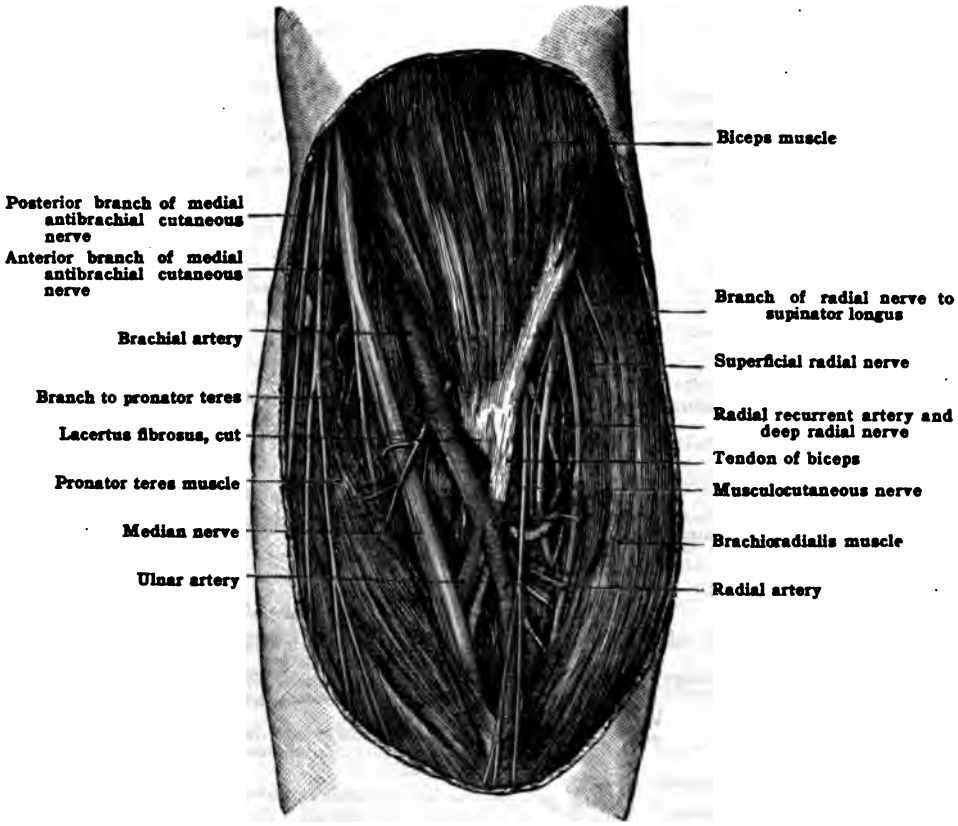
The **arterial anastomoses about the elbow-joint** (fig. 1126) are as follows: **The radial recurr** runs up under cover of the brachioradialis to anastomose with **the anterior branch of the p** funda **on the front of the lateral condyle.** The posterior interosseous **recurrent ascenda, betw** the supinator and the anconeus, to anastomose **on the back of the lateral condyle with the jp** terior branch of the profunda. It further joins, by a large **anastomotic arch across the bac** the joint, with the inferior ulnar collateral (anastomotica **magna**) **and posterior ulnar recurre** The anterior ulnar recurrent passes upward on the brachialis **to join the anterior part of** inferior ulnar collateral under the pronator teres, on the **front of the medial epicondyle.** posterior ulnar recurrent makes for the interval between **the back of the medial epicond** and the olecranon, to join with the superior and the **posterior branch of the inferior ul** collateral.

It will be seen that the inferior ulnar collateral (anastomotica magna) is the artery most largely employed, distributing branches everywhere, save to the front of the lateral epicondyle.

THE FOREARM

Bony landmarks.—The *posterior border of the ulna* can be easily traced down from the olecranon to the back of the styloid process; the bone becomes somewhat rounded below, and lies between the flexor and extensor carpi ulnaris. The tip of the *styloid process* corresponds to the medial end of the line of the wrist-joint. The *radius* is covered above by the brachioradialis and radial extensors of the carpus, and the outline of the bone is less easily followed. Its *styloid process* is readily made out below a finger's breadth above the thenar eminence. It is placed about 1.2 cm. (½ in.) lower than that of the styloid process of the ulna.

FIG. 1125.—THE BRACHIAL ARTERY AT THE BEND OF THE ELBOW.
(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)



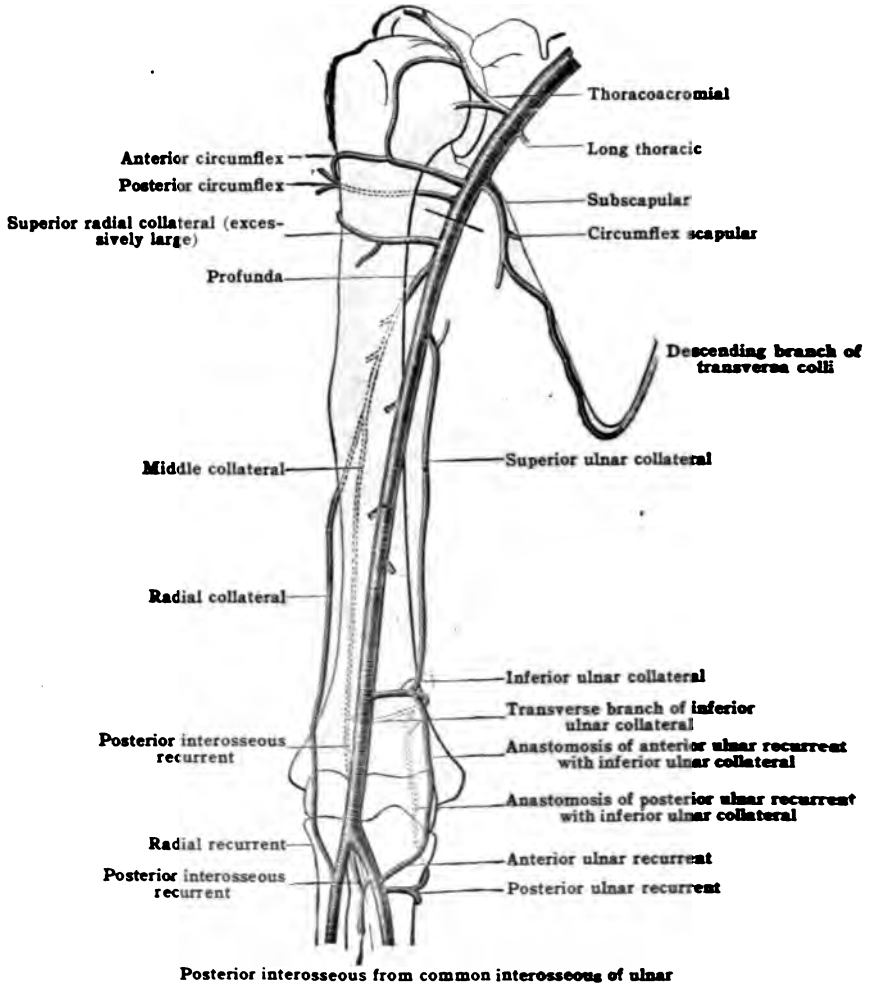
Thus, a line drawn straight between the two processes would fall a little below that of the wrist-joint, this being shown by a line drawn between the two processes forming a slight curve, with its concavity downward (corresponding to the concavity of the lower surface of the radius and fibrocartilage) about 1.2 cm. (½ in.) above the straight line given above

The radial styloid process is covered by the abductor longus and extensor brevis pollicis, while farther out lies the extensor pollicis longus. Between the styloid process of the ulna and the rounded head is the groove for the extensor carpi ulnaris. The bones are nearest to each other in complete pronation, and farthest apart in complete supination. On section (fig. 1129), the bones are found at every point nearer to the back than to the front of the limb, but increasingly so above. The lower the section proceeds down the limb, the less will the bones be covered at the sides, and the more equally will the soft parts be distributed about the anterior and posterior aspects of the limb. It will be noticed that where one bone is the more substantial, the other is the more slender, as near the elbow and wrist; and that it is about the center of the limb that the two are most nearly of equal strength. (Treves.) When the limb is pronated, the interosseous space is narrowed; in supination and the midposition it is widened out. In pronation, both styloid processes can be distinctly made out; in supination, that of the radius is the more distinct, as now the skin and soft parts are stretched and raised over that of the ulna.

Joints.—The position of the **superior radioulnar joint** is marked by a dim about 12 mm. (½ in.) below the lateral epicondyle. The **inferior** can just be f when the forearm is pronated, between the head of the ulna and lower end of radius. The recessus sacciformis here may be enlarged in rheumatic and ot affections. The **interosseous membrane** not only ties the bones together : gives attachment to muscles, but in falls on the hand it enables the ulna to part pate in the shock.

The following are important points with regard to the bones. *Common fractures. cranon.*—This usually takes place at the constricted center of the semilunar (greater sigm notch or the junction of the olecranon with the shaft. A fall is here the usual cause,

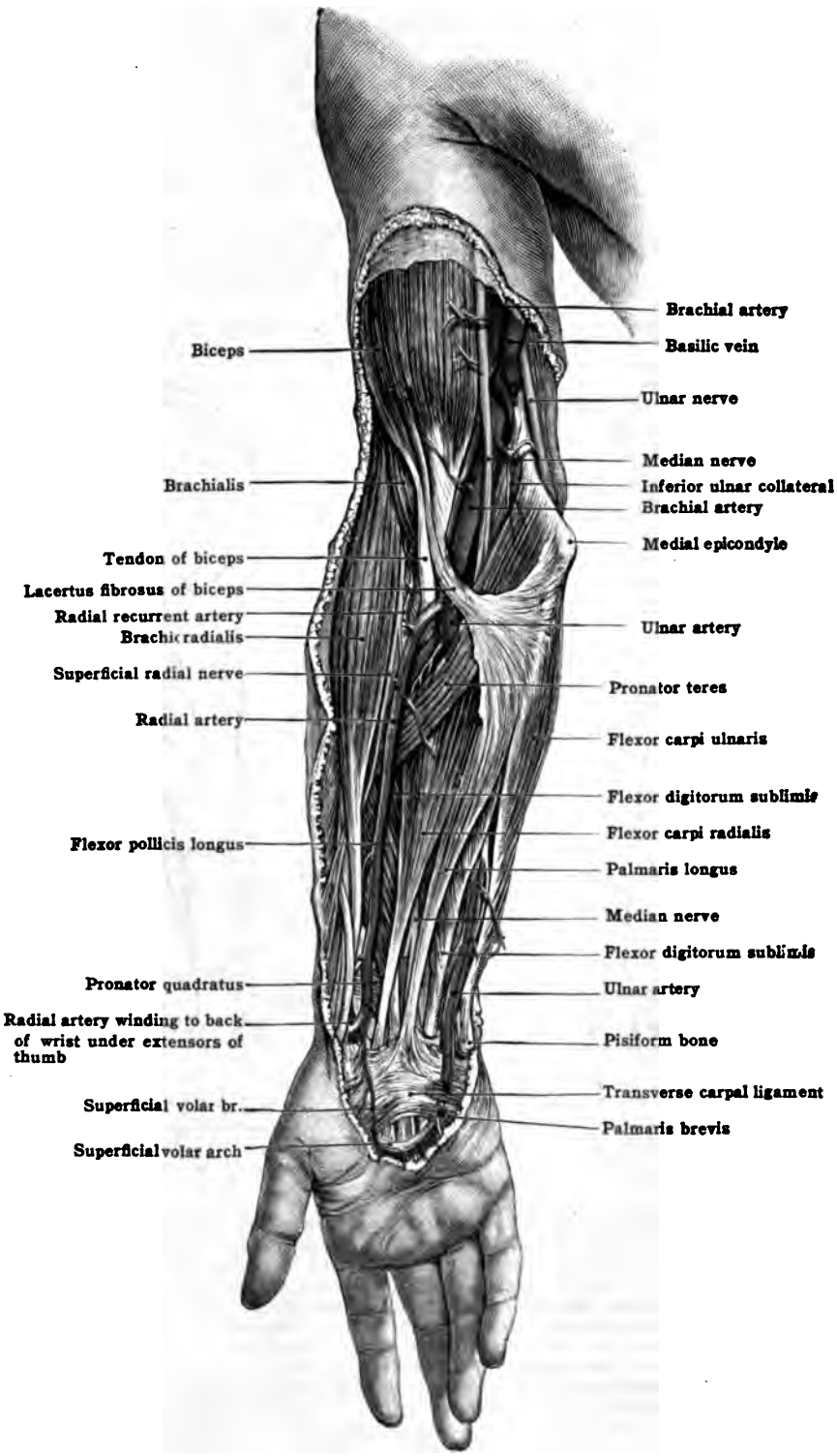
FIG. 1126.—DIAGRAM OF THE ANASTOMOSES OF THE BRACHIAL ARTERY. (MacCormac and Anderson.)



Posterior interosseous from common interosseous of ulnar

the heavier the fall, the more frequently is the fracture nearer the shaft, though displacem is now likely to be slight, owing to the abundance of fibrous and muscular structures on b sides of the fracture. *The shaft of one or both bones.* Usual site, about the middle or a li below it, fracture of the radius being more frequent from its connection with the hand. these fractures the chief muscular agencies are—(1) the extensors and flexors in drawing lower fragment or fragments upward, forward, or backward, according to the direction of fracture; (2) the biceps in drawing the upper fragment of the radius upward; (3) the influe of the pronator teres, if the fracture is, as usual, below it, and (4) that of the quadratus drawing the lower fragments together. Thus the chief practical points are—(a) the reduct of displacement, whether anteroposterior or lateral; (b) the greater the number of fragme the greater the tendency to union across the interosseous space, with its embarrassing resu and the greater the need of a supinated position in the setting; (c) the risk of gangrene h from the facility with which the vessels are compressed against the contiguous bones es cially in flexion of the forearm; and the consequent need of attention to the width of the spli

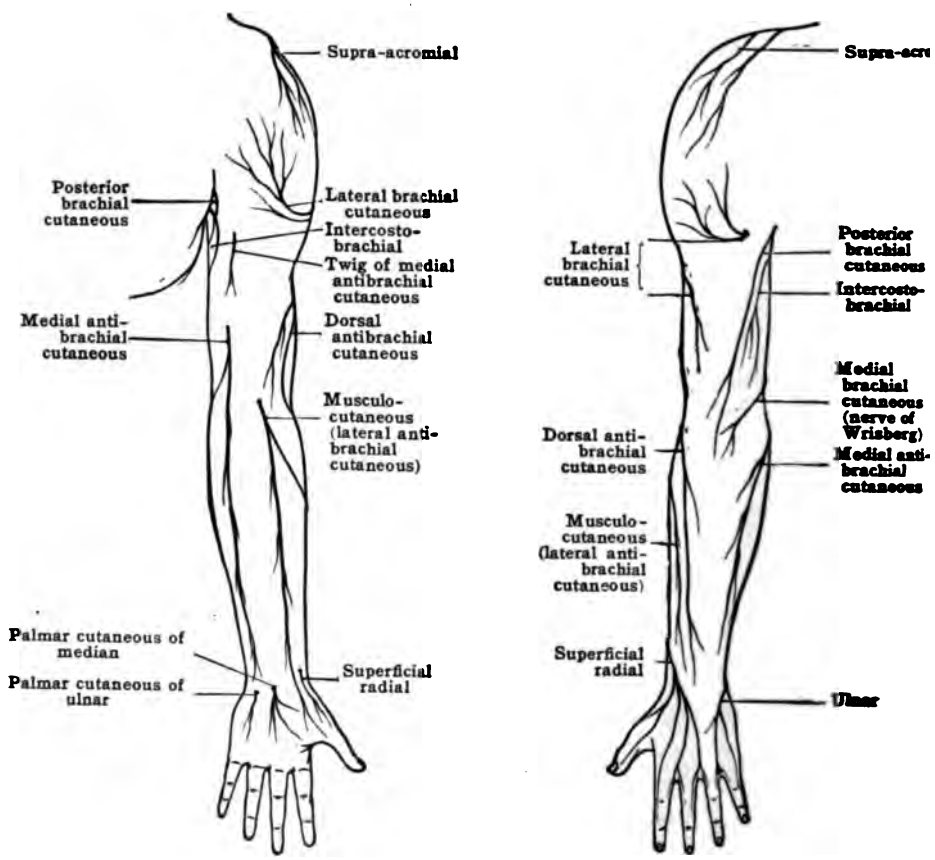
FIG. 1127.—THE MUSCLES AND ARTERIES OF THE FOREARM.



and the bandaging; (*d*) the readiness with which ischemic paralysis may rapidly and i iously be caused. It is a good rule to remember in treating fractures that the long frag which can be controlled should be dressed in line with the short fragment which cann controlled. The origins, insertion and actions of muscles on different fragments shou thoroughly understood if this principle is to be carried out. **Colles' fracture.** Here, a fall on the hand, the radius gives way usually at its weakest part, about 18 mm. (¾in.) its extremity, where the narrow compact tissue is suddenly expanding into cancellous. is frequently impaction of the upper into the lower fragment. There is a three-fold dis ment of the lower fragment:—(1) It is driven and drawn upward and backward. (2) rotated so that its articular surface looks somewhat backward. (3) It is drawn to the r side. The chief causes of the discreditable stiffness often allowed to result are non-redu of the deformity, adhesions in the opened wrist-joint, tenosynovitis, and prolonged i bilization.

Separation of epiphysis.—This may take place in the radius up to about the age of eigh it is commoner before. Its possible importance in interfering with the symmetry of the gr of the bones is obvious. Here, as in Colles' fracture, the level of the styloid processes o

FIG. 1128.—DISTRIBUTION OF CUTANEOUS NERVES ON THE ANTERIOR AND POSTERIOR ASP OF THE SUPERIOR EXTREMITY.



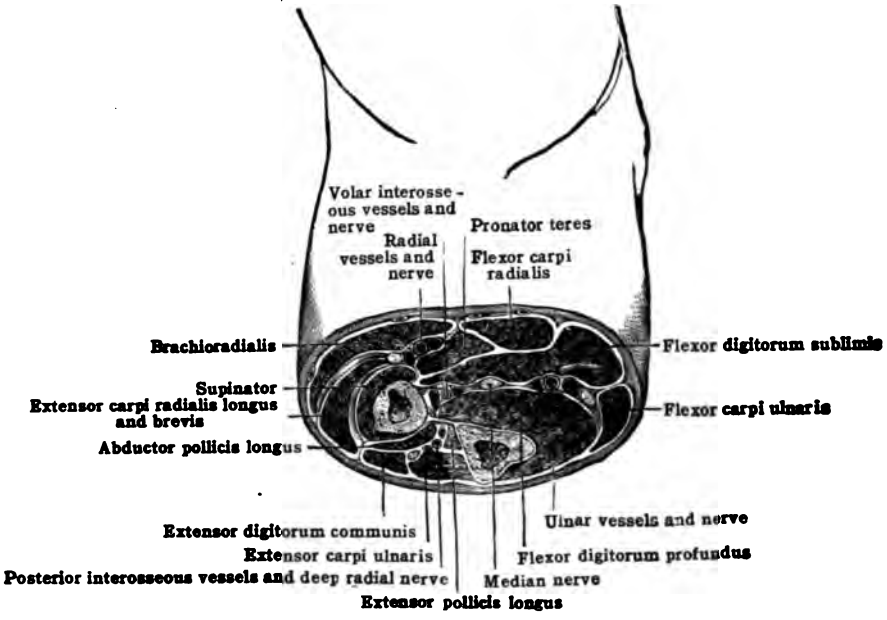
radius and ulna, and the relations of the two styloid processes to each other, are import in diagnosis. **Exposure of the bones.** In the case of ununited fracture or necrosis the ra may be reached—(*a*) *Behind*, by an incision in a line drawn from the lateral epicondyle to back of the radius. The field opened here lies between the brachioradialis and the ra extensors on the one side, and the common extensor on the other. Care must be taken of deep radial (posterior interosseous) nerve. (*b*) *In front.* The incision here lies in the su between the brachioradialis and the flexors. The pronator teres and the flexor sublimis m in part, be detached from the radius. If more room is required to reach an injured up extremity of the radius, the incision will descend from above the lateral epicondyle in the gro between the anconeus and common extensors. In the detachment of the supinator the d radial nerve will again need attention. The ulna is more easily reached by an incision betw the flexor and extensor carpi ulnaris. In removal of the lower part of the bones for mye sarcoma or osteitis, the ulna is reached in the interval last mentioned. The radius is l exposed by an incision between the brachioradialis and extensor carpi radialis longus, the su ficial radial nerve being the guide. (Morris.) Finally, the so-called 'carrying angle' of forearm deserves mention. In extension the bones of the forearm are not in a straight line v the humerus, but directed slightly laterally, the angle at the elbow-joint being obtuse, and o

laterally. This angle is so named from its facilitating carrying objects during walking. In flexion the forearm is deflected somewhat toward the middle line, mouth, etc. These properties are liable to be lost under many and widely different conditions, of which injuries to the epiphyses of the humerus, badly united fractures of the humerus (supracondylar) or forearm, and osteoarthritis of the elbow-joint are instances.

Soft parts (figs. 1127, 1129).—Along the lateral border, of the forearm descend the brachioradialis and radial extensors of the carpus, fleshy above, tendinous below. About 3.7 cm. (1½ in.) above the styloid process of the radius, a fleshy swelling directed obliquely downward and forward from behind, across this lateral border of the forearm, denotes the extensors of the thumb crossing those of the carpus.

Along the medial border is the fleshy mass of the pronator teres and flexors, the ulna being covered by the flexor carpi ulnaris and flexor profundus. The tendon of the pronator is inserted into the radius a little below its center—a point of importance in the treatment of fractures and in amputation. The flexor carpi ulnaris tendon can be felt just above the wrist making for the pisiform bone; and just lateral to it lies the **ulnar artery**, about to pass over the transverse carpal (anterior annular) ligament.

FIG. 1129.—SECTION THROUGH THE MIDDLE OF THE RIGHT FOREARM. (Heath.)



The course of the artery is denoted by the lower two-thirds of a line drawn from the front of the medial epicondyle to the lateral edge of the pisiform bone. From the bifurcation of the brachial, a line drawn to meet the former at the junction of its middle and upper third marks the upper part of the artery, here thickly covered by muscles. In **ligature of the artery** in *the middle* of the forearm, the white line and sulcus between the flexor carpi ulnaris and sublimis must be identified. A small muscular branch will often lead down to the artery. The line of the **ulnar nerve** is one drawn from the interval between the medial epicondyle and the olecranon to the medial side of the ulnar artery just above the wrist. The nerve joins the artery at the junction of the upper and middle thirds of the forearm. The **median nerve** runs in a line drawn from the medial side of the brachial artery, in the elbow triangle, to a point beneath, or just to the medial side of, the palmaris longus at the midpoint of the front of the wrist. The **radial artery** will be marked by a line drawn from the center of the bend of the elbow (where the brachial artery divides opposite the neck of the radius) to a point just medial to the radial styloid process descending along the medial edge of the brachioradialis. The muscular interval is that between the brachioradialis and pronator teres above, and the flexor carpi radialis below. The **superficial radial nerve** will be marked by the same line (it lies just lateral to the artery) for its upper two-thirds; it then leaves the artery about 7.5 cm. (3 in.) above the wrist-joint, and passes to the back of the forearm under the tendon of the brachioradialis. The **volar interosseous artery** runs down on the interosseous membrane and passes to the back of the forearm by perforating it below, having passed behind the pronator quadratus. The **dorsal interosseous** lies between the superficial and deep extensors. These small arteries reinforce the palmar through the carpal arches, and thus bring down blood after ligature of the trunks above.

being produced (see fig. 1130, A). **Sensation** will be lost over the palmar aspect of the thumb and lateral two and one-half fingers and over the distal ends of the same fingers, to a varying degree, according to the sensory distribution of the median and other cutaneous nerves. The above applies to lesions of the trunk. If the nerve be injured at the wrist, flexion of the wrist and fingers is less interfered with.

Paralysis of the ulnar nerve.—(*a*) *At wrist:* Power of flexion is diminished and that of ulnar adduction lost. (*b*) *In the hand:* Power of grasp will be lessened in the ring and little fingers. The interossei will be powerless to abduct or adduct the fingers, and there will be marked wasting of the interosseous spaces and hypothenar eminence. The thumb cannot be adducted. After a time, from paralysis of the lumbricals and interossei, the hand becomes 'clawed'—the first phalanges overextended, and the second and third flexed (**main en griffe**). (See fig. 1130, B.) Sensation will be lessened over the area supplied by the nerve.

Paralysis of the radial (musculospiral) nerve.—(*a*) *In the forearm:* This is flexed, extension being impossible The forearm is pronated, supination being impossible save by biceps, which acts now most strongly on a flexed elbow-joint. (*b*) *In the wrist:* This is dropped, owing to the loss of extension. (*c*) *In the hand:* The thumb is flexed and adducted. Some slight power of extension of the second and third phalanges of the fingers remains by means of the lumbricales and interossei. (See fig. 1130, D.) **Sensation** is impaired over the posterior and lateral aspect of the forearm and lost to a varying extent over the distribution of the radial on the back of the hand.

Paralysis of the deep radial (posterior interosseous) nerve.—The evidence here is somewhat similar to that just given, but with the following differences. (*a*) *In the forearm:* There is no loss of extension, and the loss of supination is less as the brachioradialis is not paralysed. (*b*) *At the wrist:* The 'drop' and loss of extension are not so marked, as the extensor carpi radialis longus escapes. **Sensation:** There is no loss.

Paralysis of the musculocutaneous nerve.—*Forearm:* Power of flexion is impaired, owing to complete paralysis of the biceps and partial of the brachialis (anterior). **Sensation:** This is impaired over the lateral aspect of the forearm, both back and front.

The **lymphatics of the upper extremity** are **superficial** and **deep**; the former run with the superficial veins, the latter with the deep vessels. Occasionally a few small **nodes** occur below the elbow. The epitrochlear nodes lie upon the basilic **vein**, a little above the medial epicondyle and drain the fourth and fifth digits. The majority of the lymphatics open into the axillary nodes, and terminate, on the left side in the thoracic duct, on the right in the lymphatic duct. A few, accompanying the cephalic vein, reach the subclavian or infraclavicular nodes, and thus communicate with the lymphatics of the neck.

Amputation of forearm.—The 'mixed' method by skin-flaps roundly arched and circular division of the soft parts, the dorsal flap being the longer, is the most generally applicable. The bones should always be sawn below the pronator teres, when possible. In sawing them they must be kept parallel, the limb being in the supinated position. As the radius is the less securely held above, it is well to complete the section of this bone first. The relative position of the vessels has been indicated above (p. 1423, and figs. 1127 and 1129).

THE WRIST AND HAND

Bony points.—On the medial side the *styloid process* and, further laterally, the *head of the ulna* can be made out. On the lateral side, the *radial styloid process* descends about 1.2 cm. ($1\frac{1}{2}$ in.) lower than that of the radius, and is somewhat anterior to it. Abduction of the hand is thus less free than adduction. Between the apex of the styloid process and the ball of the thumb a bony ridge can be felt, with some difficulty, formed by the *tubercle of the navicular* and the ridge of the *greater multangular* (trapezium). At the base of the hypothenar eminence the *pisiform* can be more readily distinguished. The *hook of the hamatum* (unciform) lies below and to the radial side of the pisiform. On the front of the metacarpophalangeal joint of the thumb, the *sesamoid bones* can be distinguished.

At the back of the wrist and hand the *triquetrum* (cuneiform) bone can be felt below the head of the ulna; and more toward the middle line the prominence of the *capitatum* (os magnum), which supports the third or longest digit.

A line drawn from the base of the fifth metacarpal bone to the radiocarpal joint, slightly curved downward, will give the line of the carpometacarpal joints. (Windle.) When the fingers are flexed, it will be seen that in each case it is the proximal bone which forms the prominence; thus, the knuckle is formed by the head of the metacarpal, the interphalangeal prominence by the head of the first phalanx, and the distal one by the head of the second. Thus, the joint in each case lies below the prominence, the distal joint being 2 mm. ($^1/_{12}$ in.), the interphalangeal 4 mm. ($^1/_6$ in.), and the metacarpophalangeal 8 mm. ($^1/_3$ in.) below its prominence.

Skin and skin-folds.—The *skin* over the palm is thickened over the heads of the metacarpal bones and hypothenar eminence, thinner over the thenar. It is peculiar in its absence of sebaceous glands and hair-follicles; hence the absence of

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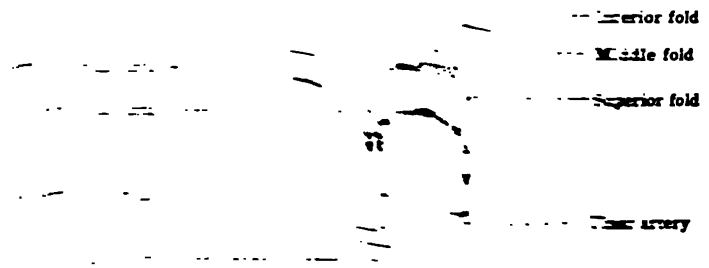

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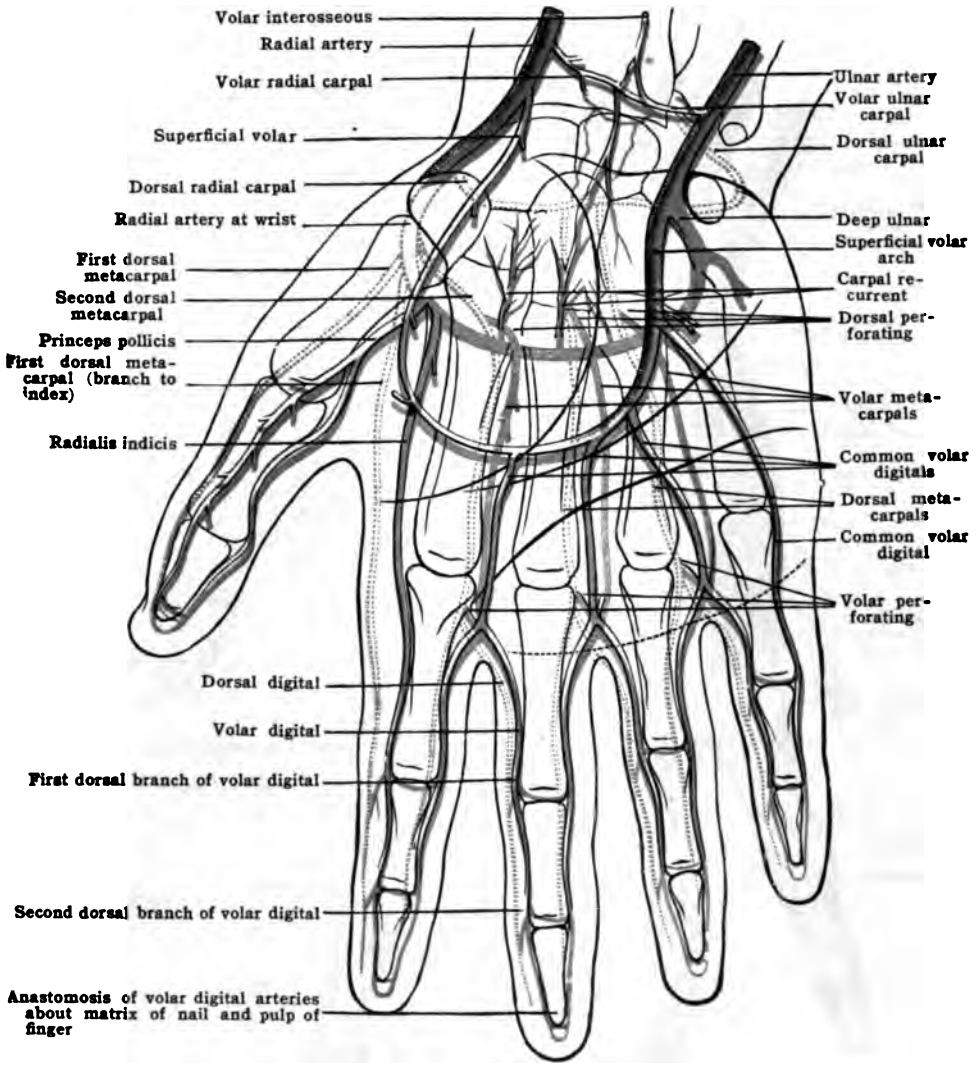
The digital arteries then descend along the sides of the fingers under the digital nerves, giving off twigs to the sheath of the tendons, which enter by apertures in it, and run in the vincula vasculosa. It is owing to the readiness with which these tiny twigs are strangled by inflammation that sloughing of the tendon takes place so readily and irreparably. Throughout its course the superficial volar arch deserves its name. It is only covered by the palmaris brevis and central part of the palmar fascia. Beneath it, mediolaterally are the flexor brevis and opponens digiti quinti, the digital branches of the ulnar and median nerves, and the flexor tendons and lumbricales.

FIG. 1132.—ANASTOMOSES AND DISTRIBUTION OF THE ARTERIES OF THE HAND.



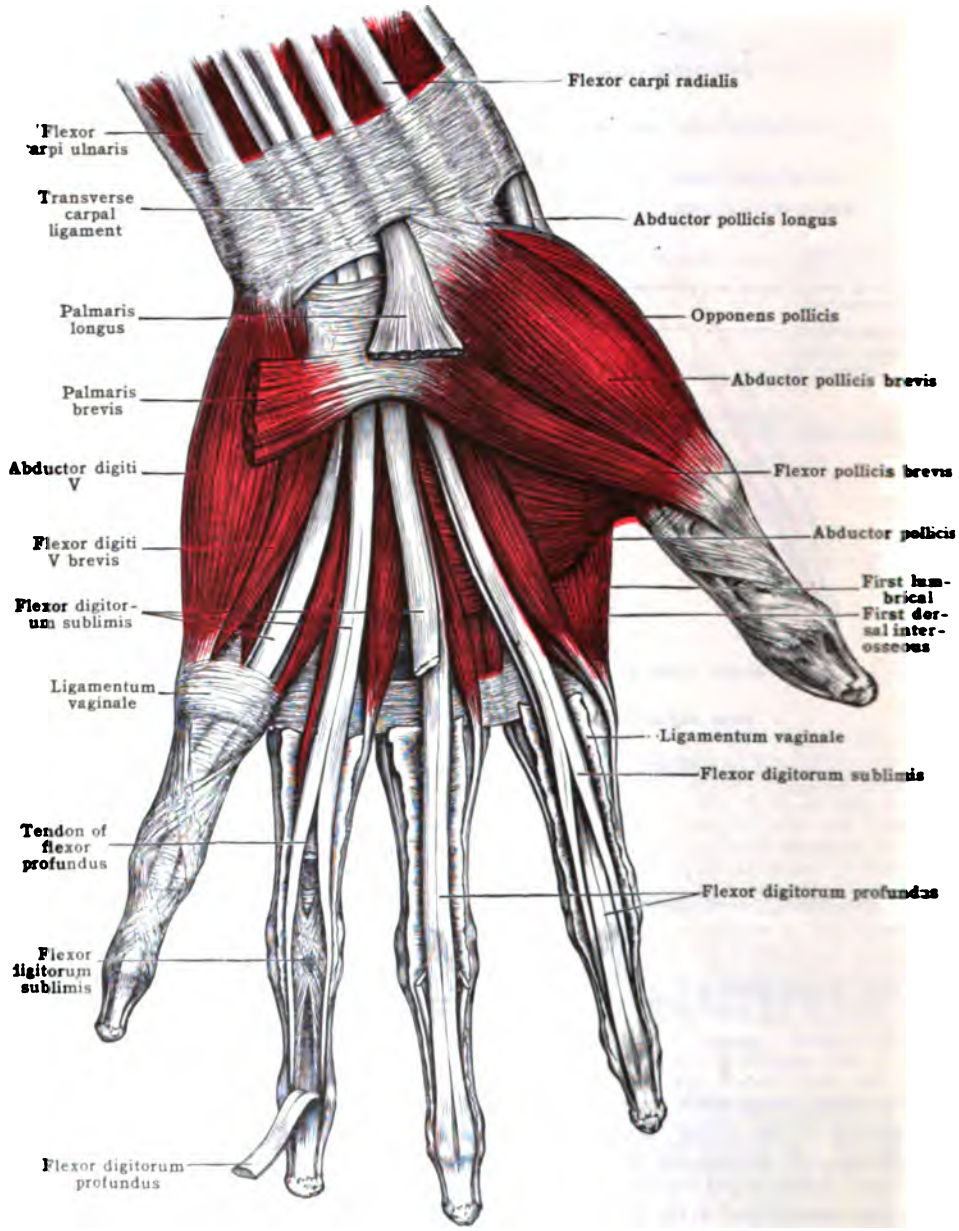
The **deep volar arch** (figs. 1131, 1132), formed by the radial and communicating branch of the ulnar, lies about 1.2 cm. (½ in.) nearer to the wrist than the superficial. It is not so curved as the superficial arch, and rests upon the interossei and metacarpal bones just below their bases. The structures separating it from the superficial arch have been already given.

Owing to the frequency of wounds here, the relation of the **structures in front of the wrist** (fig. 1135) is most important. The radial artery lies between the tendon of the brachioradialis and flexor carpi radialis. Next to this tendon is the palmaris longus, when present. At the midpoint of the front of the wrist and usually under the palmaris longus is the median nerve. To the medial side of the palmaris longus is the flexor sublimis, the tendons for the middle and ring-finger being in front. The tendon of the flexor carpi ulnaris is most medial and between

this and the superficial flexor of the finger the ulnar nerve and vessels have come up into a superficial position.

Fasciæ and sheaths.—The transverse and dorsal carpal (annular) ligaments bind down and hold in place the numerous tendons about the wrist. The **transverse carpal** (anterior annular), when healthy, cannot be detected. It is attached to the pisiform and triquetral (cuneiform) bones on the medial, and to the navicular and greater multangular (trapezium) on the lateral, side (figs. 1133, 1137).

FIG. 1133.—THE SUPERFICIAL MUSCLES OF THE PALM OF THE HAND.

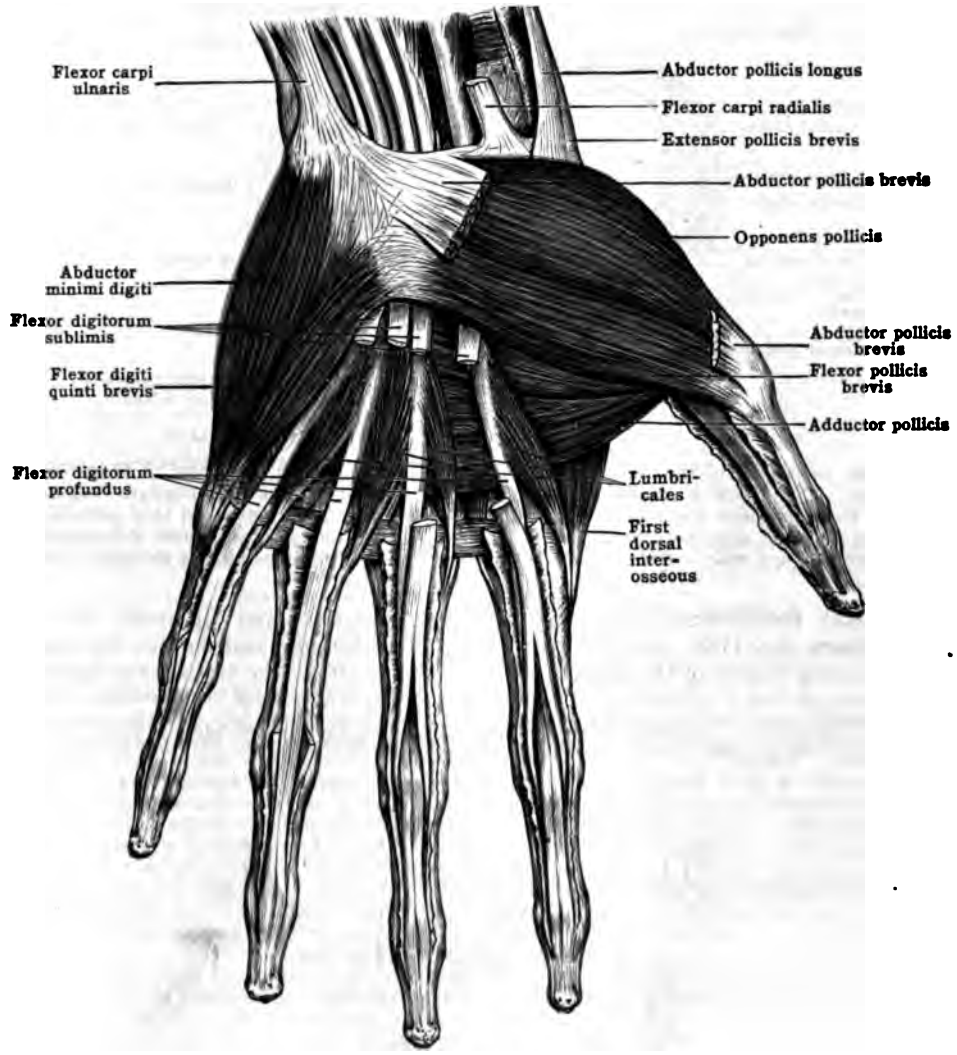


The ulnar nerve and vessels, the superficial volar, and palmar cutaneous branches of the median and ulnar pass over the transverse carpal ligament. The ulnar artery and nerve are especially protected by their position between the pisiform and hook of the hamate (unciform), and also by a process of the flexor carpi ulnaris, which passes to the transverse ligament, thus forming a kind of tunnel. The flexor carpi radialis passes through a separate sheath formed by the ligaments and the groove in the greater multangular; while beneath the ligaments lie the flexor tendons, the median nerve, and accompanying artery. Attached to its upper border

is the deep fascia of the forearm, and to its lower the palmar fascia and the palmaris longus tendon, while from the lateral and medial parts arise some of the thenar and hypothenar muscles. The upper border of the transverse carpal ligament corresponds to the lower of the two lines which cross the wrist just above the thenar and hypothenar eminences. The large synovial sheath, for all the flexors of the fingers, reaches beneath and below the transverse ligaments as far as the middle of the palm, and above the wrist for 3.7 to 5 cm. (1½ to 2 in.)

The **dorsal carpal** (posterior annular) **ligament** is attached to the back of the lateral margin of the radius above the styloid process, and medially to the back of the styloid process of the ulna, the triquetrum and pisiform. Its direction is oblique, being higher on the radial side. It contains six tendon-compartments, of which four are on the radius (figs. 1135, 1138).

FIG. 1134.—THE DEEPER MUSCLES OF THE PALM OF THE HAND.

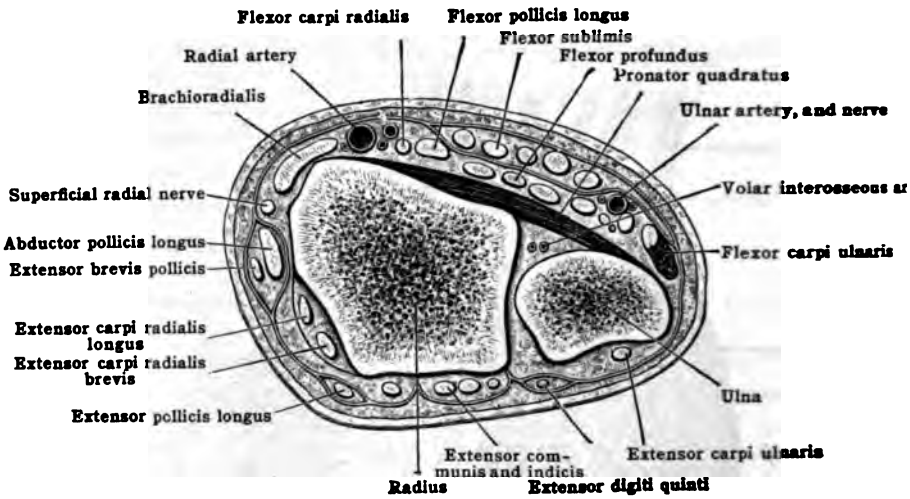


The most lateral contains the long abductor and short extensor of the thumb; the second the two radial extensors of the carpus; the third, the extensor pollicis longus; this deep and narrow groove can be identified when the hand is extended, by its prominent lateral margin; the fourth transmits the extensor communis and extensor indicis proprius; the fifth, lying between the radius and ulna, the extensor digiti quinti; and the sixth, lying just lateral to the styloid process of the ulna, the extensor carpi ulnaris. The sheaths for the last two extensors are the only ones which follow the tendons of their insertion, the others ending at a varying distance below the carpal ligament. The lower border of the dorsal carpal corresponds to the upper margin of the transverse carpal ligament.

The **palmar aponeurosis,** by its strength, toughness, numerous attachments, and intimate connection with the superficial fascia and skin is well adapted to protect the parts beneath from pressure.

The thenar and hypothenar muscles are enclosed in two processes, which are thinner not to interfere with the contraction of the subjacent muscles. The central part, pointed at its attachment to the carpal ligament, spreads out fan-like below, and gives off four each of which bifurcates into two processes, which are attached to the sides of the first ph of each finger and into the superficial transverse ligament of the web and the deeper one ties the heads of the metacarpal bones together. Transverse fibers pass between the pro into which each of the four slips bifurcates, and thus form the beginning of the theca, wh continued down the finger to the base of the last phalanx. It is the contraction of the p

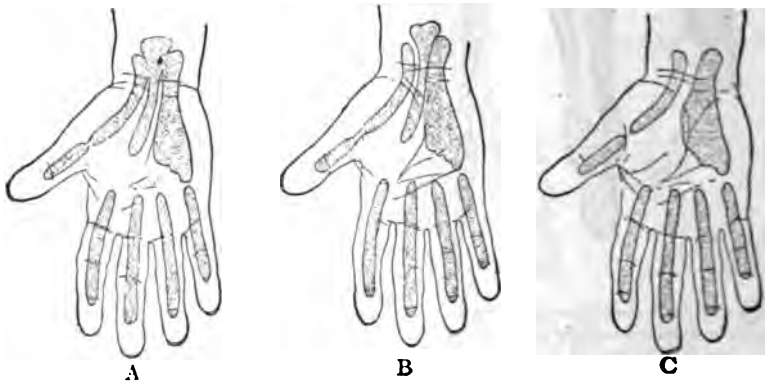
FIG. 1135.—SECTION THROUGH REGION OF WRIST, A LITTLE ABOVE THE JOINT. RIGHT UPPER HALF OF THE SECTION. (Tillaux.)



aponeurosis, especially of the slip to the two medial fingers, which gives rise to Dupuyt contraction. The theca is strong opposite the first two phalanges (ligamentum vagin weak and loose opposite the joints (ligamentum annulare). The density of this osseofib tunnel and its close proximity to the digital nerves explain the pain in thecal inflamma Its tendency to gape widely after section is to be remembered in amputations through infe parts.

Synovial membranes.—Beneath the transverse carpal ligament lie **synovial sacs** (fig. 1136), one for the flexor pollicis longus, and one for the su ficial and deep flexors of the fingers. They extend above the transverse ligam

FIG. 1136.—SYNOVIAL SHEATHS OF THE TENDONS OF THE LONG FLEXORS OF THE FING After Poirier and Charpy. A. Frequent type; B. Normal type; C. Fetal type.



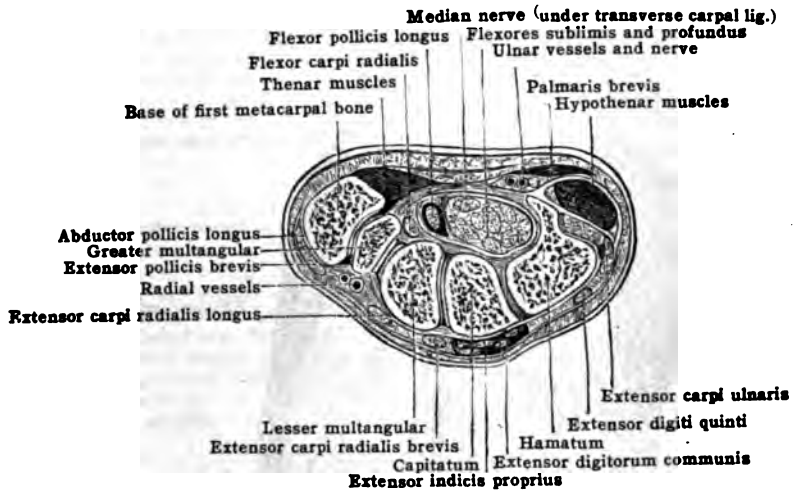
for rather more than 2.5 cm. (1 in.). The two sacs may communicate. A c pound palmar 'ganglion' has an hour-glass outline, the transverse carpal ligam forming the constriction.

The creaking sensation in tenosynovitis and that of 'melon seed' bodies often presen tuberculosis here is well known. The sheath for the long flexor of the thumb reaches to base of the last phalanx. That for the finger-flexors gives off four processes. The one for

little finger also reaches to the base of the last phalanx. Those for the index-, middle, and third fingers end about the middle of the metacarpal bones. Traced from the insertions of the flexor profundus, the digital synovial sheaths extend upward into the palm as far as the bifurcation of the palmar fascia (p. 1430), i. e., to a point about opposite to the necks of the metacarpal bones, denoted on the surface by the crease which corresponds to the flexion of the fingers. Thus, about 1.2 cm. (½ in.) separates the sheaths of the lateral three fingers from the large synovial sac beneath the transverse carpal ligament. There is no synovial sheath beneath the pulp of the fingers or thumb, this part lying on the periosteum of the last phalanx.

This has an important bearing on **whitlow.** Infection here may be merely *subcutaneous*, or deeper, in the latter case from the connection of the skin with the periosteum here existing the bone is soon affected, and necrosis keeps up a tedious ulcer. As the two centers of the phalanx do not unite till about the twentieth year, the distal one only requires removal; as the flexor sheath only reaches to the insertion of the flexor, i. e., into the proximal, part of the bone, both sheath and tendon may escape implication. Higher up along the fingers whitlow may be *cellulocutaneous* or *synovial.* While the continuity of the synovial sheath in the little finger and thumb (fig. 1136) renders infection here more dangerous, the short gap between the digital and the palmar sacs is readily traversed by acute infection, with all the grave results of synovial suppuration.

FIG. 1137.—SECTION OF CARPUS THROUGH THE HAMATE BONE. (× ⅔.) (Bellamy, after Henle.)



Suppuration in the hand owes much of its gravity to the possibility of infection of the synovial tendon sheaths and consequent sloughing of the tendons. At the same time it is now recognized that unless these sheaths are primarily infected pus collects at first in certain potential spaces, more or less well defined, in the looser connective tissue of the hand. One of these known as the **middle palmar space,** (Kanavel: Infectons of the Hand, 1912) is situated on the front of the metacarpals of the middle and ring fingers, and lies deeply between the flexor tendons and the interosseous muscles. Continuations of this potential space extend downward along the lumbrical muscles on the radial side of the three medial fingers, and may lead pus from the palm to the subcutaneous tissue of these fingers or *vice versa.* A second potential compartment, the **thenar space** (Kanavel) lies in front of the index metacarpal, between the flexors of the index-finger and the adductor transversus pollicis.. As in the former space, the corresponding lumbrical muscle prolongs it down to the radial side of the index-finger.

Distention of the middle palmar space with pus leads to obliteration of the hollow of the palm and a variable extension of the swelling along the radial side of the three medial fingers. Distention of the thenar space follows the thenar eminence, obliterates the adduction crease of the thumb, and may extend down the radial side of the index-finger. There is not in either case the extreme tenderness and pain on passive extension of the fingers that is characteristic of infection of the synovial sheaths. The pus is best evacuated by an incision on the radial side of the finger most affected, a little behind the web, sinus forceps being passed along the lumbrical muscle into the palm, so as to avoid opening and infecting the synovial sheaths.

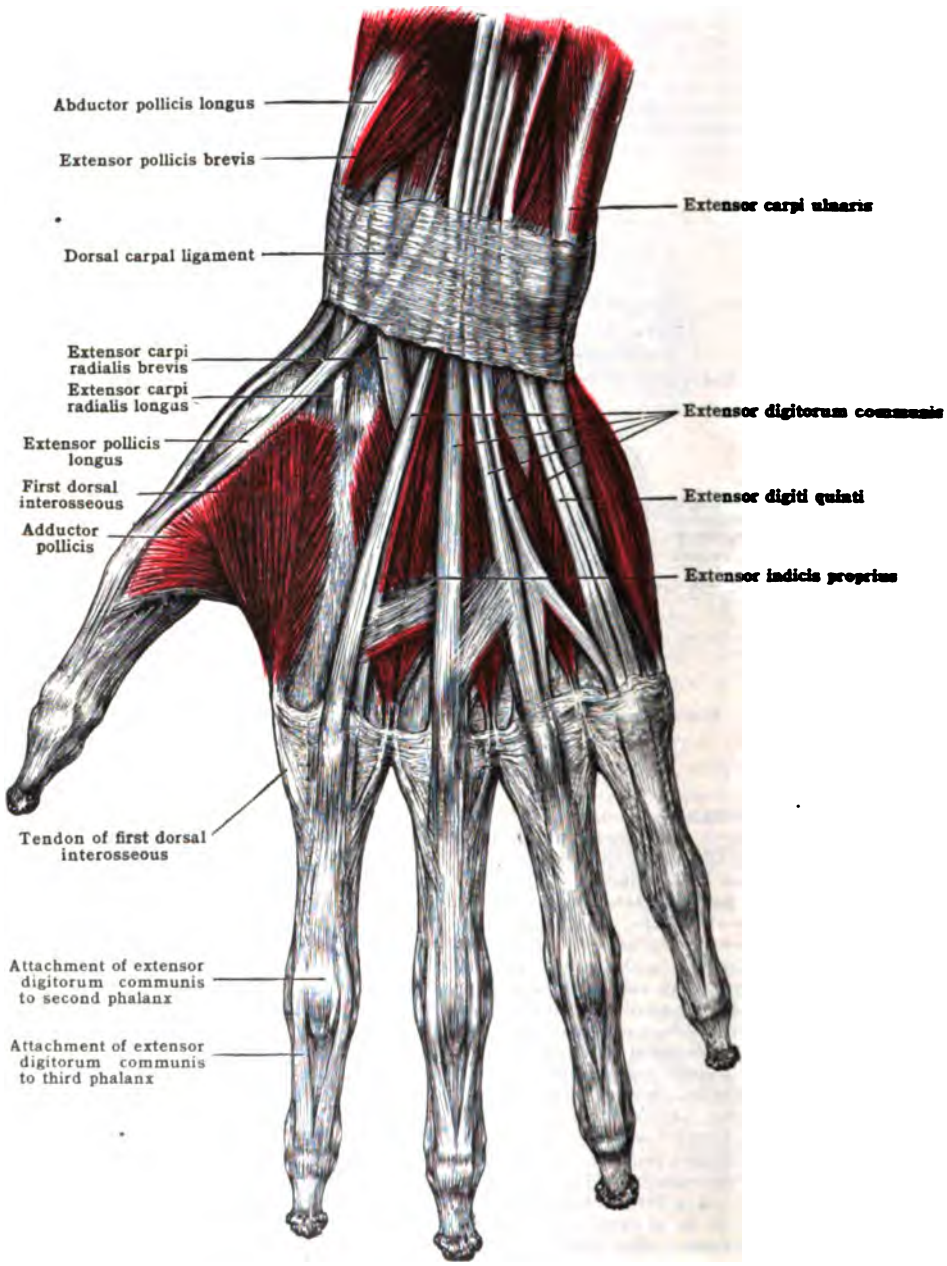
It must be remembered also that infection of the above fascial spaces may take place secondarily, by the bursting into them of pus from the synovial tendon sheaths.

Deeper are the **articular synovial sacs** (fig. 337) five in number:—(1) Between the interarticular cartilage and the head of the ulna; (2) between the radius and the interarticular cartilage above, and the navicular and lunate and triquetrum below; (3) between the greater multangular and first metacarpal bone; (4) between the pisiform and the triquetral bone; (5) between the two rows of carpal bones, sending two processes upward between the three bones of the upper row,

and three downward between the four of the lower row; these three processes being also continued below into the medial four carpometacarpal and three intermetacarpal joints.

Beneath the palmar aponeurosis covering the *thenar eminence* are the following structures:—Superficial volar artery, abductor pollicis brevis, opponens pollicis, radial head of short flexor,

FIG. 1138.—TENDONS UPON THE DORSUM OF THE HAND.



tendon of long flexor, ulnar head of short flexor, first volar metacarpal arteries, metacarpal bone of the thumb, with the tendon of the flexor carpi radialis and greater multangular.

Beneath the *central part* of the palmar aponeurosis are the superficial arch and its digital branches; the ulnar and median nerves, with their branches; the flexors, superficial and deep, with their synovial sheath; and the lumbricales; then a layer of connective tissue (the only structure, together with the deep layer of fascia over the interossei, which prevents matter pent in by the palmar aponeurosis from making its way back out through the dorsum), the deep arch, the interossei, and the metacarpal bones.

In the *hypothenar eminence* under the fascia are part of the ulnar artery and nerve, the abductor and flexor brevis digiti quinti, the opponens, the deep branch of the ulnar artery and nerve, and the fifth metacarpal bone.

The back of the wrist and hand (fig. 1138).—The dorsal carpal (posterior annular) ligament has already been described. On the lateral side is the so-called 'snuff-box space' (*tabatière anatomique* of Cloquet), a triangular hollow, bounded toward the radius by the long abductor and short extensor of the thumb, and toward the ulna by the long extensor. The navicular and greater multangular, with their dorsal ligaments, form the floor. In the roof lie the radial vein and branches of the radial nerve. More deeply is the artery, following a line from the apex of the styloid process to the back of the interosseous space.

The different tendons have already been given. Between the first two metacarpal bones is the first dorsal interosseous muscle, which forms a fleshy projection against the radial side of the index metacarpal, when the thumb and index are pressed together. On its palmar aspect is the adductor pollicis. Wasting of the former muscle is a ready indication of injury or disease of the ulnar nerve.

The skin on the dorsum, by its laxity, readily allows of edema, this being sometimes evidence of pressure on the axillary vein by carcinomatous deposits. The dorsal venous arch receives the digital plexuses, and from it the radial and posterior ulnar veins ascend. The median vein begins in plexuses at the root of the thumb and the front of the wrist.

Ganglia are common on the dorsum, in connection with the extensors of the fingers and the thumb. While usually due to a weakening of the sheath and protrusion of this and the synovial membrane, such swellings may be due to a projection of the articular synovial membrane. Owing to the laxity of the skin, the slight vascularity, the size of the tendons, their connection with joint-capsules and with each other, which fixes them, the dorsum of the wrist is the 'seat of election,' for **tendon-anastomosis** and other operations. **Metacarpophalangeal dislocation** occurs in the thumb and the index-finger especially. The chief cause in the difficulty in reduction is the accessory volar (glenoid) ligament. This, in reality a fibrocartilaginous plate, is blended with the lateral ligaments on the palmar aspect of the joint, and is firmly attached to the phalanx, but more loosely to the metacarpal. Thus when dislocation occurs in violent hyperextension, the metacarpal attachment of the glenoid ligament gives way and it is carried by the phalanx over the head of the metacarpal bone. In the case of the thumb, the buttonhole-like slit with which the two heads of the flexor brevis, now displaced, embrace the head of the metacarpal, renders reduction difficult. The contraction of the other short muscles, and, occasionally, a displaced long flexor, are additional causes of difficult reduction. In the case both of the thumb and finger, tilting the phalanx well back on the dorsum of the metacarpal and then combined pressure with the thumbs forward against the base of the phalanx, when this is sharply flexed, will with an anesthetic, be usually successful in effecting reduction. The thumb should be, first, adducted into the palm.

THE LOWER EXTREMITY

The various segments of the lower extremity will be successively considered as follows: hip and thigh, knee and leg, ankle and foot.

HIP AND THIGH

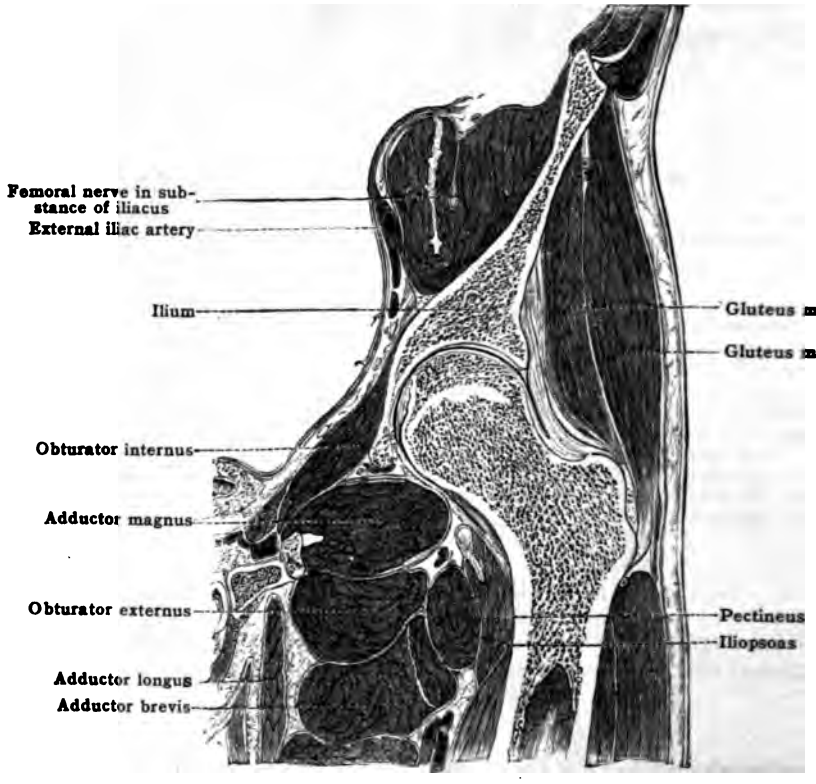
Bony landmarks.—Many of these, such as the anterior superior iliac spine and crest of the ilium and the pubic tubercle, have already been mentioned. The relative length of the limbs is obtained by carrying the measure from the anterior superior spine to the tip of the corresponding medial malleolus. The pelvis must be horizontal and the limbs parallel.

The head and shaft of the **femur** are well covered in, save in the emaciated. The head lies just below Poupart's ligament, under the iliopsoas, and a little to the lateral side of the center of that ligament. A line drawn horizontally laterally from the pubic tubercle will cross the lower part of the head. All the head and the front of the neck, but only two-thirds of the back, are within the capsule; this intracapsular position of the upper epiphysis, which, appearing at the first year, does not unite till eighteen or twenty, accounts largely for the extreme gravity of acute epiphysitis here. The structure of the neck, i. e., the two sets of lamellæ, *vertical* to support the weight, *transverse* and *intersecting* in order to meet the pull of the muscles, and the wasting of these after middle life, has an important influence on injuries. The strong process, *femoral spur* or *calcar* (Merkel) which, arising from the compact tissue on the medial and under side of the neck, just above the lesser trochanter, spreads laterally toward the trochanteric (digital) fossa, also affords strength, and its degeneration probably plays an important part in the fractures of the neck.

Hip-joint (figs. 339, 341, 343, 1139).—The chief points of surgical importance are the following:—The capsule shows fibers chiefly longitudinal in front, circular behind. Of the former, the iliofemoral or inverted Y-shaped ligament descends

from the anterior inferior spine to the two extremities of the anterior inte
chanteric line. It not only checks extension and strengthens the front o
joint, but it keeps the pelvis and trunk propped forward on the heads of the fe
thus preventing waste of muscular action. It is joined on the medial side b
pubocapsular ligament, which checks abduction. Between the two is the m
part of the front capsule, and here the iliopsoas bursa may communicate wit
joint. This fact must be remembered in tuberculous disease of the psoas.
the presence of this bursa explains certain deep-seated swellings in the front c
joint in adults. Behind, the ischiofemoral is the strongest part of the cap
its fibers blending with the circular and weaker part of the capsule here. I
cation usually occurs at the posterior, lower and medial part of the joint. It

FIG. 1139.—FRONTAL SECTION OF THE HIP-JOINT AND ITS RELATIONS. (×⅓) (Braune.)



be noted that in full extension and flexion the head of the femur is in contact w
the weakest spot in the capsule, in front and behind, respectively. From
deep aspect of the capsule fibers pass up at the line of reflection of the syno
membrane on to the neck—the retinacula (cervical ligaments of Stanley).
intracapsular fracture these fibers keep the fragments together; hence one n
of gentle handling; their softening may explain, a little later, an increase in
shortening.

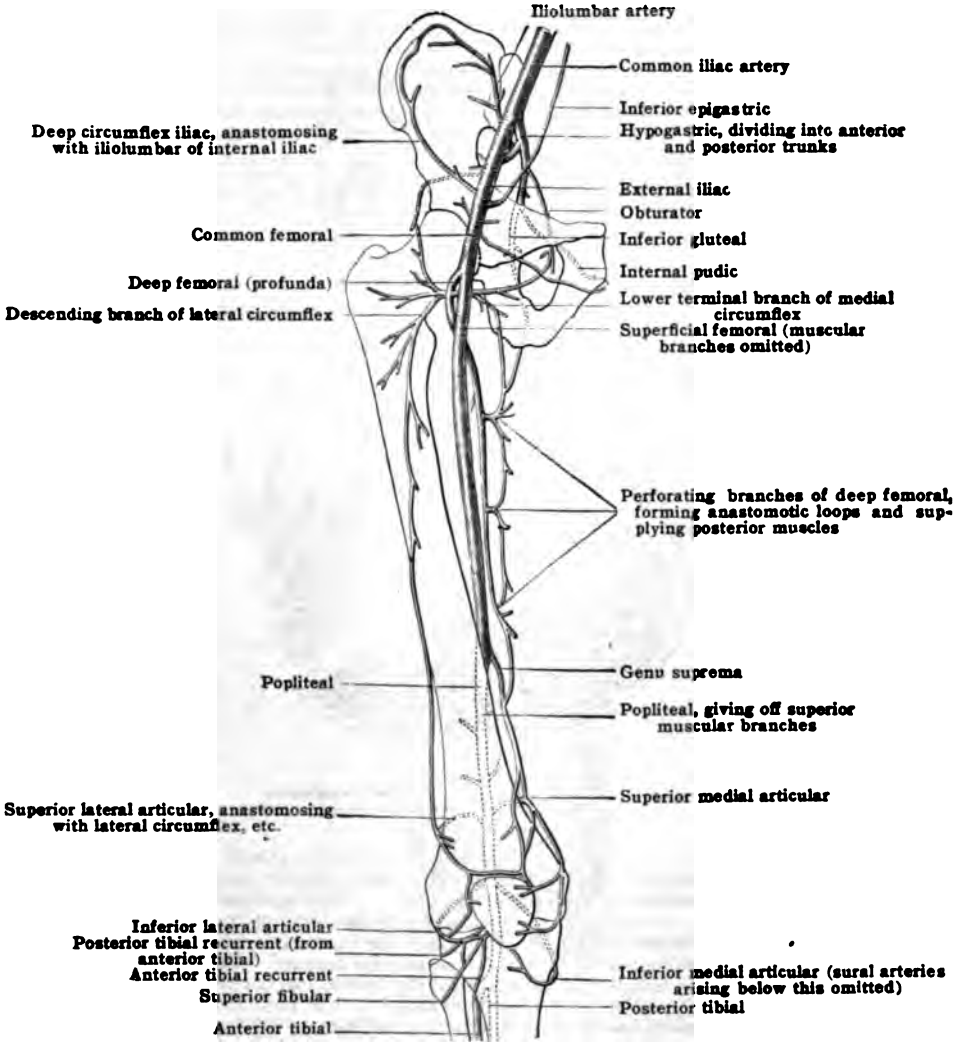
Exploration of the joint.—This is usually effected by an oblique incision downward
slightly medially between the sartorius and rectus medially and the gluteus medius and mini
laterally. A branch of the ascending division of the lateral circumflex is the only artery
with. In tapping the joint the puncture is made in the same line, 2 or 3 inches below
anterior superior spine. If the instrument is pushed upward, medially, and backward ben
the rectus, it will pass into the joint a little above the anterior intertrochanteric line. (St

Trochanter major.—This valuable landmark is most prominent when the l
is rotated medially or adducted; it lies at the bottom of a depression when
femur is everted.

The chief structure of importance between it and the skin is the upper part of the inser
of the gluteus maximus, that going to the fascia lata, and the bursa beneath the muscle. Th

often multilocular. It is, not very uncommonly, the seat of tuberculous inflammation which readily invades the cancellous tissue of the trochanter. The top of the great trochanter is about 1.8 cm. (¾ in.) below the level of the femoral head, and, when the femur is extended is a little below the center of the hip-joint. This part of the bone is covered by the gluteus medius. The slightness of the prominence of the great trochanter in the living subject compared with that in the skeleton is explained by fig. 1139, which shows how the descending gluteus medius and minimus fill up the space between the ilium and trochanter. To examine the great trochanter, the thigh should be abducted, so as to relax the strong fascia lata passing upward over the tensor and glutei to the iliac crest.

FIG. 1140.—DIAGRAM OF ARTERIES OF THIGH.


Iliolumbar artery
Common iliac artery
Inferior epigastric
Hypogastric, dividing into anterior and posterior trunks
Deep circumflex iliac, anastomosing with iliolumbar of internal iliac
External iliac
Obturator
Common femoral
Inferior gluteal
Internal pudic
Deep femoral (profunda)
Lower terminal branch of medial circumflex
Descending branch of lateral circumflex
Superficial femoral (muscular branches omitted)
Perforating branches of deep femoral, forming anastomotic loops and supplying posterior muscles
Genu suprema
Popliteal
Popliteal, giving off superior muscular branches
Superior medial articular
Superior lateral articular, anastomosing with lateral circumflex, etc.
Inferior lateral articular
Posterior tibial recurrent (from anterior tibial)
Anterior tibial recurrent
Inferior medial articular (sural arteries arising below this omitted)
Superior fibular
Posterior tibial
Anterior tibial

Nélaton's line.—This useful guide is a line drawn from the anterior superior spine of the ilium to the most prominent part of the tuberosity of the ischium. In normal limbs, the top of the great trochanter just touches this line. In dislocation, fractures of the neck, and in wasting of the neck, as in osteoarthritis, the relation of the trochanter to Nélaton's line becomes altered.

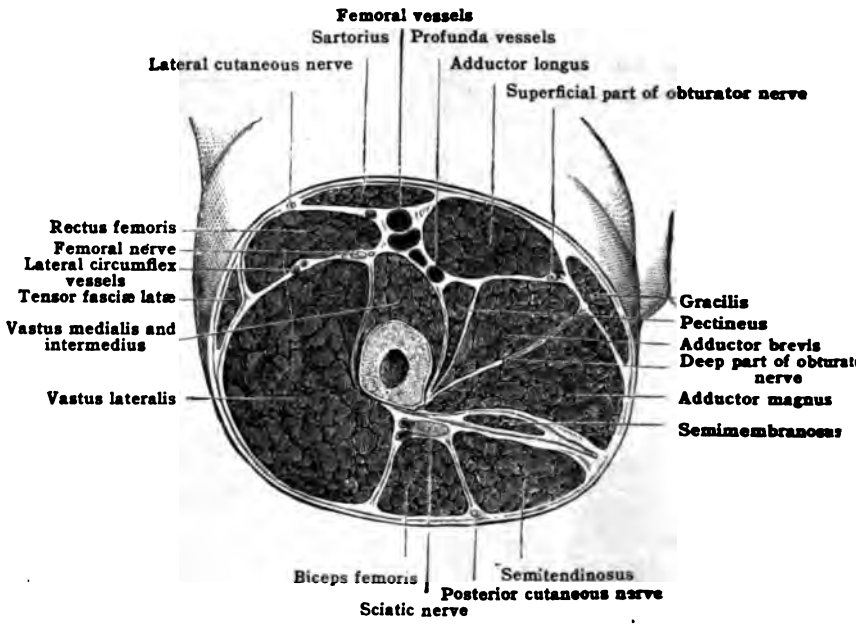
The top of the great trochanter is a guide in Adams's operation for division of the neck of an ankylosed femur, the puncture being made and the saw entered 2.5 cm. (1 in.) above and about the same distance in front of this point. Owing to the fact that in many cases of ankylosis the neck is destroyed, the above operation has been largely replaced by the simpler and more widely applicable Gant's osteotomy just below the great trochanter, from the lateral side.

Bryant's triangle.—Bryant makes use of the following in deciding the position of the great trochanter. The patient being flat on his back (1) a line is dropped vertically on to the couch from the anterior superior spine; (2) from the top of the great trochanter a straight line in the long axis of the thigh is drawn to meet the first; (3) to complete the triangle, a line is drawn from

the anterior superior spine to the top of the trochanter. This line is practically Nél
The second line will be found diminished on the damaged or diseased side.

Muscular prominences (figs. 442, 1141).—The *tensor fasciæ latæ* forms a prominence
ning just lateral to the sartorius and reaching downward and somewhat backward to the
fascia lata, 7.5 to 10 cm. (3 to 4 in.) below the great trochanter. Below this point, as far
lateral condyle of the tibia, the strong *iliotibial band* can be felt. Like the inverted Y-
ligament, this band is a powerful saving of muscular action in maintaining the erect po
At the insertion of the tensor fasciæ latæ it bifurcates into two layers, which enclose the n
The superficial is attached to the iliac crest and the sheath of the gluteus medius; th
blends with the capsule and the reflected head of the rectus. This deeper layer is perf
by the ascending branch of the lateral circumflex. The iliotibial band is a guide for re
the femur. The *sartorius*, the chief landmark of the thigh, forming a boundary
femoral trigone (Scarpa's triangle), the adductor (Hunter's) canal, and the popliteal spac
be readily brought into view by the patient's raising his limb slightly rotated laterally.
midline the *rectus* muscle stands out in bold relief, with its tendon of insertion and the p
when the leg is extended. On either side of this muscle is a furrow, and on either side, ag
this furrow the *vasti* become prominent. Between the vastus medialis and adductor musc
depression indicating the adductor canal. At the upper and medial third of the thigh,
limb be abducted, the upper part of the *adductor longus* comes into strong relief. On the

FIG. 1141.—SECTION OF THE RIGHT THIGH AT THE APEX OF THE FEMORAL TRIGONE. H



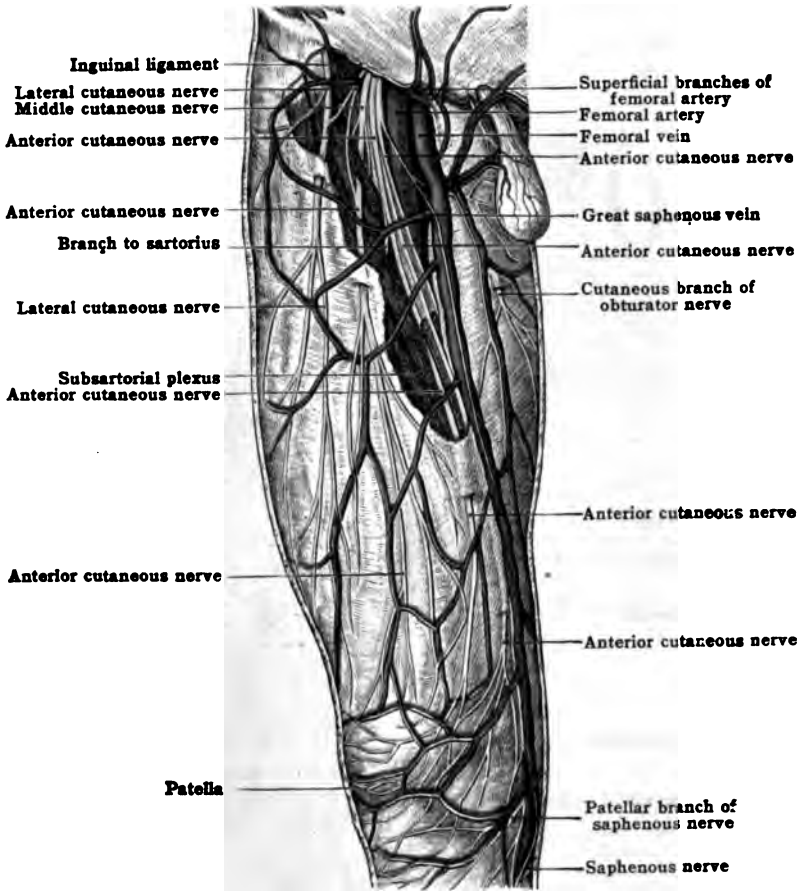
side below, above the knee-joint, the vertical fibers of the *adductor magnus* end in a po
tendon coming down to the adductor tubercle (fig. 1143). This replaces here the medial
muscular septum, and the insertion of the tendon marks the level of the lower epiphysis
of the femur. At the lateral and back part of the thigh the vastus lateralis is separated fro
biceps by a groove which indicates the lateral intermuscular septum. Of these septa, pro
tions inward from the fascia lata to the linea aspera, the lateral lies between the vastus la
and the biceps. It reaches from the lateral tuberosity of the femur to the insertion
gluteus maximus. Just above the condyle it is perforated by the superior lateral articul
sel and nerve. The medial septum extends from the adductor tubercle to the trochante
is weak in comparison, and separates the adductor from the vastus medialis. A thir
weakest of all, separates the adductor and the hamstrings. The fascia lata has the same
as that in the neck in causing pus to burrow, especially downward, and in rendering the di
sis of swellings beneath it difficult. Thickest above and on the lateral aspect, and again
the bony prominences at the knee-joint, at both of which sites it receives accessions
muscles, it is divided into iliac and pubic portions. The former is attached behind to s
and coccyx, iliac crest and the inguinal ligament, terminal line and pubic tubercle. E
blends with the pubic portion, which is connected with the pubic arch. At the fossa
(saphenous opening) the two may be said to separate, the iliac forming the upper corn
lateral falciform margin, and descending over the femoral vessels and extensors. The
much thinner, forms the medial margin of the fossa, and descends obliquely over the pec
and adductor longus behind the vessels, to blend with the sheath of the iliopsoas and caps
the hip-joint.

The inguinal (Poupart's) ligament (fig. 1142).—The abdomen is sepa
from the thigh by a fold, best marked in flexion—the inguinal furrow. In

pressure detects the meeting of the aponeurosis of the external oblique and the fascia lata, i. e., Poupart's ligament, extending between the anterior superior spine of the ilium and the tubercle (spine) of the pubis. The line representing it should be drawn slightly convex downward, owing to the attachment of the deep fascia. It forms the base of the femoral trigone; its medial attachment blends with the triangular lacunar (Gimbernat's) ligament. The parts passing under the inguinal ligament and their arrangement have been given at p. 1399, fig. 1109).

The **femoral trigone** (**Scarpa's triangle**) (figs. 1142, 1143).—Immediately below the inguinal ligament a hollow is seen corresponding to this region, the

FIG. 1142.—SUPERFICIAL DISSECTION OF THE FRONT OF THE THIGH.
(Hirschfeld and Leveillé.)



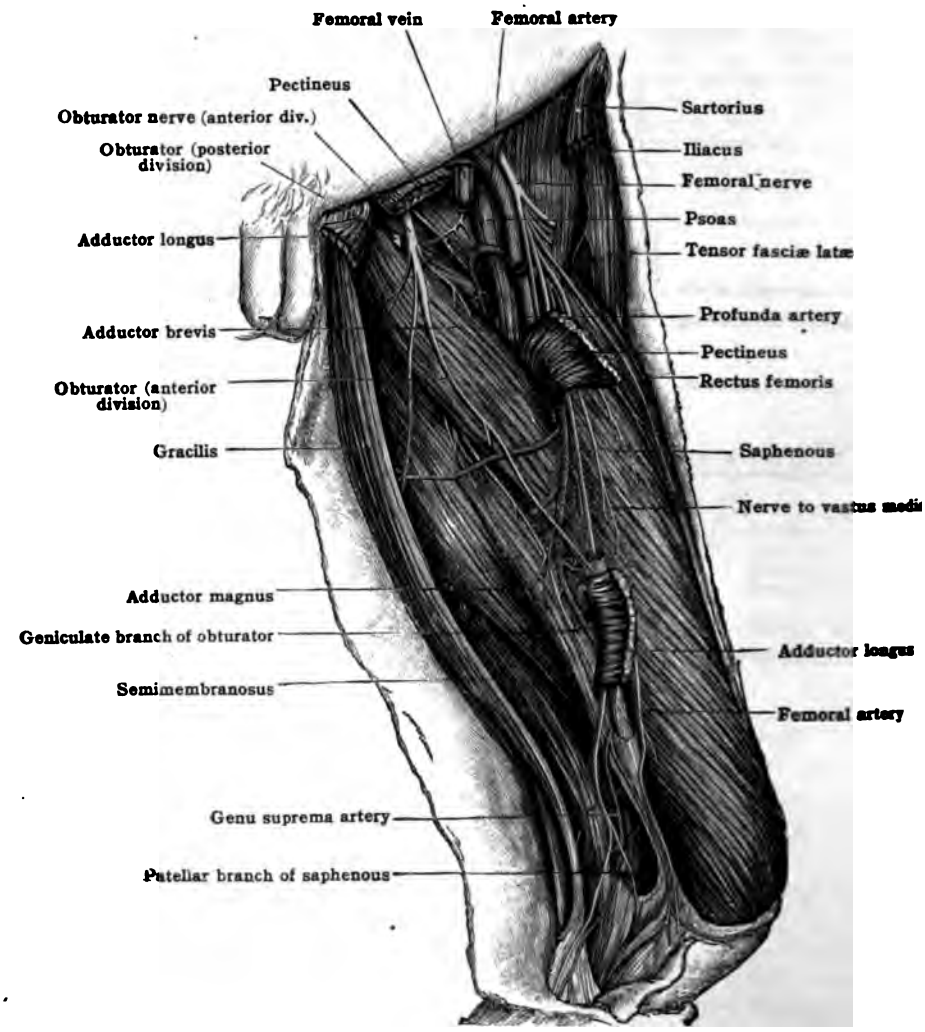
lateral and medial boundaries of which are brought into view when the limb is raised, the adductor longus especially when the limb is abducted, and the sartorius when the thigh is flexed and the limb extended and rotated laterally. The floor of the femoral trigone is not horizontal, the plane of the medial part being very oblique. It is formed lateromedially by the iliopsoas, pectineus, adductor brevis (slightly), and adductor longus.

A **psoas abscess** descending below the inguinal ligament usually does so on the lateral aspect of the femoral vessels; if the sheath gives way, or if the abscess follows the profunda artery, it will pass beneath the adductor longus and point toward the medial side of the thigh. (Taylor.) If it simulate a femoral hernia, examination of the back and the fact that the swelling is below the fossa ovalis will prevent mistakes. Three **nerves** come into the thigh between the pelvis and Poupart's ligament, i. e., the lumboinguinal (genitocrural) in the femoral sheath, the femoral (anterior crural) between the iliacus and psoas and the lateral femoral cutaneous close to the lateral attachment of the inguinal ligament.

The **obturator nerve** divides into two in the obturator foramen, the two divisions being separated by some fibers of the obturator externus, and lower down by

the adductor brevis (fig. 1143). The relations, course, and distribution
nerve, in the medial fibers of the psoas, over the sacroiliac joint and und
iliopelvic or sigmoid colon (Hilton), through the obturator foramen wi
branches (from the superficial division) through the cotyloid notch to th
and (from the deep) along the popliteal artery to the knee, and others to the
third of the thigh, and sometimes the upper and medial aspect of the leg (Hi
may be of much surgical importance, e. g., in carcinoma of the bowel, dise
the sacroiliac and hip-joints, growths of the pelvis, and the rare obturator h

FIG. 1143.—FEMORAL AND OBTURATOR NERVES. (Ellis.)



The distribution of the cutaneous nerves is shown in fig. 1142. Lying super
ally in the base of the trigone, the inguinal lymphatic nodes can be detected
thin person (fig. 1153)

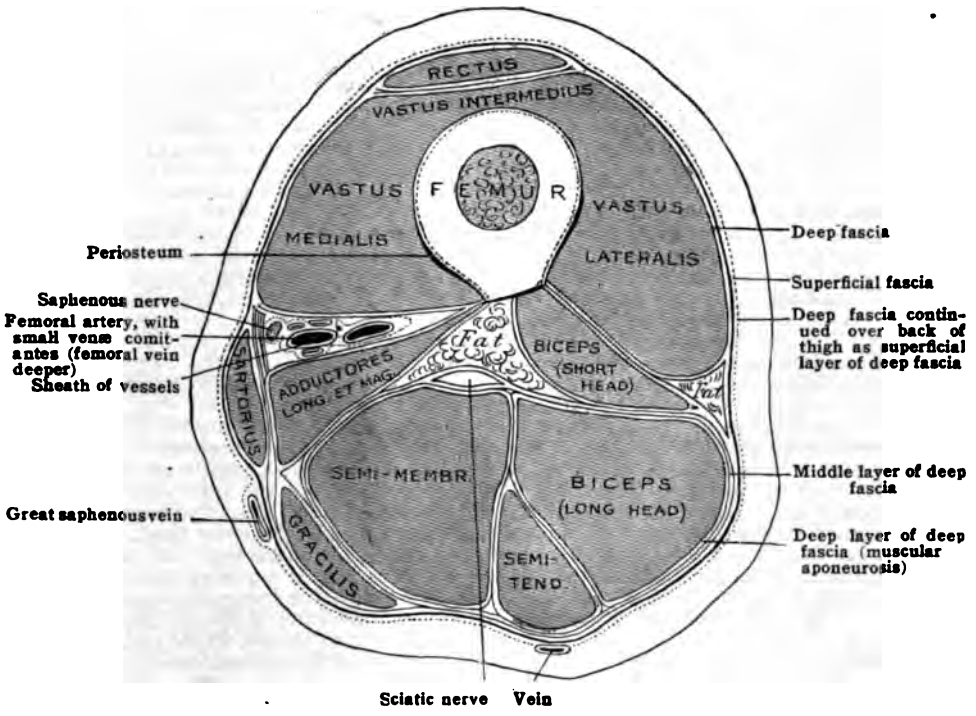
The fossa ovalis (saphenous opening).—The depression corresponding to
is placed just below the lacunar (Gimbernat's) ligament, with which its upper
tremity blends. Its center is about 3.7 cm. (1½ in.) below and also lateral
line dropped vertically from the pubic tubercle. This and the other structu
concerned in femoral hernia are fully described under this section (p. 1398).
course of the great saphenous vein is given below, p. 1454.

Line of femoral artery.—A line drawn from the midpoint between the ante
superior spine and the symphysis pubis to the adductor tubercle will corresp
with the course of this vessel. The sartorius usually crosses it 10 cm. (3 to 4 i

below the inguinal (Poupart's) ligament. The profunda artery arises usually 3.7–5 cm. (1½ to 2 in.) below Poupart's ligament.

The incision for tying the femoral in the femoral trigone should be about 7.5 cm. (3 in.) long, in the line of the artery, and begins about 7.5 cm. (3 in.) below the inguinal ligament, and runs over the apex of the triangle. The femur is flexed slightly, abducted and rotated laterally. The fascia lata being divided, the sartorius, readily recognized by its direction, is drawn laterally. The closely subjacent sheath must be opened on its lateral side. Structures that may be seen are a vein joining the great saphenous, the anterior cutaneous, saphenous nerve, and that to the vastus medialis. The *collateral circulation* (fig. 1140) is mainly through the following channels:—(1) The lateral and medial circumflex above, with the genu suprema and lower muscular branches of the femoral, and the articular of the popliteal. (2) The perforating branches of the profunda above, with the vessels below first given. (3) The comes nervi ischiadici with the articular of the popliteal. Ligature of the femoral artery and vein results in gangrene in 36 to 39 per cent. of cases (Kagiyama).

FIG. 1144.—SECTION OF THIGH THROUGH UPPER PART OF HUNTER'S CANAL. (W. A.)



The **femoral vein** below the inguinal ligament lies immediately to the medial side of the artery. From this point on the vein gets to a somewhat deeper plane, though still very close to the artery, and gradually inclining backward, lies behind its companion at the apex of the triangle, and below lies somewhat laterally to it.

From the apex of the femoral trigone (Scarpa's triangle) a depression runs down along the medial aspect of the thigh, corresponding to the groove already mentioned between the vastus medialis muscle and the adductors. Along this groove lies the sartorius, and beneath it the **adductor (Hunter's) canal,** a triangular intermuscular gap with its apex toward the linea aspera, and its base or roof formed by the fibrous expansion which ties together its boundaries, viz., the adductor longus and magnus and the vastus medialis (fig. 1144).

The vein, which in the upper part of the canal lies behind the artery, separating it from the three adductors, lower down inclines more and more to the lateral side. The saphenous nerve lies also in the canal, but not in the sheath. The above-mentioned space terminates at about the junction of the middle and lower thirds of the thigh, in the opening in the adductor magnus by which the artery enters the upper and medial part of the popliteal space. The saphenous, the largest branch of the femoral nerve, having crossed the femoral vessels lateromedially, accompanies them as far as the opening in the adductor magnus. Here it perforates the aponeurotic roof, and is prolonged under the sartorius, accompanied by the superficial part of the genu suprema artery, to perforate the fascia lata between the sartorius and gracilis, and run with the great saphenous vein at the upper and medial part of the leg.

Pressure may be applied to the femoral artery—(1) Immediately below the inguina ment, where it should be directed backward so as to compress the vessel against the brim pelvis and the capsule of the hip-joint; (2) at the apex of the femoral trigone, the pressur being directed laterally and a little backward, so as to compress the vessel against the (3) in the adductor canal the pressure should be directed laterally with the same object. must be taken, especially above, to avoid the vein, which lies very close to the artery, an the femoral nerve, which enters the thigh about 1.2 cm. ($\frac{1}{2}$ in.) lateral to the artery, and s breaks up into its branches, superficial and deep.

In **ligature of the femoral artery in Hunter's canal,** the line of the incision, in the r third of the thigh, must exactly follow that of the vessel. It is frequently made too l exposing the vastus medialis. Branches of the saphenous vein being removed, the fasci is slit up and the sartorius identified by its fibers descending medially. Those of the medialis are less oblique and are directed downward and laterally. The sartorius havin drawn to the medial side, usually, the aponeurotic roof of the canal is opened, and the fe sheath identified. The vein, here posterior and to the lateral side, is closely connected artery. The saphenous nerve and the nerve to the vastus medialis are superficial to the and should be avoided.

The close contiguity of the femoral artery and vein accounts for the comparative freq of arteriovenous aneurysms especially in the upper part, where the vessels are easily wo Their superficial position here further accounts for the facility with which malignant di e. g., epitheliomatous glands, may cause fatal hemorrhage.

The femur.—Access to the femur is best attained on the lateral side of the shaft along t of the lateral intermuscular septum (fig. 1144), the biceps being pulled backward, and the lateralis detached anteriorly. On the medial side the bone may be exposed by an incision ing from a point midway between the medial margin of the patella and the adductor tubere passing obliquely upward and laterally, but the parts here are more vascular. **Fractures** shaft usually occur about the center. The main tendency to displacement is of the lowe ment upward by the ham-strings. The upper fragment is displaced anteriorly in fra through the middle of the shaft. In fractures below the lesser trochanter—i. e., throu upper third of the femur the upper fragment will be flexed, abducted and rotated lat In the lower third the forward curve of the femur and its more superficial position expla fact that it is here that compound fractures of the femur may, occasionally, occur. **Os tion.**—The unstable nature of the tissues about the upper epiphysis, which appears at the the first year and unites about eighteen, and the frequency of tuberculous disease in early li well known. In the lower epiphysis ossification begins before birth, a point of medic importance in deciding whether a newly born child has reached the full period of uterine gest From this epiphysis, the level of which is denoted by a line drawn horizontally laterally fro adductor tubercle, and the vascular growing tendon of the adductor magnus—the origin exostosis is not uncommon. **Displacement of this epiphysis** (it unites about twenty) in bo and adolescence is a grave injury from the immediate risk of the popliteal vessels. The mi is usually done by overextension of the leg, as when this is caught in a rapidly moving car wheel; the epiphysis is carried forward in front of the diaphysis, the lower end of wh directed backward, endangering the vessels which are posterior and closely adjacent.

Amputation through the thigh.—This is usually performed in the lower third, by an and posterior flaps, the former being the longer, so as to ensure a scar free from pressure circular division of the muscles, vessels, and nerves. The vessels requiring attention a femoral, which lie at the medial side, and more posteriorly, the lower the amputatio descending branch of the lateral circumflex, and the termination of the profunda ne linea aspera. The femoral artery has a marked tendency to retract in the adductor Care should be taken not to include the saphenous nerve when the femoral vessels are tied to cut the sciatic cleanly and high up. When amputation has to be performed in the third of the thigh, the tendency of the iliopsoas to flex the shortened limb and thus bri sawn femur against the end of the stump must be remembered, and met by keeping the p propped up and the stump as horizontal as possible. Some of the structures now divide shown in figs. 1144, 1145).

The buttocks. Bony landmarks.—The finger readily traces the whole line of the iliac crest. Behind, it terminates in the posterior superior iliac sp which corresponds in level to the second sacral spine and the center of the sa liac joint. (Holden.)

The second sacral spine marks the lowest limit of the subdural sac and the cerebro fluid; it also corresponds to the upper border of the great sciatic notch. The first piece coccyx corresponds to the spine of the ischium. (Windle.) Its apex is in the furrow just b the lower part of the rectum.

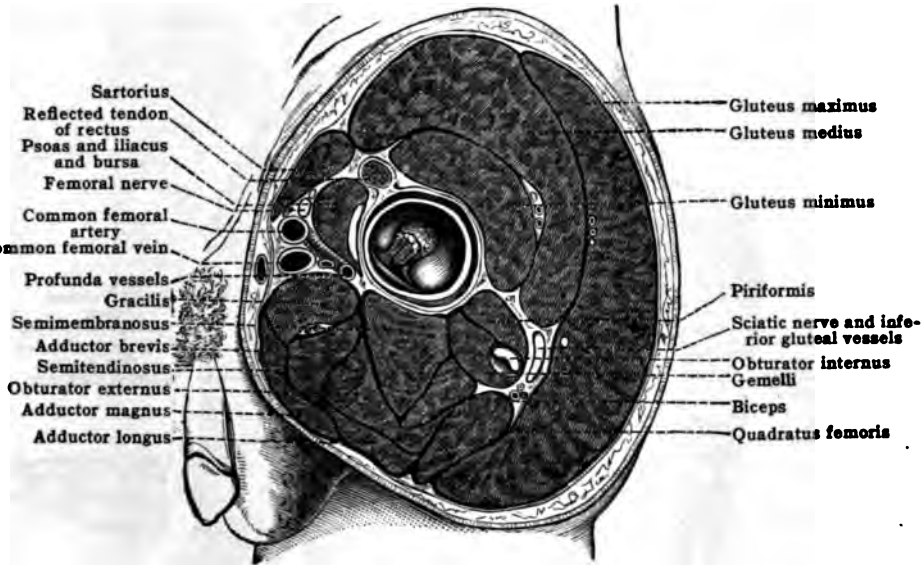
The **tuberosities of the ischium** are readily felt by deep pressure on either side of the In the erect position they are covered by the lower margin of the **gluteus maximus.** In s they are protected by tough skin, fasciæ, with coarse fibrous fat, and often by a bursa kn according to the occupation of the patients in whom it becomes enlarged, as weaver's, c man's, lighterman's or drayman's bursa. The skin of the buttock is coarse and diffic cleanse satisfactorily. The abundance of sebaceous glands accounts for the frequency of here.

Gluteus maximus.—The 'fold of the buttock' does not correspond to lower margin of this muscle. Thus, medially, it lies below the lower margi the muscle, as it runs laterally it crosses it, and comes to lie on the muscle. fold is really due to creasing of the skin adherent here to the coarsely fibro-f

tissue over the tuber ischii during extension. But in early hip disease, in which flexion of the joint is, with wasting of the muscle, almost invariably present, the fold disappears with well-known rapidity. The prominence of the buttock is mainly due to the gluteus maximus, especially behind and below, and in less degree to the other two glutei in front. Under the lower edge of the gluteus maximus the edge of the sacrotuberous (great sacrosciatic) ligament can be felt on deep pressure.

To mark out the upper border of the **gluteus maximus** a line is drawn from a point on the iliac crest 5 cm. (2 in.) in front of the posterior superior spine, downward and laterally to the back of the great trochanter. The lower border is marked out by a second line drawn from the side of the coccyx parallel with the former, and ending over the linea aspera at the junction of the upper and middle thirds of the thigh. It must be remembered that only the lower and internal fibers of the muscle are inserted into the gluteal ridge on the femur. The greater part of

FIG. 1145.—SECTION THROUGH THE HIP-JOINT AND GLUTEAL REGION. (×⅓.)



it is inserted into the fascia lata and iliotibial band and so into the lateral condyle of the tibia. Weakness of the gluteus maximus and tensor fasciæ latæ, with consequent laxity of the iliotibial band, gives rise to abnormal side-to-side passive mobility at the knee-joint in full extension.

Nerves and vessels.—The following **superficial nerves** can be marked in over the buttock (fig. 1163).

Behind the great trochanter, branches of the lateral femoral cutaneous; coming down over the crest, the lateral cutaneous branch of the last thoracic (about in a line with the great trochanter), and behind this the lateral branch of the iliohypogastric. Two or three offsets of the posterior primary branches of the lumbar nerves cross the hinder part of the iliac crest at the lateral margin of the sacrospinalis. Two or three twigs from the posterior divisions of the sacral nerves pierce the gluteus maximus close to the coccyx and sacrum, and ramify laterally. Finally, over the lower border of the gluteus maximus, turn upward branches of the posterior cutaneous (small sciatic) and its perineal branch (inferior pudendal), and the fourth sacral nerve.

Sciatic nerve (fig. 1146).—The point of emergence below the gluteus maximus and the track of this nerve (fourth and fifth lumbar and first three sacral nerves) will be given by a line drawn from a point a little medial to the middle of the space between the great trochanter and the tuber ischii to the lower part of the back of the thigh, where it usually divides into the tibial and common peroneal (internal and external popliteal) nerves.

To stretch the nerve, an incision about three inches long is made in the line of the nerve, beginning about 3.7 cm. (1½ in) below the gluteus maximus. The long head of the biceps which covers the nerve trunk and which is descending mediolaterally, is drawn medially. If the nerve is exposed lower down, the interval between the hamstrings is identified and these muscles drawn aside. The perineal branch of the posterior cutaneous (inferior pudendal) perforates the deep fascia about 2.5 cm. (1 in.) in front of the tuber ischii, and turns forward to supply the genitals.

bone after fracture, is a ready explanation of the difficulty of ensuring bony union here. (Macewen.) The patella is separated from the tibia by a pad of fat and a deep bursa, save at its insertion. Owing to the lowest part of the patella being thus separated from the joint by fat, fracture here does not, necessarily, open the joint.

FIG. 1147.—KNEE-JOINT AS SHOWN BY THE RÖNTGEN-RAYS, ANTEROPOSTERIOR VIEW. Epiphyses of the femur, tibia and fibula are visible. (Cf. fig. 261.)

The bone has the following *relation to the femur* in different positions:—(1) In **extension,** the **patella rises** over the condyles, and in full extension only the lower third of its articular surface **rests upon** that of the condyles; its upper two-thirds lies upon the bed of fat which covers the **lower** and front part of the femur. (2) In extreme **flexion,** as the prominent anterior surface **of the condyles affords** leverage to the quadriceps, the patella needs to project very little; thus, **only its upper** third is in contact with the femur, its lower two-thirds now resting on the pad of **fat between** it and the tibia. (3) In **semiflexion** the middle third of the patella **rests upon the most prominent** part of the condyles. (Humphry.) While the bone now affords **the greatest**

amount of leverage to the quadriceps, it is also submitted to the greatest amount of strai this muscle, which is acting almost at a right angle to the long axis of the patella. This p may therefore be called the 'area of danger,' as, in a sudden and violent contraction, the may be snapped across by muscular action, aided by the resistance given by the condy the same way as a stick is snapped across the knee. The amount of separation of the fra in a fracture of the patella is due chiefly to the extent to which the lateral tendinous exp of the vasti are torn; to a less degree to the hemorrhage from the numerous articular (p. 1448) and synovial effusion. The lower fragment is usually the smaller, and its fra surface tilted forward; that of the upper one usually looks backward.

The patella, the largest of the sesamoid bones, ossifies by a center which appears fr third to the fifth year. The process is completed about puberty. The rareness with necrosis and caries occur here, when the exposed situation of the bone is remembered, is explained by the density of its tissue, especially in front, and the intimate blending of the fibers with its periosteum. When the knee-joint is bent, the trochlear surface of the fem be made out, with some difficulty, underneath the quadriceps expansion. The upp lateral angle of this surface forms a useful landmark (Godlee) as a line drawn from it adductor tubercle marks the level of the lower epiphysis of the femur.

Dislocation of the patella.—The following anatomical facts account for this taking much more frequently laterally:—(1) The medial edge of the patella is more prominer thus more exposed to injury; it is also well supported, as is seen when, the parts being r the fingers are insinuated beneath each border. (2) The pull of the extensor upon the p ligamentum patellæ, and tibia is somewhat laterally, as the tibia is directed a little la to the femur, to meet the medial direction of this bone; the femora being directed medially to bring the knee-joints nearer the center of gravity, and, so, counterbalance their wide s tion above at the pelvis. The lateral pull of the quadriceps upon the patella is, in all n action of the muscle, counteracted by the space taken in the trochlear surface by the l condyle, this being wider and creeping up higher, and having a more prominent and thu tective lip. In violent contraction, however, these counteracting points may be overcor

The condyles of the femur and tibia.—It should be noted that on the m side the prominence of the medial epicondyle of the femur is well marked that of the tibia is less so, while on the lateral side this condition is reve Descending to the lateral condyle of the tibia, the iliotibial band of the f lata can be traced. The more distinct lateral condyle is a good landmar opening the joint in amputation and excision. It also indicates the lower of the synovial membrane of the knee-joint.

Farther back are the biceps and fibular collateral (long external lateral) ligament. Th on the medial side between the femoral and tibial condyles is the place for feeling for a disp medial meniscus (fibrocartilage) in 'internal derangement' of the knee, and also for 'lippi suspected osteoarthritis. On each femoral epicondyle, posteriorly, in a thin subject, can h its tubercle, which gives attachment to the collateral ligament. Owing to their being p behind the center of the bone, these ligaments become tight in extension. On the uppe posterior part of the medial femoral epicondyle the adductor tubercle and the vertical tend the adductor magnus can be felt during flexion. This bony point is a guide to the lowe physis, the ossification of which and its occasional exostosis have been mentioned. The m aspect of this epicondyle faces practically in the same direction as the head of the femur.

A *sesamoid bone* is frequently found in the lateral head of the gastrocnemius poster the joint. The X-ray shadow cast by such a bone has occasionally been interpreted floating cartilage.

Ligamentum patellæ and tuberosity of tibia.—These, in a well-formed should, with the center of the ankle-joint, be all in the same straight line, a us point in the adjustment of fractures. (Holden.) Behind the upper half of ligament is the infrapatellar pad of fat; below, the lower half is separated f the tibia by a deep bursa. The tuberosity (tubercle) of the tibia is on a level the head of the fibula.

Occasionally, the ligamentum patellæ pulls upon the tuberosity of the tibia to such a tent that the epiphyseal cartilage becomes greatly widened. The tuberosity may even be rated. This widening of the cartilage is associated with marked pain and enlargement o tuberosity.

Prepatellar bursa.—This usually protects the lower part of the patella and upper pa the ligamentum patellæ. It is liable to be enlarged in those who habitually kneel much enlargement being either fluid or solid, and occasionally, in tertiary syphilis. Its close con tion with the patella and, at the sides, with the joint itself, is to be remembered in infe inflammations of the bursa. Usually the deep fascia, passing off from the sides of the pa upward to the thigh and downward to the leg, serves to conduct inflammation away from joint.

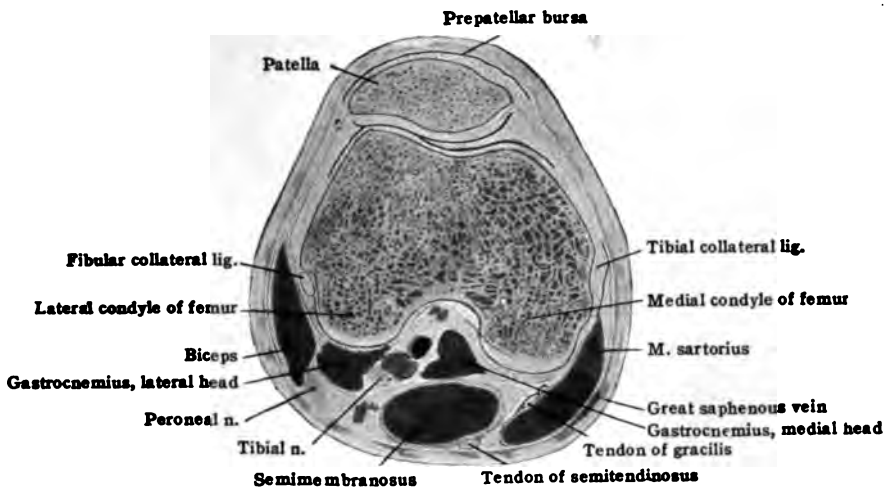
Synovial membrane (fig. 1149).—This, the largest of the synovial membra forms a short *cul-de-sac* above the patella, between the quadriceps extensor the front of the femur, this process reaching about 2.5 cm. (1 in.) above trochlear surface of the femur. At its highest point this ***cul-de-sac*** communic

with another synovial, bursa-like sac lying between the quadriceps and front of the femur. Thus, synovial membrane will usually be met with 6.2 cm. (2½ in.) or more above the trochlear surface or the upper border of the patella when the limb is extended. Flexing the joint draws the membrane down very slightly.

During extension, the above pouch is supported by the articularis genu (subcrureus). Traced downward, the membrane reaches the level of the head of the tibia, being separated in the middle line from the upper part of the ligamentum patellæ by fat. It here gives off to the intercondyloid notch the patellar synovial fold (ligamentum mucosum), with its free lateral prolongations, the alar folds (ligamenta alaria). These three so-called ligaments contain fat, the processes not only padding gaps, but also meeting concussions.

The enlargement of these processes, under conditions not yet understood, may certainly be a cause of 'internal derangement,' and simulate a loosened meniscus. But the synovial membrane of this joint is not only the largest: it is also the most complicated, a fact accounting for the grave peril of infective arthritis, and the well-known difficulty of effective drainage and cleansing this joint. Thus 'it passes over the greater portion of the crucial ligaments, but the posterior surface of the posterior crucial, which is connected by means of fibroareolar tissue

FIG. 1148.—HORIZONTAL SECTION OF THE KNEE-JOINT. (× ½). (Braune.)



to the front of the ligamentum posticum, and the lower portions of both crucial ligaments, where they are united together, of course cannot receive a complete covering from the membrane' (Morris.)

From the above ligaments the membrane is conducted, lining the lower part of the capsule and other ligaments, to the menisci (semilunar cartilages) first over their upper surfaces to their free borders, and then along their under surfaces to the tibia. Between the lateral of these and the upper and back part of the tibia is a prolongation of the synovial membrane to facilitate the play of the popliteus tendon.

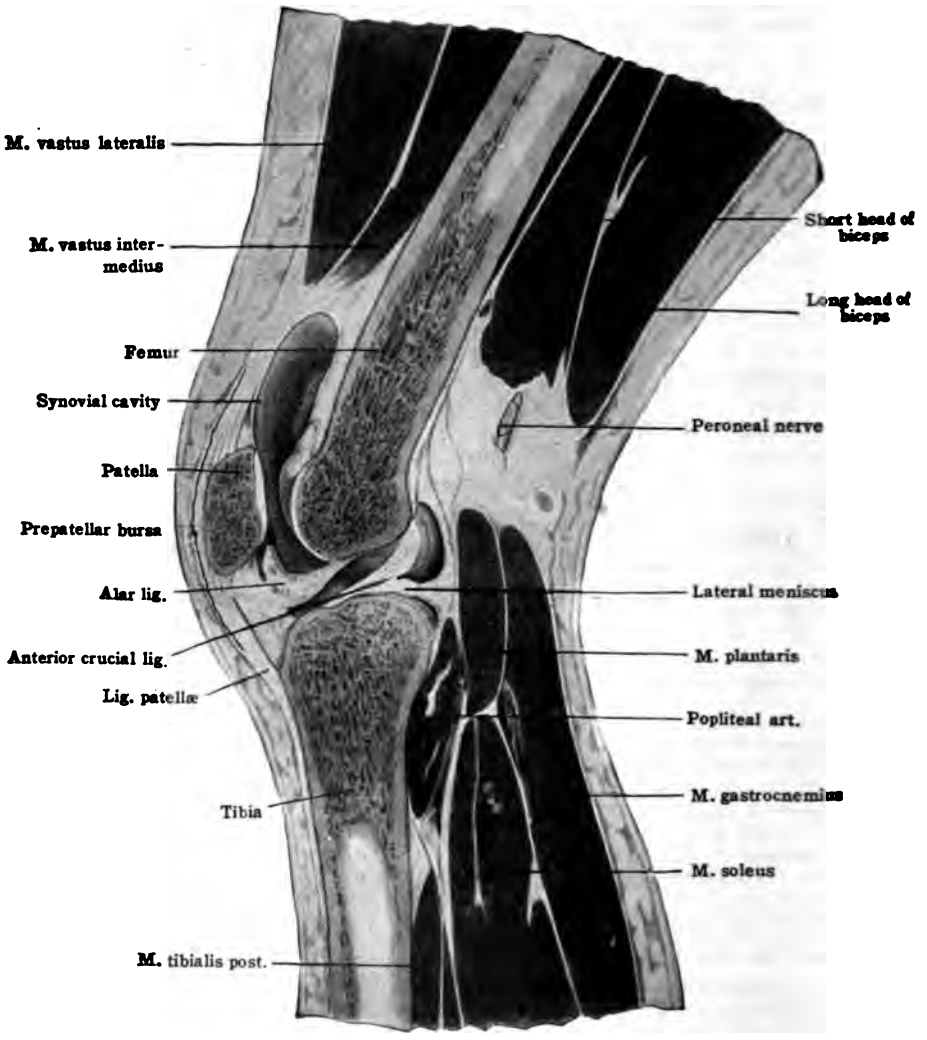
Finally, amid the complications of this synovial membrane, its communication with some of the bursæ mentioned below, and occasionally with the superior tibiofibular joint, is to be borne in mind. In effusion the bony prominences are obliterated, and the patella 'floats.' The knee-joint is easily opened by free lateral incisions lying midway between the margins of the patella and the tuberosities of the condyles.

Structures on the head of the tibia.—From before backward these are:—(1) Transverse ligament. (2) Anterior end of medial meniscus (fibrocartilage). (3) Lower attachment of anterior crucial. (4) Anterior end of lateral meniscus blending with (3). (5) Posterior extremity of lateral meniscus giving off a strong process to posterior crucial. (6) Posterior extremity of medial meniscus. (7) Posterior crucial ligament. The menisci serve as buffer-bonds and cushions between the contiguous bones.

The more frequent displacement of the medial meniscus is explained by—(*a*) its greater fixity, and, therefore, its feeling strains more. Thus, in addition to weaker attachments to the coronary and transverse ligaments, it is connected all along its convex border with the inside of the capsule, and strongly with the tibial collateral ligament. The lateral meniscus, on the other hand, is more weakly attached to the capsule, especially opposite to the popliteus tendon, and has no tie to the fibular collateral ligament. (*b*) When, in the erect position, the knee-joint is rotated laterally and slightly flexed, a common position, an especial strain is thrown upon the very important tibial collateral ligament, and from the above-mentioned connection, on the medial meniscus also.

Position of knee-joint in disease.—In inflammatory effusion, the position which accommodates the collection of fluid is one of moderate flexion, the ligaments being now m relaxed. Later on, when the ligaments are softened, the hamstrings obstinately displac leg backward, the tibia being rotated laterally by the biceps. The anteroposterior displace is always more marked than the lateral. In straightening an ankylosed joint, the resistar the shortened lateral, crucial, and posterior ligaments, and the facility with which a soft upper epiphysial line of the tibia may give way, must never be forgotten. **Erasion and exc** —The extent and complications of the synovial membrane render attention to the follc points imperative:—(1) Free exposure of the joint usually by an anterior curved incisior medial extremity of which must not damage the great saphenous vein. (2) The extent c

FIG. 1149.—VERTICAL SECTION OF THE KNEE-JOINT IN THE ANTEROPOSTERIOR DIREC (The bones are somewhat drawn apart. The synovial bursa usually present above the u synovial *cul-de-sac* is not shown.) (After Braune.)

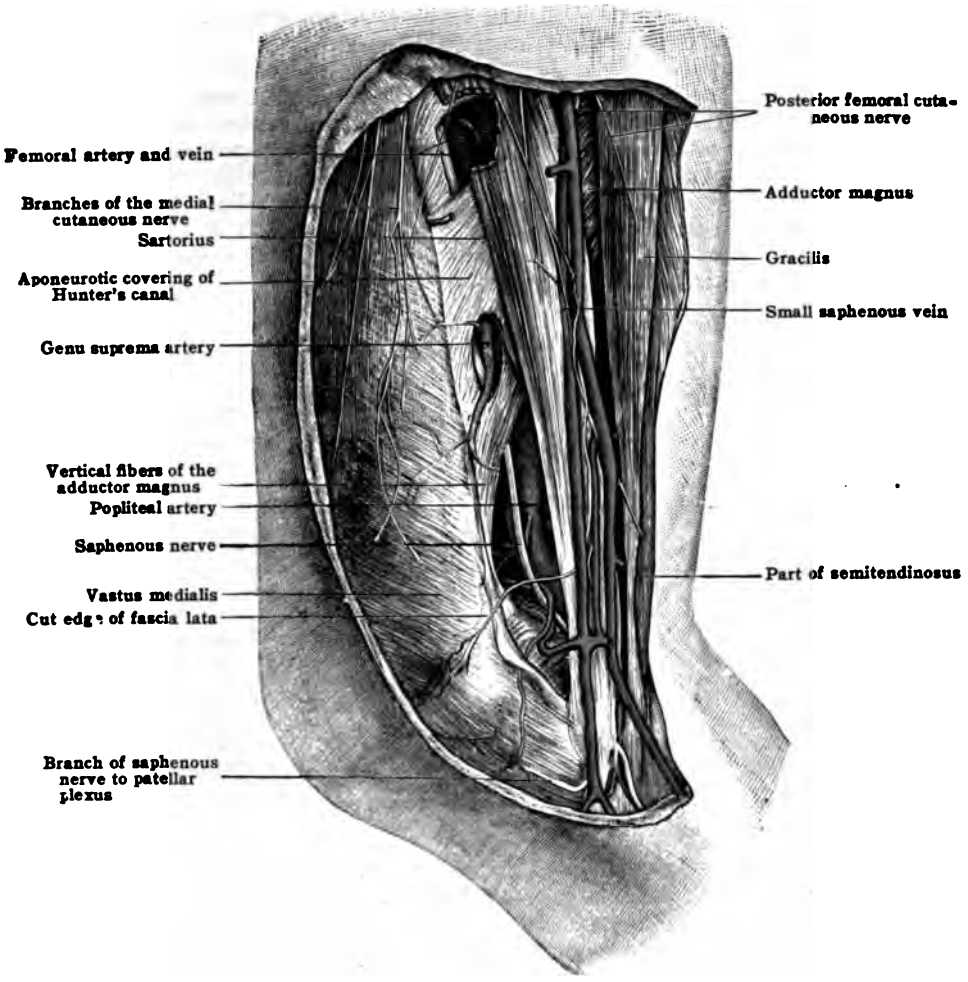


pouch under the quadriceps, it may be for 5 cm. (2 in.) above the patella, and the lateral rec under the vasti. The pouches at the back of the joint are far more difficult to deal with, the partial covering of the posterior crucial ligament, the proximity of the popliteal ar the pouches in relation to the popliteus, gastrocnemii, and back of the femoral condyles. **erasion,** the cartilage and bone, where diseased, are removed with a gouge. Owing to removal, in addition to the synovial membrane, of the menisci and crucial ligaments, and damage to lateral and patellar ligaments, there is a most obstinate tendency to flexion after In **excision,** to avoid injury to the epiphysis, the section of the femur should not pass hi than through the upper third of the trochlear surface. Of the tibia, only 12 mm. (½ should be removed.

Genu valgum.—Here the natural angle at which the femur inclines medially to the is increased. As shown by v. Mikulicz, this is due to an abnormal growth downward of medial part of the femoral diaphysis, the epiphysial line being gradually altered from on

right angles to the shaft to one which runs obliquely from without downward and medially. The femur is not only elongated on its medial side, but bent at its lower end, the concavity of the curve being lateral. Other changes have to be remembered. Pes valgus very commonly coexists, and in the tibia there may be a compensatory curve, the concavity being medial, in the lower third, or an analogous alteration in the line of the upper epiphysis may be present, its direction being no longer at a right angle with the shaft, but oblique. In Sir W. Macewen's supracondyloid osteotomy, a longitudinal incision, about 3.7 cm. (1½ in.) long is made where the following lines meet, viz., one transverse, a finger's breadth above the upper margin of the lateral condyle, and one longitudinal, 1.2 cm. (½ in.) in front of the adductor magnus tendon. The bone is divided in front of the genu suprema and above the superior medial articular artery, above the epiphysial line and behind the upward extension of the synovial membrane under the quadriceps.

FIG. 1150.—MEDIAL DISSECTION OF THE POPLITEAL REGION.
(From a dissection in the Hunterian Museum.)



The following **bursæ about the knee-joint** must be remembered. Some, it will be seen, are much more constant than others:—

A. **In front.**—(1) One between the patella and skin, the bursa prepatellaris subcutanea (fig. 1149); (2) a deeper one between the ligamentum patellæ and the upper part of the tibia; (3) between the skin and the lower part of the tuberosity of the tibia. This is not constant.

B. **On the medial side.**—(1) One between the medial head of the gastrocnemius and medial condyle, often extending between the above muscle and the semimembranosus. This is the largest of the bursæ about the knee-joint, and, after adult life, usually communicates with the knee-joint. But, owing to the narrow communication, it is rarely possible, when the parts are relaxed by flexion of the joint, to empty the cyst. For its removal a straight incision is made over the most prominent part of the swelling, its neck found by drawing aside the tendons. A ligature is then pushed high up around the neck, and the cyst cut away. (2) One superficial to the tibial (collateral) ligament, between it and the tendon of the sartorius, gracilis, and semitendinosus. (3) One beneath the ligament, between it and the tendon of the semimembrano-

sus. (4) One between the medial condyle of the tibia and the semimembranosus. (5 between the semimembranosus and semitendinosus. Of the above bursæ, the first two are constant. The second and third are often one bursa prolonged.

C. **On the lateral side.**—(1) One between the lateral head of the gastrocnemius a condyle; (2) one superficial to the fibular collateral ligament between it and the biceps t (3) one under the ligament between it and the popliteus tendon; (4) one between the po tendon and the lateral condyle of the femur. This is usually a diverticulum from the sy membrane of the knee-joint, and may enlarge to form a swelling (hygroma) in the po fossa.

The following explanations may be given of an inflamed knee-joint usually taki flexed position:—(1) By experimental injections, Braune found that the capacity of the sy sac reaches its maximum with a definite degree of flexion, i. e., at an angle of twenty-five d (2) As the same nerves supply the synovial membrane and the muscles which act up joint, reflex spasm of the flexors will help to explain the flexed position. (Hilton.)

Anastomoses around the front and sides of the knee-joint (figs. 538, 11 The most important of these take the form of **three transverse arches.** The **highest** passes through the quadriceps fibers just above the upper edge patella. It is formed by a branch from the deep division of the genu sup (anastomotica magna) and one from the lateral circumflex and superior l articular. The middle and lowest arches lie under the ligamentum patellæ. The **middle arch,** formed by branches from the genu suprema and sup medial articular on the medial side, and the inferior lateral articular, o lateral, runs in the fatty tissue close to the apex of the patella. (3) The l **arch** lies on the tibia just above its tuberosity, and results from the anasto of the recurrent tibial and the inferior medial articular. Seven arteries take place in this series of anastomoses.

POPLITEAL SPACE

The diamond-shaped popliteal space is shown in fig. 1151. In flexion hollow of this space appears; in extension it is obliterated and its boundari ill-defined the only ones now to be made out being the semitendinosus an biceps.

Popliteal tendons.—When the knee is a little bent and the foot rests on the groun following can be made out:—on the *lateral aspect*, behind the iliotibial band, and descend the prominence on the lateral side of the head of the fibula, is the tendon of the biceps. prominence also gives attachment to the fibular collateral ligament, which splits the t into two parts. Behind is the apex (styloid process) from which the posterior part fibular collateral ligament arises. Parallel and close to the medial border of the tendo peroneal nerve descends, as a rounded cord, to cross the neck of the fibula and enter the p eus longus. In tenotomy of the biceps an open incision should be employed to avoid inj the nerve and insure the division of any contracted fascial bands. On the *medial side* th dons are thus arranged: Nearest to the middle of the popliteal space is the long and more sl tendon of the semitendinosus; next, the thicker tendon of the semimembranosus; this an gracilis, which comes next, appear as one tendon, but by a little manipulation the finger c made to sink into the interval between the semimembranosus, with its thick rounded h laterally and the gracilis medially. The sartorius can easily be thrown into relief on the m side of the joint by telling the patient to raise the leg extended, the limb being rotated lat and one leg crosses over the other.

Popliteal vessels (fig. 1150, 1151, 1155).—The **artery** traverses this s from above downward, appearing beneath the semimembranosus, a little t medial side of the middle line, and then passing down in the center of the spa the interval between the gastrocnemii. Its course corresponds with a line d from the medial side of the hamstrings to the center of the lower part of the s The artery bifurcates on the level of a line corresponding to the tuberosity c tibia. It lies on the popliteal surface of the femur, the oblique popliteal liga and the popliteus. It is the second of these structures which usually pre popliteal aneurism and abscess from making their way into the joint.

The **popliteal vein,** intimately adherent to the artery, lies to the lateral side abov crosses to its medial side below. The popliteal sheath is also unusually strong. The **nerve** crosses the artery in the same direction as the vein, by which it is separated fro artery. This nerve is the direct continuation of the sciatic nerve (fig. 1151), and enter into the space than its fellow branch. The close relation of the vein and nerve explai early stiffness of the knee, the pains below, often called 'rheumatic,' and the edema, in po aneurism; also the pulsation of swellings not aneurismal.

The **superior articular arteries** (figs. 1151, 1153, 1155) course laterally and medially in ately above the femoral condyles; the way in which they cling closely to the bone here provision to prevent overstretching of the artery; the inferior one lies just above the head

fibula and below the medial condyle of the tibia. The deep part of the genu suprema artery runs in front of the tendon of the adductor magnus; the superficial with the saphenous nerve.

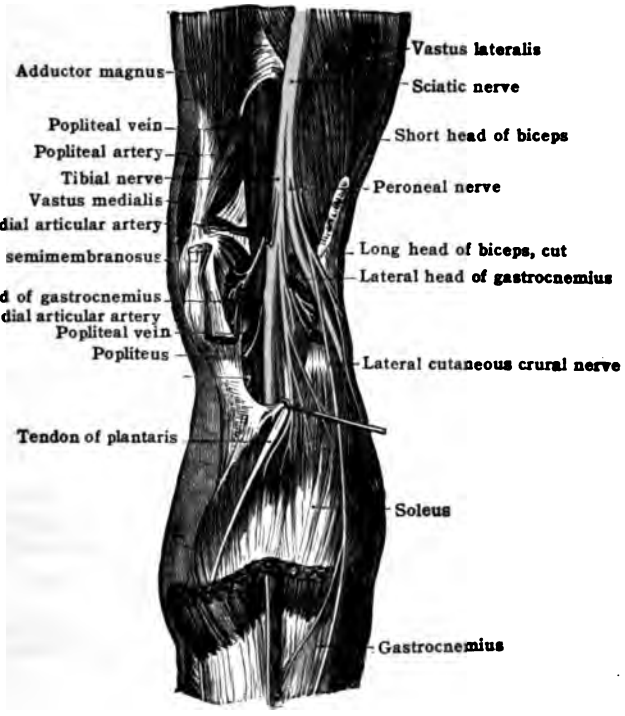
The **popliteal artery may be ligatured**—(A) **Behind,** in the upper part of the popliteal space, just after its emergence from under the semimembranosus. Here, for a short space of about 2.5 cm. (1 in.), the vessel is comparatively superficial after division of the fasciæ. The nerve is generally seen first, and, with the vein, must be drawn laterally. (B) **From the front,** at the medial side. The thigh being flexed, abducted, and rotated laterally, a free incision is made parallel and just behind the adductor magnus tendon, commencing at the junction of the middle and lower third of the thigh. The sartorius and the hamstrings are drawn backward, and the adductor magnus forward. Care must be taken of the genu suprema (fig. 1150). The space between the hamstrings and the adductor magnus being carefully opened up, the artery will be found in fatty areolar tissue. The vein and tibial nerve are on the lateral side of the vessel. The collateral circulation (fig. 1140) depends chiefly on the genu suprema.

The **small saphenous vein** perforates the roof of the popliteal space in its lower part. As a rule, it is not visible, unless enlarged.

The **popliteal nodes** are not to be felt unless enlarged.

Bursæ in the popliteal space.—These have been already mentioned (p. 1447).

FIG. 1151.—DEEP VIEW OF THE POPLITEAL SPACE. (Hirschfeld and Leveillé.)



THE LEG

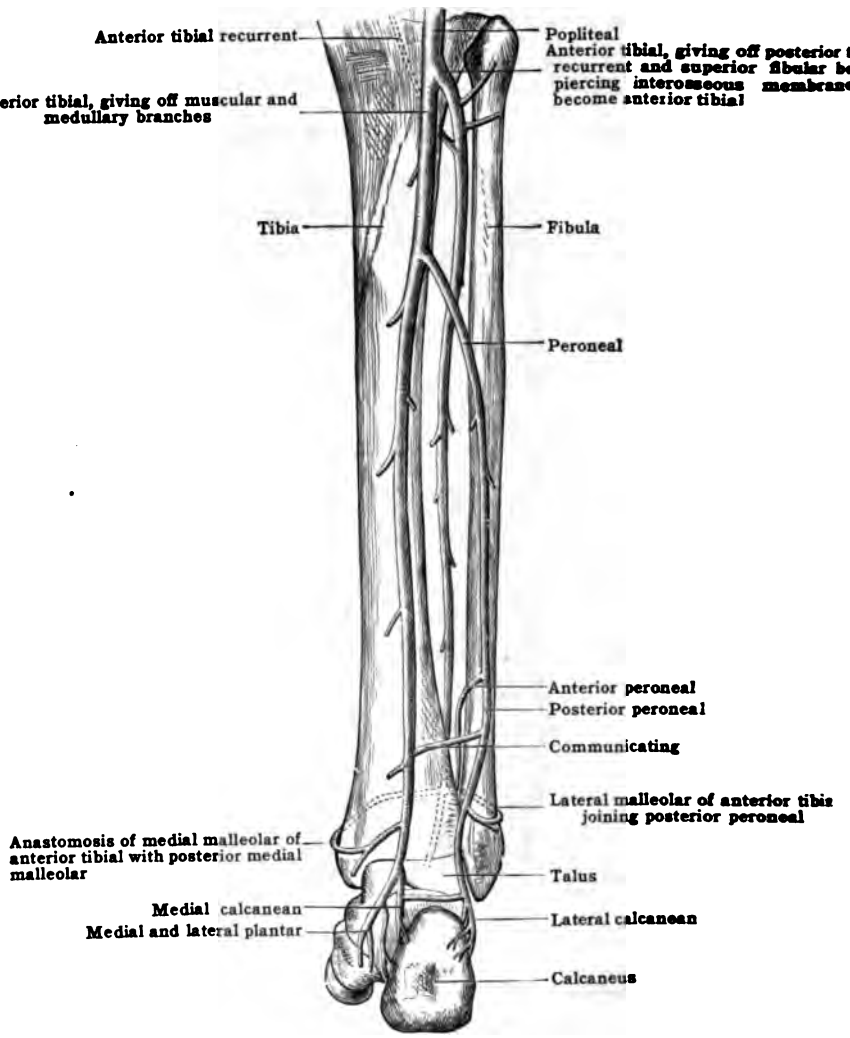
The skin.—The proneness of the skin to dermatitis in the lower third of the medial and front aspect of the leg as a result of varicose veins is well known. The close contiguity of the periosteum to the skin here accounts for the difficulty in healing chronic ulcers whose callous base has become fixed to the periosteum, and the frequency with which the upper fragment of a fractured tibia perforates the skin.

Bony landmarks.—From the *tuberosity* (tubercle) *of the tibia* descends the *anterior border* or 'shin.' This soon becomes sharp, and continues so for its upper two-thirds; in the lower third it disappears, to be overlaid by the extensor tendons. It is curved somewhat laterally above and medially below. The *medial border* can also be felt from the medial condyle to the medial malleolus. Between these two borders lies the *medial surface,* subcutaneous save above, where it is covered by the three tendons of insertion of the gracilis and semitendinosus and sartorius. The tibia is narrowest and weakest at the junction of the middle and lower thirds, the most common site of fracture. Behind the *medial malleolus,* part of the groove for and the tendon of the tibialis posterior can be felt. The

head of the fibula can be felt distinctly, but the shaft soon becomes buried an muscles till about 7.5 cm. (3 in.) above the *lateral malleolus*, where the expands into a large triangular subcutaneous surface.

This lies between the peroneus tertius and the other two peronei. The peroneus l overlaps the brevis, especially in the upper two-thirds of the leg. In the lower third the t tends to become anterior. Behind the lateral malleolus these tendons descend to the f a groove on its posterior border. The shaft of the fibula is placed on a plane posterior to of the tibia, and curves backward in a direction reverse to that of the tibia.

FIG. 1152.—ANASTOMOSES OF TIBIAL ARTERIES.

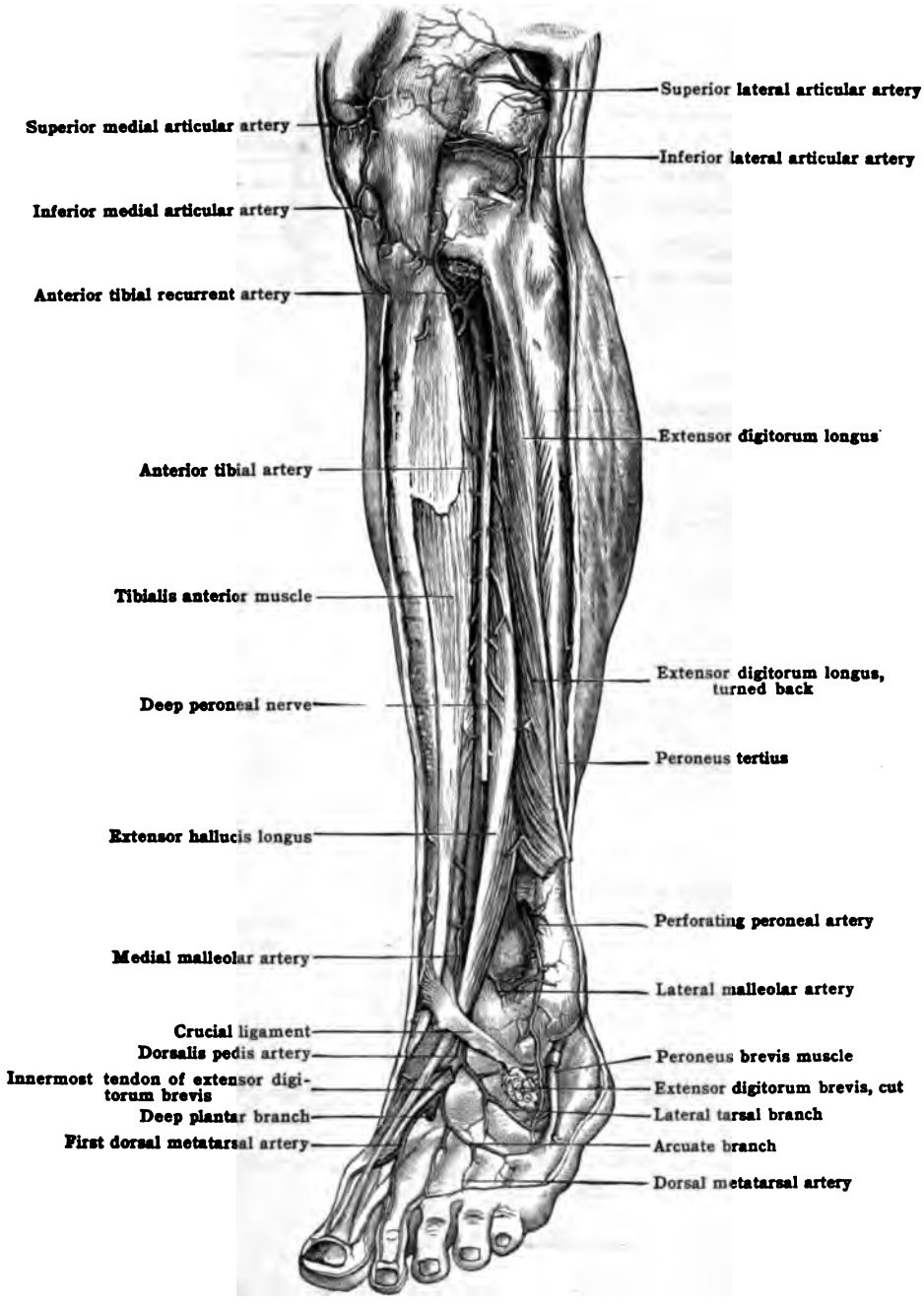


Muscular compartments and prominences.—When the muscles of the leg thrown into action by dorsiflexion and plantar flexion of the foot or by stand on the toes, several groups of muscles stand out on the surface, owing to cert compartments, and the origin of certain muscles from, and their separation the deep fascia. The bones and the two peroneal septa divide the leg into f compartments (fig. 1156).

These are, mediolaterally:—(1) A medial, corresponding to the medial surface of the t (2) An anterior, between the crest of the tibia and the anterior peroneal septum, atta to the anterolateral border of the fibula, and separating the extensors from the peronei. surface-marking would be a line from the front of the head of the fibula to the front of lateral malleolus. In this anterior compartment lie the extensor muscles and origin of peroneus tertius, and the anterior tibial vessels and nerves. (3) A lateral or peroneal c partment, lying between the anterior and posterior peroneal septa, the latter being atta to the posterolateral border of the fibula, and separating the peronei from the calf and d

flexors. This peroneal compartment, a narrow one, contains the two chief peronei and the peroneal (external popliteal) nerve and its three divisions. (4) Much the largest, this, the posterior, lies between the posterior peroneal septum and the medial border of the tibia, and contains the calf and deep flexor muscles, the posterior tibial vessels and nerves, and the peroneal artery and its posterior branch.

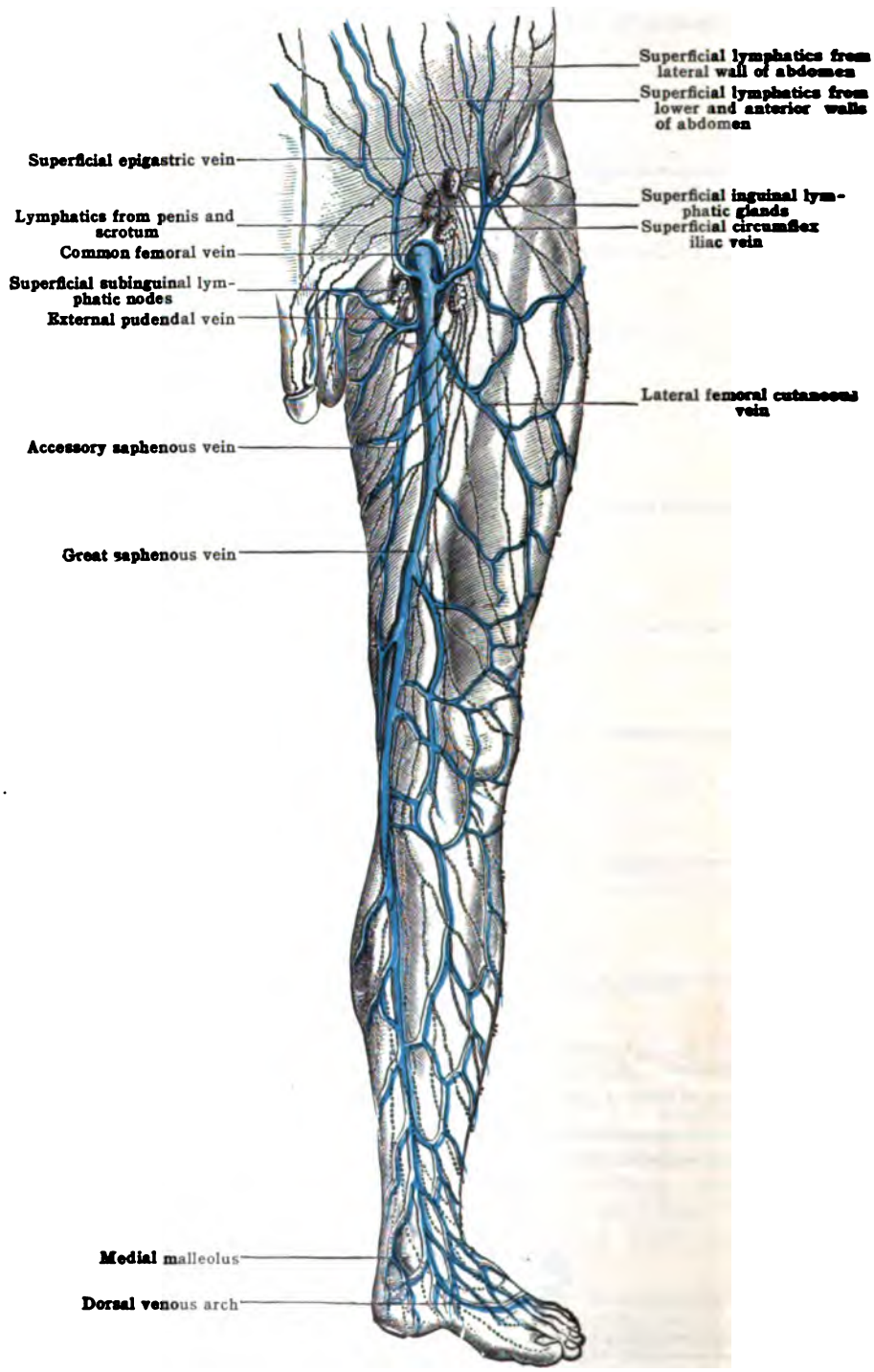
FIG. 1153.—THE ANTERIOR TIBIAL ARTERY, DORSAL ARTERY OF THE FOOT, AND PERFORATING BRANCH OF THE PERONEAL ARTERY, AND THEIR BRANCHES.



The space between the tibia and fibula in front is mainly occupied by the fleshy belly of the tibialis anterior; lateral to this, and much less prominent, is the narrower extensor digitorum longus; lateral to this, again, are the peronei longus and brevis. Lower down, in an interval between the tibialis and the extensor of the toes, the extensor hallucis, here almost entirely tendinous, comes to the surface. Behind, the prominence of the calf is mainly formed by the gastrocnemius. On the patient's rising on tip-toe, the tendo Achillis starts into relief from about the middle of the leg. Of the two heads of the gastrocnemius, the medial is seen to be the

larger. On either side of the tendon, but more distinctly on the lateral side, where it is less overlapped by the gastrocnemius, the soleus comes into view. Its muscular fibers are continued on the deep surface of the tendon to within a short distance of the heel. Between the tendon and the upper part of the os calcis is a bursa, occasionally the seat of effusion, as in gonorrhea.

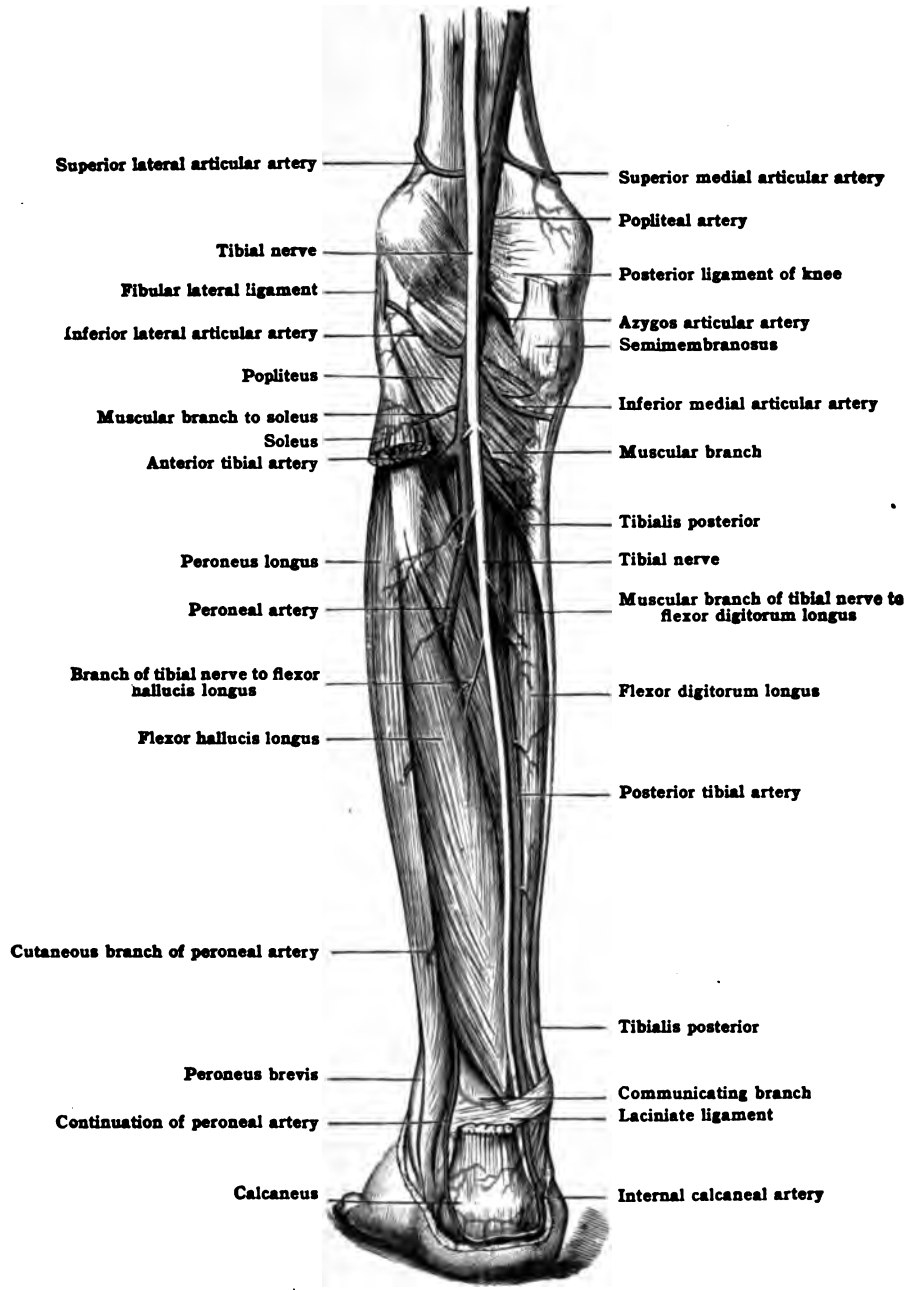
FIG. 1154.—THE SUPERFICIAL VEINS AND LYMPHATICS OF THE LEFT LOWER LIMB.


Superficial lymphatics from lateral wall of abdomen
Superficial lymphatics from lower and anterior walls of abdomen
Superficial epigastric vein
Lymphatics from penis and scrotum
Common femoral vein
Superficial subinguinal lymphatic nodes
External pudendal vein
Superficial inguinal lymphatic glands
Superficial circumflex iliac vein
Lateral femoral cutaneous vein
Accessory saphenous vein
Great saphenous vein
Medial malleolus
Dorsal venous arch

The bones.—Their relative position and curves have been mentioned (p. 1449). **Access.**—That to the **tibia** is easy along the medial aspect. The **fibula** is best explored by a free incision along the line of the posterior peroneal septum, which lies between the peronei and the muscles at the back (p. 1450). The presence of the superficial peroneal (musculocutaneous) nerve per-

forating the deep fascia in the lower third below and that of the the common peroneal (external popliteal) in relation to the neck of the fibula above, must be remembered. **Fractures.**—When, as is most frequent, the tibia gives way from indirect violence, the fracture is usually at the weakest spot, or the junction of the middle and lower thirds. The line of obliquity is generally marked, and from above downward and forward. The lower fragment, pulled upward by the powerful calf muscles, rides behind the upper, which projects forward under the skin. The

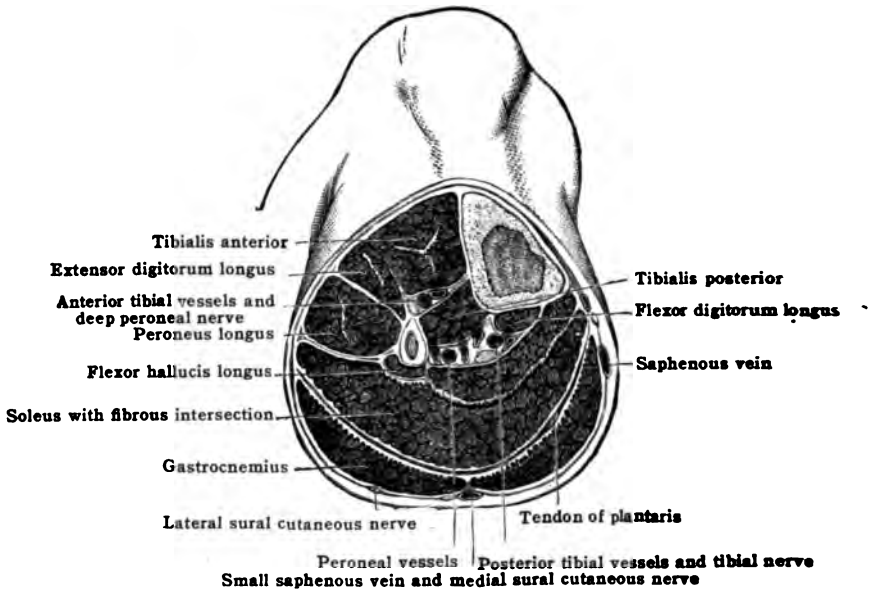
FIG. 1155.—POPLITEAL AND POSTERIOR TIBIAL ARTERIES.



fibula, bending more than the tibia, snaps at a higher level. Tenderness on pressure is the best guide here, as it is in suspected fractures of the upper tibia, transverse from direct violence. The most common variety of **fracture of the fibula** is that called after **Pott**, complicated with displacement of the foot. Here, from abduction of the foot, a severe strain is thrown upon the deltoid ligament, which gives way; the talus (astragalus) is pressed against the lateral malleolus, and the inferior tibiofibular ligaments resisting, the fibula yields 5 to 7 cm. (2 to 3 in.) above the ankle, the upper end of the lower fragment being usually displaced toward the tibia. If the deltoid ligament is strong, the strain often tears off the medial malleolus. The medial margin

of the foot is turned toward the ground, the lateral raised (pes valgus). The foot is also displaced backward. On the medial side of the ankle there is a marked projection of the lower end of the tibia; higher up, on the lateral side, a depression where the fibula is broken. The need of replacing the foot and the weight-bearing talus (astragalus) accurately, the fact that the ankle-joint is opened and the numerous tendons likely to be matted are the chief points to bear in mind. In **Dupuytren's fracture** there is not only fracture of the lower end of the fibula, but the inferior tibiofibular ligaments are now torn. The foot is displaced upward and laterally, together with the lower end of the fibula. **Epiphyses.**—The upper one of the tibia appears shortly before birth and includes the condyle and tuberosity (fig. 1147). It does not fuse with the shaft till the age of twenty or later. This fact and the powerful strain of the rectus on this epiphysis explain the obscure pain sometimes complained of in young adults much given to athletics, over the tibial tuberosity. The lower epiphysis, including the medial malleolus, appears in the second and joins about the eighteenth year. Separation here is not very uncommon up to puberty. In **osteotomy** of the tibia, simple or cuneiform, when the curve is anteroposterior as well as lateral, the close proximity of the tibialis anterior tendon to the lateral border of the crest must be remembered, and when the fibula does not yield to careful force, it, also, must be divided, or damage may be done to the superior and inferior tibiofibular ligaments, or to the epiphyses of the bones.

FIG. 1156.—UPPER SEGMENT OF A SECTION OF THE RIGHT LEG IN THE UPPER THIRD. (Heath.)



Vessels.—The **saphenous veins** should be carefully traced, owing to the tendency of these and their branches to become varicose. The **great saphenous** (figs. 1142, 1154), having passed from the arch on the dorsum over the medial malleolus, runs up close to the medial border of the tibia, where it is to be avoided in ligature of the posterior tibial, to the back of the medial condyle; here this vessel is to be remembered in operations on the knee-joint; then upward along the thigh, over the roof of the adductor (Hunter's) canal, to the fossa ovalis (saphenous opening) (p. 1438 and fig. 1154), where it joins the femoral by perforating the cribriform fascia and the femoral sheath. Four to six valves are present, chiefly in the upper part.

The 'dangerous area,' or that in which thrombosis is most likely to occur, reaches from the center of the thigh to the middle of the leg. (Bennett.) The saphenous nerve joins the vein below the knee, having been under the sartorius above this point (figs. 1143 and 1144). The surface-marking of the upper part of the vein is a line drawn from the posterior border of the sartorius or the adductor tubercle to the lower part of the fossa ovalis. The small saphenous vein passes behind the lateral malleolus, runs upward over the middle of the calf, and joins the popliteal by perforating the deep fascia in the lower part of the popliteal space. This vein is accompanied by the medial sural cutaneous (external saphenous) nerve throughout its course.

The **popliteal artery** bifurcates at the lower border of the popliteus, about on a level with the tuberosity of the tibia. About 5 cm. (2 in.) lower down the peroneal artery comes off from the posterior tibial (figs. 1152, 1155).

The course of the **posterior tibial** corresponds with a line drawn from the center of the lower part of the popliteal space to a point midway between the tip of the medial malleolus and the medial edge of the calcaneus.

In the lower third, the artery becomes more superficial, passing from beneath the calf muscles, lying between the tendo Achillis and medial border of the tibia, and covered only by the skin, deep fascia, and, lower down, by the laciniate (internal annular) ligament. It is here, in its close relation to the tendons of the tibialis posterior and flexor digitorum longus, that it is liable to be injured in the older methods of tenotomy. The nerve is medial above, lateral below (fig. 1155).

Ligature of the posterior tibial in the middle of the leg.—The following are the chief points in the technic. An incision, 7.5 to 10 cm. (3 to 4 in.) long, is made 1.2 cm. (½ in.) behind the medial border of the tibia, to avoid the trunk of the great saphenous. The deep fascia being freely opened, the medial head of the gastrocnemius is drawn backward. The tibial attachment of the soleus, thus exposed, is cut through carefully, so as to allow of identification of its central membranous tendon, which must not be confused with the deep intermuscular septum over the flexor. Any sural vessels are now tied. The above-mentioned special septum is next made out, passing between the bones (vertical line descending from oblique line of tibia and oblique line of fibula). On division of this septum the nerve usually comes into view, the artery lying more laterally. The needle is passed from the nerve; the venæ comitantes may be included. The muscles should now be fully relaxed by flexion of knee and plantar flexion of foot. The ligature will be placed below the peroneal artery. The posterior tibial in its upper part may also be ligated through a straight incision down the middle of the leg posteriorly. Ligation of the posterior tibial is followed by gangrene in a large percentage of cases.

The course of the **anterior tibial artery** corresponds with a line drawn from a point midway between the lateral condyle of the head of the tibia and the head of the fibula to one on the center of the ankle-joint.

This line corresponds to the lateral border of the tibialis anterior and the interval between it and the extensor digitorum longus (figs. 1152, 1153). This is shown when the first of these muscles is thrown into action. The accompanying nerve is in front in the middle third of the leg, lateral above and below.

Ligature of the anterior tibial artery at the junction of the upper and middle thirds of the leg. The limb being flexed and rotated medially, an incision is made, 7.5 to 10 cm. (3 to 4 in.) long, in the line of the artery, distant 2.5 cm. (1 in.) or more (according to the size of the leg) from the crest, and beginning about 5 cm. (2 in.) below the head of the tibia. If, on exposure of the deep fascia, the intermuscular septum between the tibialis and long extensor of the toes is not well defined, the fascia must be freely slit up in the line of the artery, and the sulcus felt for. A small muscular artery may lead down to the trunk. The foot is now dorsiflexed and the artery sought for deep on the interosseous membrane. The nerve should be drawn to the outer side. The venæ comitantes may be included in the ligature.

In **senile gangrene** the liability of the tibial arteries to disease and consequent thrombosis and interference with the collateral circulation accounts both for the extension of the disease and the difficulty in detecting pulsation.

The **peroneal artery** (figs. 1152, 1155) given off from the posterior tibial about an inch below the popliteus, or two inches below the head of the fibula, runs deeply along the medial border of this bone, covered by the flexor hallucis longus, the nerve to which accompanies the vessel.

It gives off the *anterior peroneal*, through the interosseous membrane, to the front of the lateral malleolus about an inch above the level of the ankle-joint. Its continuation, as the posterior peroneal, runs behind the malleolus, to join the anastomosis about the ankle-joint.

The **nutrient artery** of the tibia arises from the posterior tibial near its commencement. It is the largest of all the nutrient arteries to the shafts of long bones; that for the fibula comes from the peroneal.

As a general rule, in **amputation** 2.5 cm. (1 in.) below the head of the fibula, only one main artery—the popliteal—is divided. In amputations 5 cm. (2 in.) below the head of the fibula, two main arteries—the anterior and posterior tibials—are divided. In amputations 7.5 cm. (3 in.) below the head, three main arteries—the two tibials and the peroneal—are divided. (Holden.) (Cf. figs. 1152, 1156.) In an amputation through the middle of the leg, the anterior tibial artery would be found cut on the interosseous membrane between the tibialis anterior and the extensor hallucis longus, the deep peroneal nerve here lying in front of the vessel. The posterior tibial would be between the superficial and deep muscles at the back of the leg lying on the tibialis posterior, its nerve being to the lateral side. The peroneal would be close to the fibula in the flexor hallucis longus.

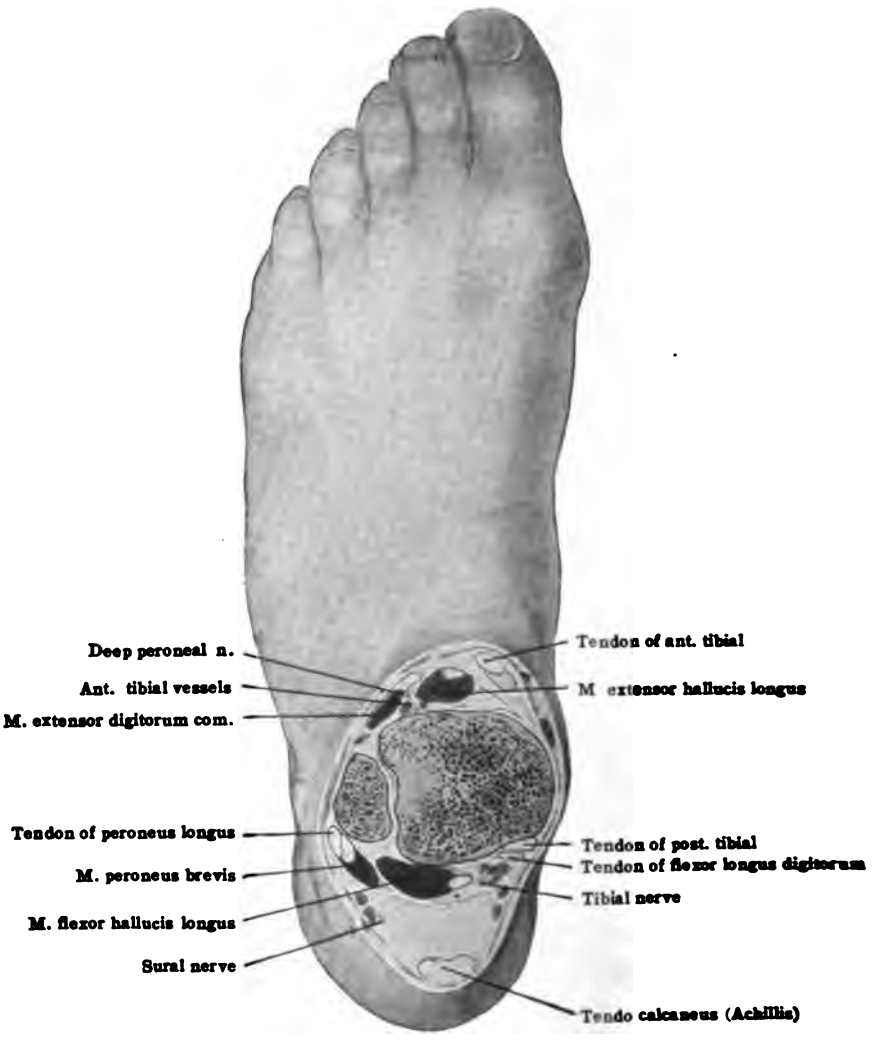
The **superficial peroneal** (musculocutaneous) nerve (fig. 1157), having passed through the peroneus longus and then between the peroneus longus and peroneus brevis, perforates the deep fascia in the lower third of the leg in the line of the septum between the peronei and extensors. Directly after, it divides into its two terminal branches.

Amputation of the leg.—To give one instance only, amputation at the seat of election, or a hand's-breadth below the knee-joint, will be alluded to. The above name was given because the pressure of the body is well carried on the prominences about the knee-joint, especially the tuberosity of the tibia, when the patient walks with the knee flexed on a "bucket" artificial limb. Thus the scar, being central, is here not of importance. Two broadly oval lateral flaps of skin and fasciæ are raised, and the remaining soft parts severed down to the bones with circular sweeps of the knife. In sawing the bone, the smaller size of the fibula and its

subperiosteally, leaving the tip and calcaneofibular, will admit of the insertion of a tube and good drainage if the foot is so slung as to keep its lateral aspect dependent.

Tendons.—(A) **In front of ankle** (figs. 1157, 1159).—Lateromedially are—(1) The tibialis anterior, the largest and most medial. This tendon appears in the lower third of the leg, lying just under the deep fascia, close to the tibia; then, crossing over the lower end of this and the ankle-joint, it passes over the medial side of the tarsus, to be inserted into the medial and lower part of the first cuneiform and the adjacent part of the first metatarsal. (2) The extensor

FIG. 1159.—HORIZONTAL SECTION THROUGH THE LOWER PART OF THE LEG. (After Braune.)



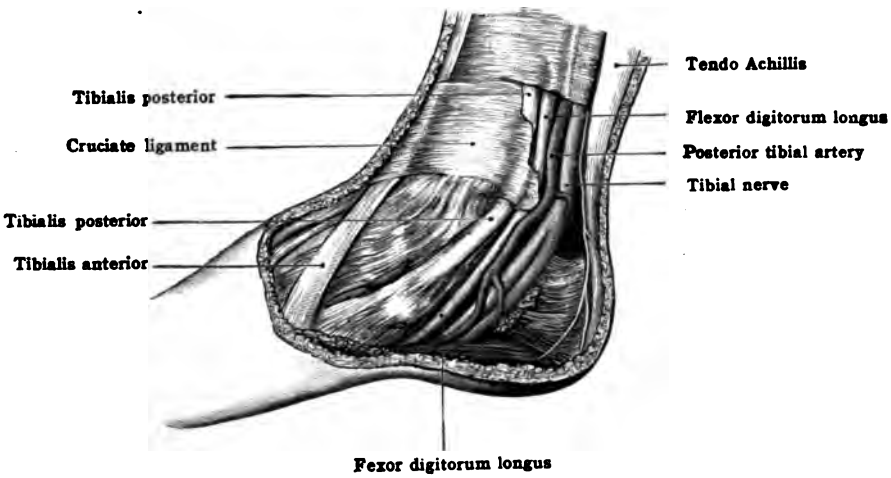
hallucis longus. This tendon, concealed above, appears low down in a line just lateral to the last, and then, crossing over the termination of the anterior tibial vessels and nerves (to which its muscular part lies lateral), it descends along the medial part of the dorsum to be inserted into the base of the last phalanx of the great toe. (3) and (4) The extensor digitorum longus and peroneus tertius enter a common sheath in the transverse crural ligament. The former then divides into four tendons, which run to the four lateral toes. The peroneus tertius is inserted into the upper surface of the base of the fifth (often also the fourth) metatarsal bone.

(B) **Behind.**—The tendo calcaneus (Achillis), the thickest of all tendons, begins near the middle of the leg, in the junction of the tendons of the gastrocnemii and, a little lower, (p. 1451) the soleus.

Very broad at its commencement, the tendon gradually narrows and becomes very thick. About 3.7 cm. (1½ in.) from the heel, or about the level of the medial malleolus, is its narrowest point. After this it again expands slightly, to be inserted into the middle of the back part of the calcaneus. The long tendon of the plantaris runs along its medial side, to blend with it or to be attached to the calcaneus. On either side of the tendo Achillis are well-marked furrows below. Along the medial, the tendon of the tibialis posterior and the posterior tibial vessels and nerve come nearer the surface. Along the lateral, the small saphenous vein (more superficially) ascends from behind the lateral malleolus.

(C) **On the medial side.**—The tendon of the tibialis posterior, which has previously crossed from the interspace between the bones of the leg to the medial side, lies behind the inner edge of the tibia above the medial malleolus, then behind this, being here under the flexor digitorum longus, the two tendons having become superficial on the medial side of the tendo Achillis. It then passes forward over the deltoid and under the laciniate (internal annular) ligament between the medial malleolus and the sustentaculum tali, and then below and close to the plantar calcaneonavicular ligament (*vide infra*), and so to its insertion, by numerous slips, into the tarsus and metatarsus, especially the tuberosity of the navicular. The tendon of the flexor hallucis longus cannot be felt. Having passed medially from the fibula, it crosses the lower end of the tibia in a separate furrow, then grooves the back of the talus, and passes under the sustentaculum tali on its way to its insertion.

FIG. 1160.—RELATIONS OF PARTS ON THE MEDIAL ASPECT OF THE ANKLE. (Heath).



The arrangement of the structures on the medial side of the ankle from above downward, and mediolaterally, is as follows (fig. 1159):—tibialis posterior, flexor digitorum longus, companion vein, posterior tibial artery, companion vein, tibial nerve, flexor hallucis longus. The tibiales posterior and anterior turn the sole medially, antagonizing the peronei. They also bear a large share in maintaining the longitudinal arch of the foot. The flexors not only act upon the toes, but aid the calf muscles in straightening the foot upon the leg in walking or standing upon tiptoe; hence the value of educating them in cases of flat-foot.

(D) **Tendons on the lateral aspect.**—The tendons of the two peronei, which arise from the fibula between the extensor digitorum longus and flexor hallucis longus, pass behind the lateral malleolus, the brevis being nearer to the bone (fig. 1159). They then pass forward over the lateral surface of the calcaneus, separated by the peroneal tubercle when present, and diverge.

The brevis—the upper one—passes to the projection at the base of the fifth metatarsal; the longus, lying below the brevis on the calcaneus, winds round the lateral border of the foot, grooving the lateral border and under surface of the cuboid. Finally, crossing the sole obliquely forward and medially, it is inserted into the adjacent parts of the first cuneiform and the back part and under surface of the first metatarsal. While in connection with the under surface of the cuboid, this tendon is covered in by a sheath from the long plantar ligament, and often contains a sesamoid bone. The two peronei evert the foot, as is seen in talipes valgus and in fracture of the lower end of the fibula; the peroneus longus aids in the support of the arch of the foot (p. 1464), and, by keeping the great toe on the ground, is important in the third stage of walking, skating, etc.

Annular ligaments and synovial membranes of tendons.—These strap bands of deep fascia, which serve to keep the above tendons in position, three in number, viz.:—

(A) **Lateral.**—This, the superior peroneal retinaculum, extends from th of the lateral malleolus to the lateral surface of the calcaneus. It keeps the peronei in place, and surrounds them behind the fibula in one sheath with a si synovial sac, which extends upward into the leg for 3.7 cm.(1½ in.), and s two processes into the two sheaths in which the tendons lie on the calcar Further on, while in relation with the cuboid, the peroneus longus has a se synovial sheath.

(B) **Medial.**—This, the laciniate ligament, crosses from the medial malle to the medial surface of the calcaneus.

Beneath the laciniate ligament are the following canals:—(1) For the tibialis post This tendon-sheath is lined by a synovial membrane extending from a point 3.7 cm. (1½ above the malleolus to the navicular. (2) For the flexor digitorum longus. The syn sheath of this tendon is separate from that of the closely contiguous tibialis posterior extends upward into the leg about as high as the sheath just given. It reaches down int sole of the foot; but where the tendon subdivides to enter the thecæ, each of these is line a separate synovial sheath. Next comes (3) a wide space for the posterior tibial vessel nerve; and, lastly, (4) a canal, like the other two, with a separate synovial sheath, for the te of the flexor hallucis longus. The lower margin of this annular ligament gives an attach to the abductor hallucis and blends with the plantar fascia. The medial calcaneal vessel nerve perforate the ligament.

(C) **Anterior annular ligament.**—This is a double structure. (1) **U (transverse crural ligament), above the level of the ankle-joint,** and tying tendons down to the lower third of the leg, passes transversely between the a rior crests of the tibia and fibula. Here is one sheath only, with a synovial m brane for the tibialis anterior. (2) **Lower, over the ankle-joint.** This band. **cruciate ligament,** is arranged like the letter ≺, placed thus. It is attached b root to the calcaneus, and by its bifurcations to the medial malleolus and pla fascia.

This arrangement of the branches of this ligament is not constant. In this, the l annular ligament, there are usually three sheaths with separate synovial membranes- most medial (the strongest in each) for the tibialis anterior, the next for the extensor hal longus, and the third common to the extensor communis and peroneus tertius. The exte digitorum brevis has a partial origin from this ligament.

Points in tenotomy and guides to the tendons.—The **tendo Achillis** should be div about 3.7 cm. (1½ in.) above its insertion, its narrowest point, which is about on a level wit medial malleolus. The knife should be introduced on the medial side and close to the ten so as to avoid the posterior tibial artery (fig. 1160).

The **tibialis anterior** may be divided about 25 mm. (1 in.) above its insertion into the cuneiform, a point which is below the level of its synovial sheath. The tendon has here dorsalis pedis on its lateral side, but separated by the tendon of the extensor hallucis lor The knife is introduced on this side.

The **tibialis posterior.**—The usual rule for dividing this tendon is to take a point 5 (2 in.) above the medial malleolus, and as accurately as possible midway between the ant and medial borders of the leg. This point will give the medial margin of the tibia, in clos position to which the tendon is lying, and is a point at which the tendon is rather farther the artery than it is below, and is also above the commencement of its synovial sheath sharp-pointed knife is used first to open the sheath freely, and then a blunt-pointed or divide the tendon. The flexor digitorum longus is usually cut at the same time.

Owing to the risk of injury to the posterior tibial vessels, the difficulty of ensuring div of the tendons, the following open method is, nowadays, superior, being more certain, and mitting of division of ligaments, e. g., talonavicular and anterior part of deltoid (syndesmot of Parker), which are always contracted in advanced talipes equinovarus. A V-shaped with its apex over the first metatarsal bone and its two limbs starting, the lower below margin of the plantar fascia on a line with the medial malleolus, the upper from a point the head of the talus, is turned backward. The plantar fascia is divided, the tibialis anter found, near its insertion, under the upper lip of the wound, the tibialis posterior and the f digitorum longus in the lower, the former close to the navicular. If necessary, the calca and talonavicular and anterior part of the deltoid ligaments can be divided also.

Peronei.—The peronei longus and brevis may be divided 5 cm. (2 in.) above the la malleolus, so as to be above the level of their synovial sheath. The knife should be inse very close to the bone, so as to pass between the fibula and the tendons. Division below lateral malleolus by a small flap is easier.

THE FOOT

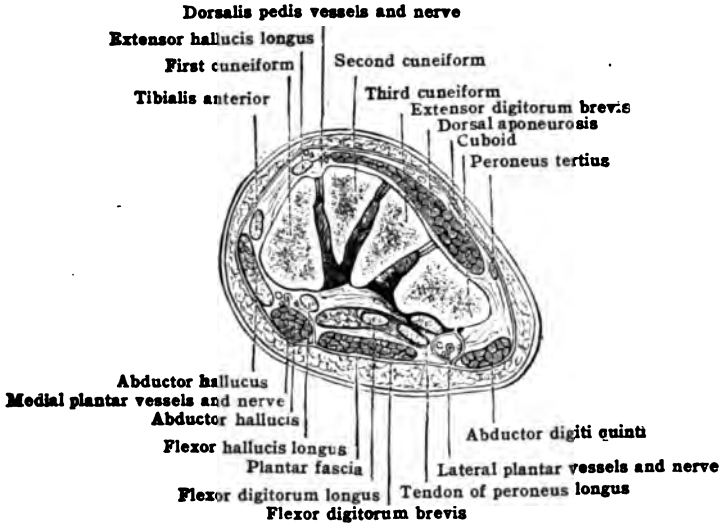
Bony landmarks.—The following are of the greatest practical importa owing to the operations which are performed upon the foot.

(A) **Along the medial aspect of the foot are the following:—**

(1) Medial tuberosity of the calcaneus; (2) medial malleolus; (3) 2.5 cm. in (1 in.) below the malleolus, the sustentaculum tali; (4) about 2.5 cm. (in front of the medial malleolus, and a little lower, is the tuberosity of the navicular, the medial guide in Chopart's amputation, the gap between it and the sustentaculum being filled by the calcaneonavicular ligament and the tendon of the tibialis posterior, in which there is often a sesamoid bone; (5) the first cuneiform; (6) the base of the first metatarsal; and (7) the head of the same bone, with its sesamoid bones below. (Holden).

(B) **Along the lateral aspect** are:—(1) The lateral tuberosity of the calcaneus; (2) the lateral malleolus; (3) the peroneal tubercle of the calcaneus (when present), 2.5 cm. (1 in.) below the malleolus, with the long peroneal tendon below it, and the short one above; (4) the projection of the anterior end of the calcaneus, and the calcaneocuboid joint, midway between the tip of the lateral malleolus and the base of the fifth metatarsal bone; (5) the base of the fifth metatarsal bone; (6) the head of this bone. The greater process of the calcaneus and the muscular origin of the short extensor lie between the peroneus brevis and tertius.

FIG. 1161.—VERTICAL SECTION THROUGH THE CUNEIFORM AND CUBOID BONES. (× ½.)



Levels of joints and lines of operations.—The line of the ankle-joint has been given at p. 1457. That of the talocalcaneal joint—the limited lateral movements of the foot take place here and at the mediotarsal joint—corresponds, on the lateral side, to a point a little in front of the lateral malleolus and midway between it and the peroneal tubercle; on the medial side, to one just above the sustentaculum tali. In **Syme's amputation** through the ankle-joint, the incision starts from the tip of the lateral malleolus, and is then carried, pointing a little backward toward the heel, across the sole to a point 1.2 cm. (½ in.) below the medial malleolus. The chief supply to the heel-flap is from the medial calcaneal. Care should be taken to divide the posterior tibial below its bifurcation and not to prick this vessel afterward.

In **Pirogoff's amputation** the incision begins and ends at the same points, but is carried straight across the sole. In each amputation the extremities of the above incision are joined by one going directly across the ankle-joint, which lies about 1.2 cm. (½ in.) above the tip of the internal malleolus.

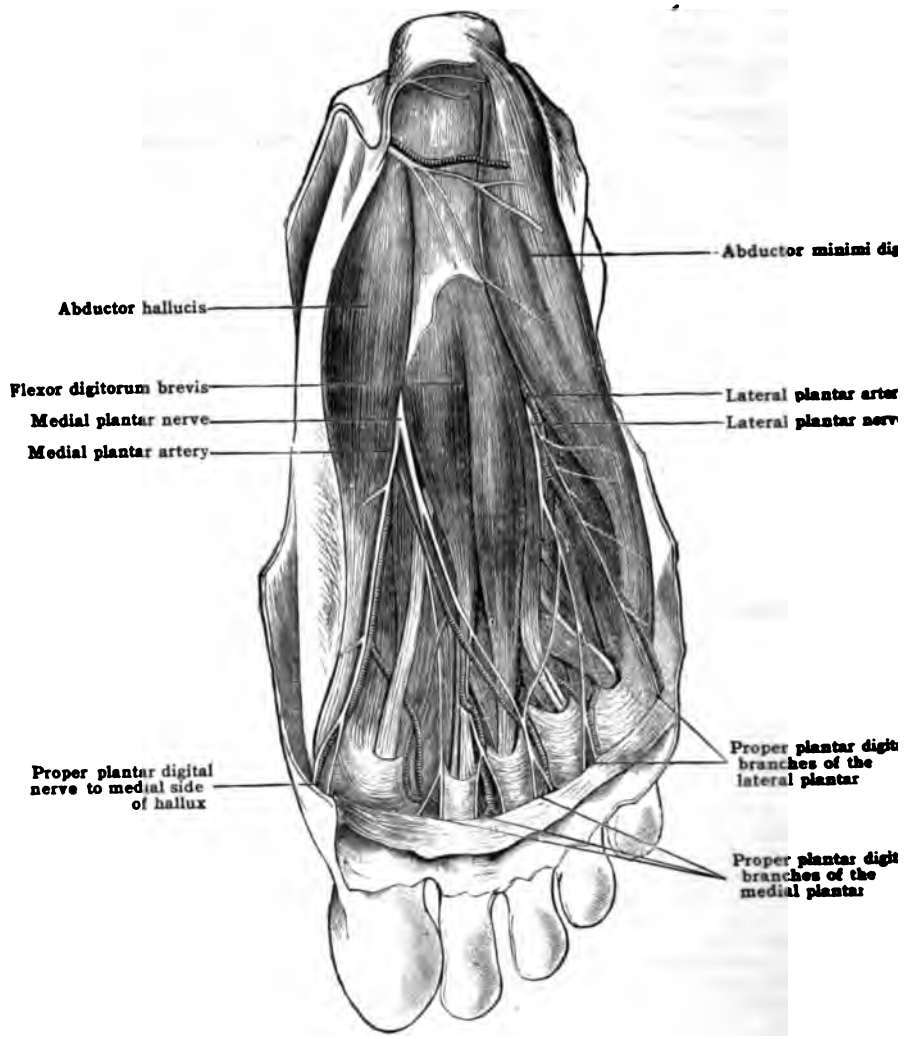
In **Chopart's mediotarsal amputation,** which passes between the talus and the navicular on the medial side, and the calcaneus and the cuboid on the lateral, the line of the joints to be opened would be one drawn across the dorsum from a point just behind the tuberosity of the navicular to a point corresponding to the calcaneocuboid joint, just midway between the tip of the lateral malleolus and the base of the fifth metatarsal bone. The convexity of the plantar flap should reach to a point 2.5 cm. (1 in.) behind the heads of the metatarsal bones. Owing to the tendency of the unbalanced action of the calf muscles to tilt up the calcaneus and thus throw the scar down into the line of pressure, the powerful tibialis anterior tendon and those of the extensors should be carefully stitched into the tissues of the sole flap.

In **Lisfranc's (Hey's)** or the **tarsometatarsal amputation,** the bases of the fifth and first metatarsals must be defined. The first of these can always be detected, even in a stout or swollen foot; on the medial side the joint between the first cuneiform and the first metatarsal bone lies 3.7 cm. (1½ in.) in front of the navicular tuberosity. In opening the joint between the second metatarsal and the middle cuneiform, its position (the base of the former bone projecting upward on to a level 6 or 8 mm. (¼ or ⅓ in.) above the others), and the way in which it is locked in between its fellows and the cuneiform bones, must be remembered. The convexity of the plantar-flap here reaches the heads of the metatarsal bones.

These amputations are not employed as much as formerly. The introduction of th ficial limb has rendered them somewhat useless and unnecessary. They are of interest, ho in an anatomical and historical sense.

In marking out the flaps for the amputation of the great toe, the large size of the h the first metatarsal, and the importance of leaving this so as not to diminish its supp power and the treading width of the foot, and thus of marking out flaps sufficiently lo large, must be borne in mind. The dorsal incision should begin 3.7 cm. (1½ in.) above th The line of the joint is a little distal to the center of the ball of the toe (fig. 1163). Th moid bones should be left, so as not to endanger the vitality of the flaps. In amputat the other toes, the line of their metatarso-phalangeal joints lies a full inch above the we

FIG. 1162.—SUPERFICIAL NERVES IN THE SOLE OF THE FOOT. (Ellis.)


Abductor minimi dig
Abductor hallucis
Flexor digitorum brevis
Medial plantar nerve
Medial plantar artery
Lateral plantar arter
Lateral plantar nerv
Proper plantar digit branches of the lateral plantar
Proper plantar digital nerve to medial side of hallux
Proper plantar digit branches of the medial plantar

Bursæ and synovial membranes.—The synovial sheath of the extensor lucis longus extends from the front of the ankle, over the instep, as far as metatarsal bone of the great toe. There is generally a bursa over the ins above, or it may be below, the tendon.

There is often an irregular bursa between the tendons of the extensor digitorum l and the projecting end of the talus over which the tendons play. There is much friction It is well to be aware that this bursa sometimes communicates with the joint of the head talus. (Holden.) There is a deep synovial bursa between the tendo Achillis and th caneus. Numerous other bursæ may appear over any of the bony points in the foot, espe when they are rendered over-prominent by morbid conditions. Bursæ may develop whe long continued and excessive pressure is exercised.

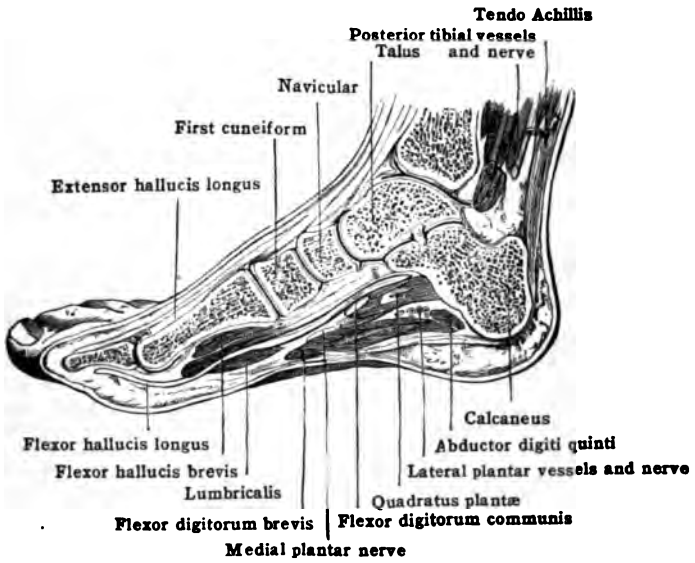
Synovial membranes.—In addition to that of the ankle-joint, there are synovial membranes in the tarsus, viz.:—(1) Talocalcaneal, peculiar to t

bones; (2) talocalcaneonavicular, common to these bones and the navicular; (3) between the calcaneus and the cuboid; (4) between the cuboid and the lateral two metatarsals; (5) between the first cuneiform and the first metatarsal; (6) a complicated and extensive one, which branches out between the navicular and cuneiform bones; between the cuneiforms; between the third cuneiform and the cuboid; between the second and third cuneiform and the second and third metatarsal bones; and between the second and third and the third and fourth metatarsal bones.

Dorsal artery.—The line of this is from the center of the ankle-joint to the upper part of the first interosseous space. On its medial side is the tendon of the extensor hallucis longus; on its lateral, the most medial tendon of the extensor digitorum longus. It is crossed by the most medial tendon of the extensor brevis. The origin of this muscle should be noted on the lateral and fore part of the calcaneus.

Cutaneous nerves (figs. 1157, 1162, 1164).—The sites of these, numerous on the dorsum of the foot, are as follows:—The **superficial peroneal (musculocutaneous) nerve,** having perforated the fascia in the lower third of the leg, divides into two chief branches, medial and lateral, which supply all the toes

FIG. 1163.—LONGITUDINAL SECTION OF FOOT. (×⅓.) (Braune.)



save the lateral part of the little, and the adjacent sides of the first and second. The **deep peroneal** becomes cutaneous in the first space, and is distributed to the contiguous sides of the above-mentioned toes. The **sural nerve** runs with the small saphenous vein below the malleolus, and supplies all the lateral border of the foot and the lateral side of the little toe. The **saphenous nerve,** coursing with the great saphenous vein in front of the medial malleolus, supplies the medial border of the foot as far as the middle of the instep. The cutaneous nerves to the sole (from the medial calcaneal, medial, and lateral plantar) are shown in fig. 1162.

Plantar arteries.—The line of the medial would be one drawn from the bifurcation of the posterior tibial, or about midway between the tip of the medial malleolus and the medial border of the heel, to the middle of the plantar surface of the great toe. The course of the lateral plantar runs in a line drawn from the bifurcation, first obliquely across the foot to a point a little medial to the medial side of the base of the fifth metatarsal, and thence obliquely across the foot till it reaches the first space and joins with a communicating branch from the dorsal artery. It thus crosses the foot twice. In the first part, it is more superficial, in the second very deep; it here forms the plantar arch, and is only separated from the bases of the metatarsals by the interossei.

The anastomosing branches about the ankle-joint are shown in figs. 1152 and 1153.

Tarsal bones.—The chief surgical points about these is the frequency with which they are diseased and their changes in talipes. **Frequency of disease.**—This is explained, chiefly, by their delicate structure and the fact that on the aspect in which they are most exposed to injury the soft parts are scanty. Disease once started, often by slight injury, finds in the terminal circulation of the parts, and the frequent want of rest, other contributing causes. The numerous and complicated synovial membranes mentioned above explain the extension of the disease. The calcaneus is the only bone in which mischief is likely to remain limited. The presence of an epiphysis to this bone appearing about the age of ten and joining at puberty is to be remembered as a starting-point of disease here. **Talipes.**—To take one instance, a case of talipes equinovarus, of congenital origin and confirmed degree, the following are the chief structural changes which should have been obviated and now have to be met, given briefly. *Calcaneus.*—This is elevated posteriorly, and rotated so that its long axis is directed obliquely medially. *Talus.*—The inclination of the neck medially is much increased, and the whole bone protruded from the ankle-joint. According to some, the neck is increased in length. *Navicular.*—This is displaced medially so that it articulates with the medial side of the head of the talus, and its tuberosity may form a facet on the medial malleolus. *Cuboid.*—The dorsal surface of this is displaced downward, and bears much of the pressure in walking. *Tendons.*—Those chiefly shortened are the tendo Achillis and those of the tibials and flexor digitorum longus. The tendo Achillis is displaced medially. *Ligaments.*—Those on the lateral side are stretched, those on the medial, especially the anterior part of the deltoid, the dorsal talonavicular and the plantar calcaneonavicular ligaments are shortened. The plantar fascia is also shortened, together with the abductor hallucis, which arises from it.

ARCHES OF THE FOOT

These are two—the **longitudinal** and the **transverse.**

(A) **Longitudinal arch** (fig. 1163).—This is by far the most important. **Extent:** From the heel to the heads of the metatarsal bones. The toes do not add much to the strength and elasticity of the foot. (Humphry.) They enlarge its area and adapt it to inequalities of the ground, are useful in climbing, and in giving an impulse to the step before the foot is taken from the ground, in the third stage of walking.

Two pillars.—The late Professor Humphry laid stress on the important differences between these two:—(1) **Posterior pillar:** This consists of the calcaneus and hinder part of the talus, viz., only two bones in order to secure solidity, and to enable the calf-muscles to act directly upon the heel, without any of that loss of power which would be brought about by many moving joint-surfaces. (2) **Anterior pillar:** Here there are many bones and joints to provide (*a*) elastic springiness, and (*b*) width. This anterior pillar may again be divided into two: (*a*) A **medial pillar,** very elastic, consisting of the talus, navicular, three cuneiforms, and three medial metatarsals. (*b*) A **lateral,** formed by the cuboids and two lateral metatarsals. This is stronger and less elastic, and tends to buttress up the medial pillar. **Keystone:** This is represented by the summit of the trochlear surface of the talus. It differs from the keystones in ordinary arches in the following important particulars (Humphry): (*a*) in not being wedge-shaped; (*b*) in not being so placed as to support and receive support from the two halves of the arch: in front the talus does fulfil this condition by fitting into the navicular; behind, it overlaps the calcaneus without at all supporting it; (*c*) this arch and the support of its keystone largely depend on ligaments and tendons; (*d*) it is a mobile keystone: to give it chances of shifting its pressure, and so obtaining rest, its equilibrium is not always maintained in one position.

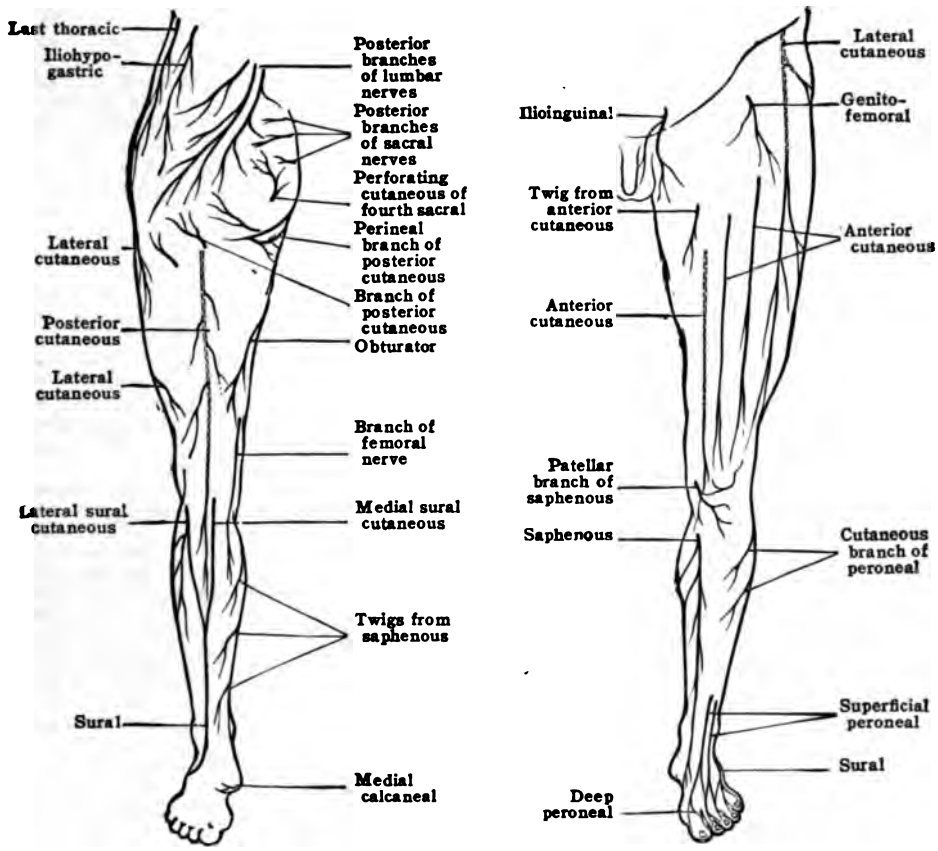
(B) **Transverse arch** (fig. 1161).—This is best marked about the center of the foot, at the instep, along the tarsometatarsal joints. This, as well as the longitudinal arch, yields in walking, and so gives elasticity and spring.

Uses of the arches.—(1) They give combined elasticity and strength to the tread. Thus they give firmness, free quickness, and dignity, both in standing and walking, instead of what we see in their absence, viz., the lameness of an artificial limb, and the shuffling or hobbling which goes with tight boots, deformed toes, flat-foot, bunions, corns, etc.; (2) they protect the plantar vessels, nerves, and muscles; (3) they add to man's height; (4) they make his gait a perfect combination of plantigrade and digitigrade, as is seen in man's walking, when he uses first the heel, then all the foot, and then the toes. (Humphry.)

Maintenance of the arch.—(1) **Plantar fascia.**—This is (*a*) a binding tie between the pillars of the longitudinal arch; (*b*) it protects the structures beneath; (*c*) it is a self-regulating ligament and protection. Thus, having a quantity of muscular tissue attached to its upper and back part, it constantly responds by the contraction of this, to the amount of any pressure made upon the foot. (2) **Plantar calcaneonavicular ligament.**—This is a thick tie-plate of fibrocartilaginous tissue, partly elastic, hence called the 'spring-ligament,' attached to the anterior margin of the sustentaculum tali and under surface of navicular. It is thickest at its medial side, where it blends with the anterior part of the deltoid ligament, and below, where the tibialis posterior

passing into the sole, is in contact with the ligament and gives much support to the head of the talus and the navicular, while it assists the power and spring of this ligament (*vide infra*). The dropping of the talus and navicular and their projection on the medial side in flat-foot are largely due to the giving way of the above ligament. (3) **Calcaneocuboid ligaments.** (*a*) **Long;** (*b*) **short.**—These ligaments are the main support of the lateral, firm, and less elastic part of the longitudinal arch. (4) **Tibialis posterior.**—The reason why this muscle has so many insertions below is to brace together the tarsal bones, and to prevent their separation when, in treading, the elastic anterior pillar tends to widen out. Of these numerous offsets, that to the navicular is the most important. Thus it strengthens the calcaneonavicular ligament by blending with it, and thus supports the arch at a trying time. By coming into action when the heel is raised, this tendon helps the calcaneonavicular ligament to support the head of the talus, and to maintain the arch of the foot when the weight of the body is thrown forward on to the instep. In other words, the tibialis posterior comes into play just when the heaviest of its duties is devolv-

FIG. 1164.—DISTRIBUTION OF CUTANEOUS NERVES ON THE POSTERIOR AND ANTERIOR ASPECTS OF THE INFERIOR EXTREMITY.



ing upon this ligament, viz., when the heel is being raised, and the body-weight is being thrown over the instep on to the opposite foot. (5) **Peroneus longus.**—This raises the lateral pillar, and steadies the lateral side of the arch. Further, by its strong process attached to the first metatarsal bone, it keeps the great toe strapped down firmly against the ground; thus, keeping down the anterior pillar of the longitudinal arch, it aids the firmness of the tread. (Humphry.) (6) **Tibialis anterior.**—This braces up the keystone of the arch. Thus, by keeping up the first cuneiform, it maintains the navicular, and so indirectly the talus *in situ*.

Fig. 1154 will remind the reader of the arrangement of the **superficial lymphatics of the lower extremity.** These follow chiefly the saphenous veins, and enter the inguinal nodes, except those from the lateral aspect of the heel, which drain into the popliteal lymph-nodes. The superficial lymphatics of the buttock enter the lateral, and those over the adductor muscles the most medial group of the inguinal glands.

The deep lymphatics of the lower limb, comparatively few in number, follow the course of the deeper vessels. After passing through some four or five glands deeply placed about the popliteal vessels (these glands also receive the lymphatics along the small saphenous vein), the lymph is carried up by lymphatics along the

femoral artery to the deep inguinal nodes; one very often occupies the femoral canal.

Fig. 1164 shows the distribution of the **superficial nerves** on both aspects of the limb.

Paralysis of the nerves of the lower extremity.—The student should take this opportunity of considering from the surgical anatomy the results of paralysis of the nerve chiefly affected, viz., the great sciatic and its branches. *Sciatic:* The limb hangs flail-like, much in the position of one affected with advanced infantile paralysis. In addition to the results of paralysis of its two divisions, flexion at the knee will be lost, owing to paralysis of the hamstrings. *Peroneal (external popliteal) nerve:* The extensors and peronei being paralyzed the foot drops, it cannot be dorsiflexed at the ankle nor abducted at the mediotarsal joint. Adduction at the latter joint is impaired owing to paralysis of the tibialis anterior. The arch of the foot is largely lost owing to paralysis of the peroneus longus. Slight extension of the two distal phalanges of the four lateral toes is still possible by means of the interossei. Sensation is impaired over the distribution of the medial sural cutaneous deep, and superficial peroneal nerves. *Tibial (internal popliteal) nerve:* Here the calf muscles, the flexors, and the muscles of the sole of the foot are paralyzed. The ankle cannot be plantar-flexed.

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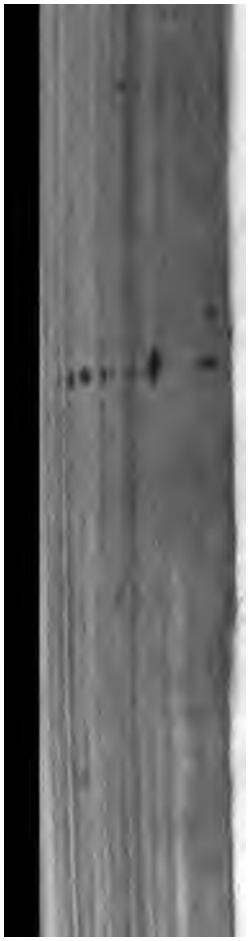

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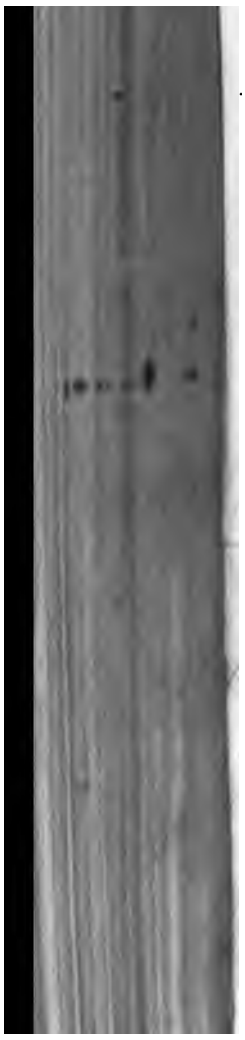

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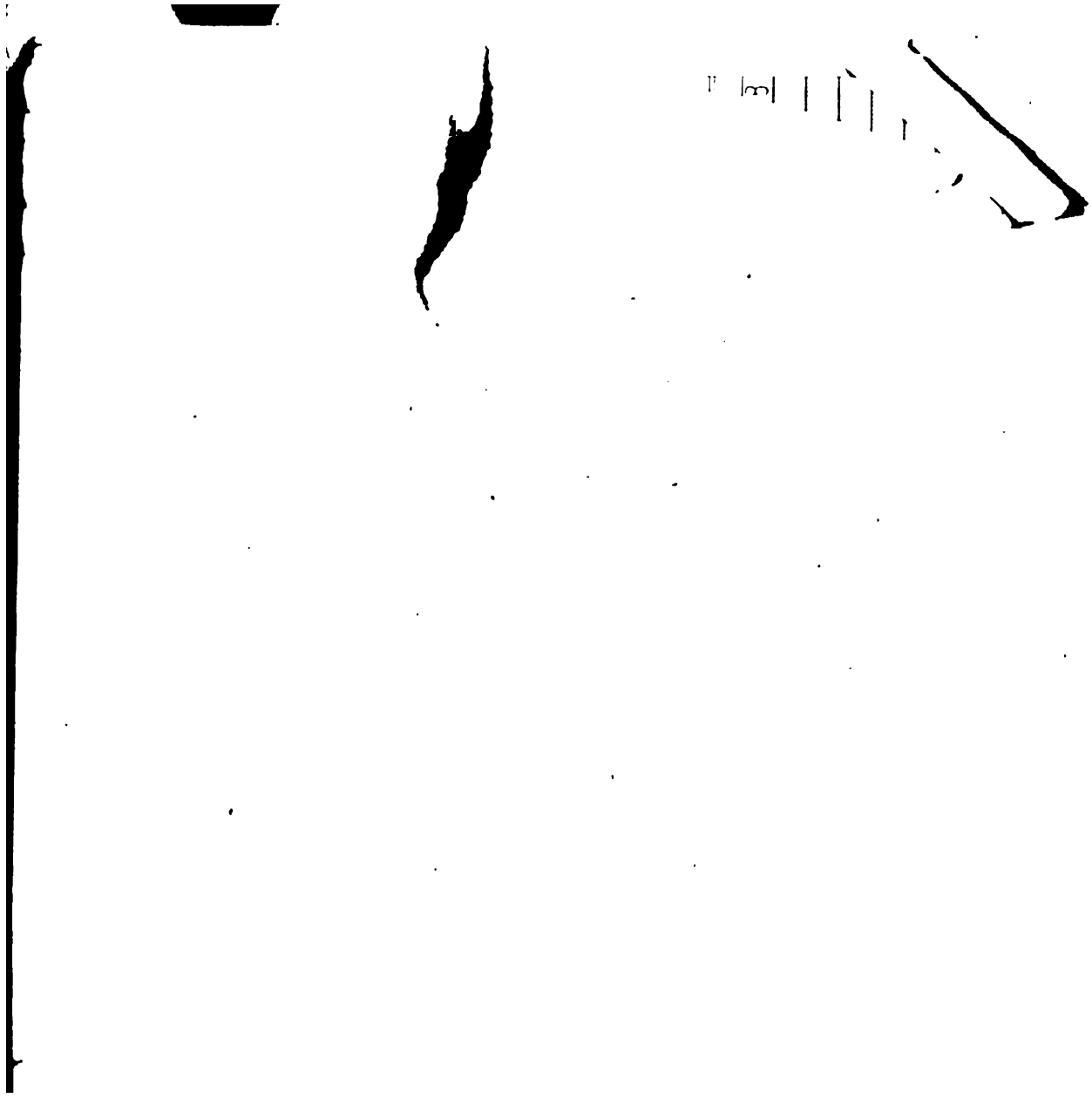

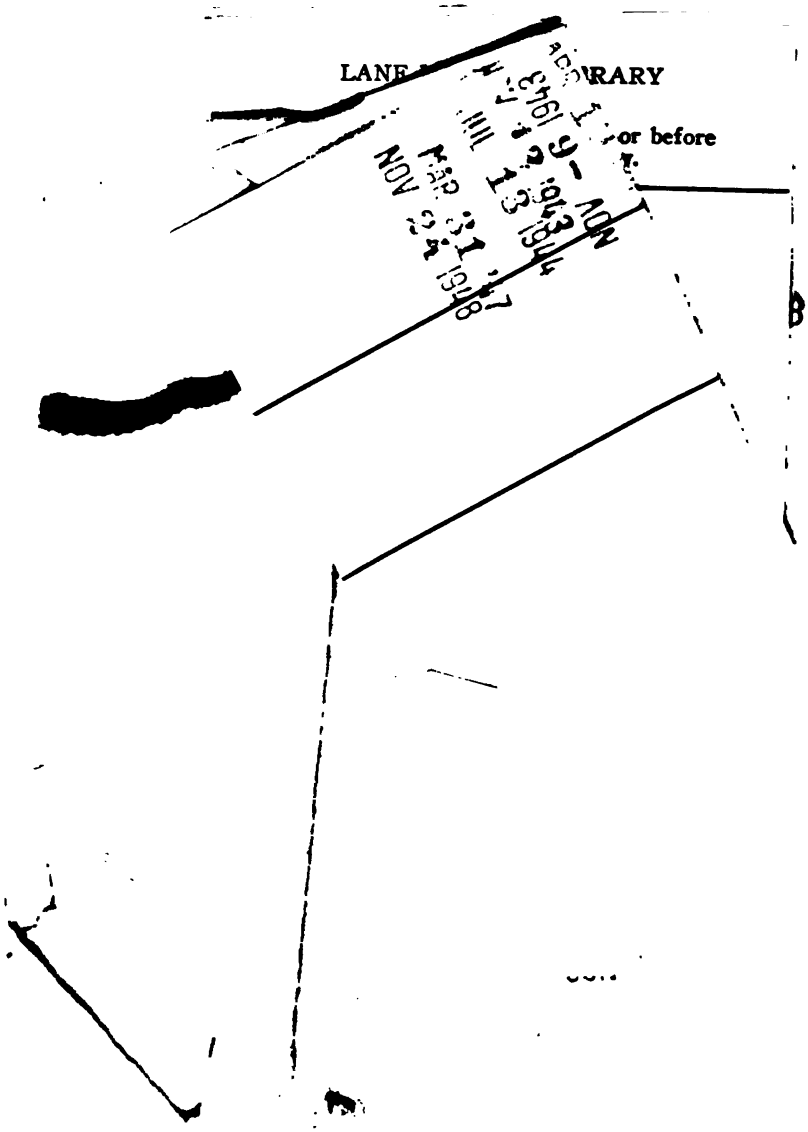
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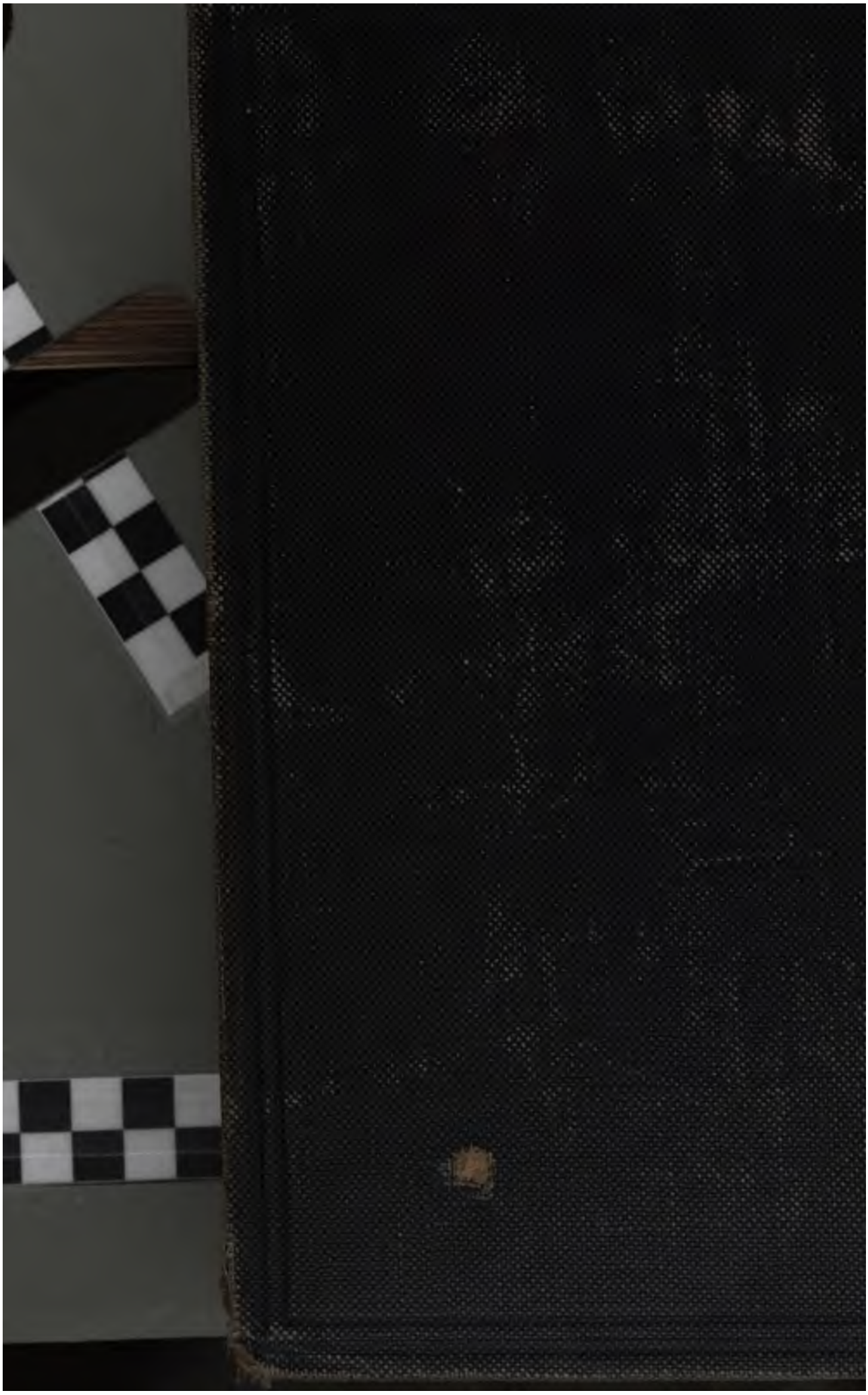
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